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VOL. XIII. 1899. *PART I.*

TRANSACTIONS
OF THE
Canadian Society of Civil Engineers
JANUARY TO JUNE, 1899.

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Portrait, W. T. JENNINGS, PRESIDENT, 1899, Frontispiece.

ILLUSTRATIONS.

PROCEEDINGS.

Montreal:
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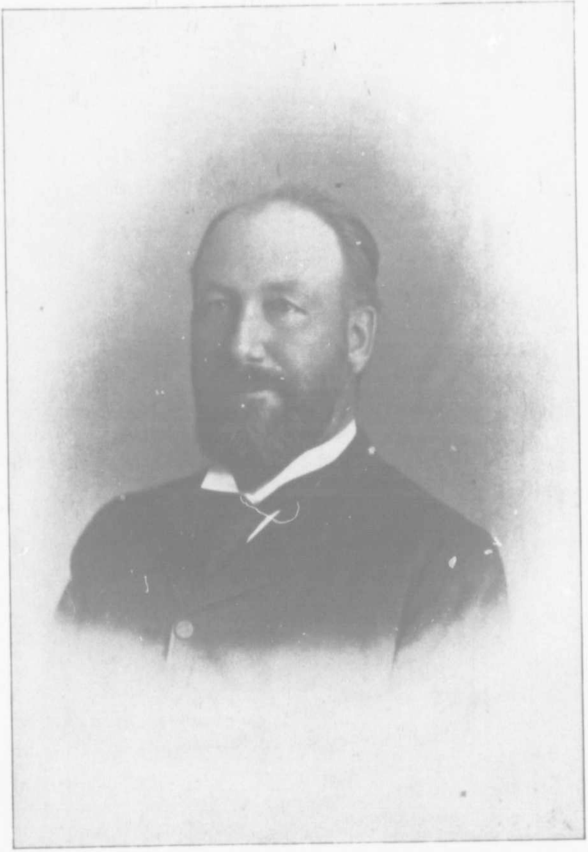
1899.



Sincerely Yours

Wm. T. Fleming.

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CONTENTS.

ILLUSTRATIONS.

PROCEEDINGS.

INSTRUCTIONS FOR PREPARING PAPERS, ETC

In writing papers, or discussions on papers, the use of the first person should be avoided.

They should be legibly written on foolscap paper, on one side only, with a margin on the left side.

Illustrations, when necessary, should be drawn on the dull side of tracing linen to as small a scale as is consistent with distinctness. They should not be more than 10 inches in height, and *in no case* should any one figure exceed this height. Black ink only should be used, and all lines, lettering, etc., must be clear and distinct.

When necessary to illustrate a paper for reading, diagrams must be furnished. These must be bold, distinct and clearly visible in detail for a distance of thirty feet.

Papers which have been read before other Societies, or have been published, cannot be read at meetings of this Society.

All communications must be forwarded to the Secretary of the Society, from whom any further information may be obtained.

The attention of Members is called to By-laws 46 and 47.

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Thursday, 5th January.

Duncan MacPherson, Member of Council, in the Chair.

The discussion of Mr. Irwin's paper on "Disputed Points in Connection with the Construction and Maintenance of Macadamized Roads" occupied the evening.

Thursday, 19th January.

H. Irwin, Member of Council, in the Chair.

Paper No. 140.

SAND FILTRATION OF PUBLIC WATER SUPPLIES.

By R. S. Lea, A. M. Can. Soc. C. E.

The present century is especially noted for the wonderful progress which has been made in scientific knowledge. None of the results are of more practical importance than the developments which have taken place in the facilities for transportation, and for the transmission of power over long distances.

The direct outcome has been a continually growing tendency towards centralization in most industrial operations; which, in turn, has resulted in an increase in the number of people living in towns quite out of proportion to the total growth of the population. For instance, in the year 1790 there were but three towns in the United States with populations of 8,000 and over; and these comprised less than 4 per cent. of the whole number of inhabitants. In 1880 there were 286 such towns; ten years later the number had increased to 448, and these included about 30 per cent. of the total population. Again, in 1840, there were only three cities with populations as great as 100,000; in 1890 there were 30; while at the present time almost half the people in the country live in places with populations of at least 1,000.

These are figures which apply to the country at large. In certain districts, however, the percentages are much higher. For example in the State of New Jersey, 52 per cent. of the people live in places of 8,000 or over, in Connecticut 54 per cent., in New York 60 per cent., and in Massachusetts 70 per cent. The last State, with a total population of about 2½ millions, has 40 cities of 10,000 and over, and 20 of 25,000 and over. In the countries of Europe the same conditions and tendencies obtain to even a greater degree.

These figures, derived from census reports, etc., are given in order to call attention to the magnitude and direction of this movement, which has taken place to any considerable extent only during the last few decades; but which has, nevertheless, practically created an important branch of engineering.

From this crowding together of people in restricted areas, in close proximity to industrial establishments, have arisen many new and complicated problems; among the most important of which are those connected with the maintenance of sanitary conditions of existence. Besides this, not only are these problems rapidly increasing in number and difficulty, but there is a growing appreciation of the danger of unsanitary surroundings, and consequently, of the necessity of having such matters properly dealt with.

In thickly populated districts and in the neighbourhood of cities and towns the wastes of human life and human industry are a continual menace to the health of the inhabitants. Nature's method of preserving the balance between growth and decay, by utilizing animal waste as plant food, is no longer effectual. The lakes and streams begin to serve the double purpose of sources of water supply and receptacles for sewage. Hence it is evident that among the most urgent of the questions with which the municipal engineer may have to deal are those connected with the securing and maintaining of the degree of purity necessary in water intended for domestic use.

The proper methods to be employed in the accomplishment of this object depend as much upon biological as upon mechanical principles, so that a certain degree of familiarity with these principles and with the methods of the chemist and biologist will be necessary to the engineer engaged in such work, in order that he may be able to avail himself intelligently of their assistance.

European cities, having earlier felt the necessity, have devoted much more attention to these matters, and are consequently further advanced in their methods of dealing with them than is the case with the cities in America. Nevertheless, by far the most important series of investigations into the subject of the purification of water and sewage are those known as the "Lawrence" experiments, carried on under the direction of the Board of Health of the State of Massachusetts.

This Board, from its foundation in 1869, always devoted a great deal of attention to the condition of the water supplies of the State. In 1886, the time being particularly appropriate, it appointed a body of experts to the exclusive duty of conducting a series of observations and experiments, with the object of finding the best methods for purifying both water and sewage. These experiments are still in progress, and the annual reports of the department, giving the results of their investigations, are exceedingly valuable to engineers and others interested in such questions.

In Berlin and in a few other large European cities having water works departments provided with the necessary scientific equipment and management, many careful experiments have been made on the working of the large water-filter beds of the systems. The results of such experiments as these have an especial value from the fact that they are conducted on a large scale, and under conditions which exist in actual practice. On the other hand, these same circumstances render them less reliable as a means of determining the true principles upon which the process of filtration depends.

The object of this paper is to describe, as fully as reasonable limits will permit, first, the circumstances under which water supplies become polluted, and the nature of this pollution; and second, the process of purifying it again in large quantities by sand filtration.

Of course pure water is preferable to purified water; or, as has been said, with water "innocence is better than repentance." Unfortunately, however, water whose natural state is above suspicion is often exceedingly difficult to procure, except at a cost which is practically prohibitive. Consequently, many cities and towns, especially the larger ones, are forced to use such waters as may be practically available, and to make the best of them. But this best is by no means to be held lightly. By the methods to be described later it is possible to so change the nature and characteristics of polluted water as to convert it to the appearance, taste, and probably absolute wholesomeness of the most innocent of mountain torrents.

Water has the unfortunate capacity of readily dissolving many of the substances with which it may come in contact; so that outside of the laboratory, chemically pure water is practically unknown. Some of these foreign elements may not only be quite harmless, but may actually improve the quality of the water. It is, however, with the others, which make the water containing them unsightly in appearance, disagreeable to taste or smell, or dangerous to health,—in other words, with the substances which constitute pollution,—that we are especially concerned.

If we divide all potable waters according to their source, into *ground* waters and *surface* waters, the general statement may be made, that it is chiefly in the latter class that are found what may be properly termed polluted supplies. The former are for the most part subjected to such a rigorous process of natural purification as to place them beyond the need of any artificial treatment.

Surface waters, or the waters of lakes, ponds, rivers, streams, etc., are liable to receive more or less serious pollution from the following sources:—

1. They may be coloured by the drainage of swamps.

2. The waters of many streams become turbid with clay and other suspended matters after heavy rains.

3. The waters of lakes, ponds, and storage reservoirs are liable, at certain seasons of the year, to contain large growths of algæ and other minute water-plants which float about barely visible to the eye, but which are capable of imparting to the water disagreeable tastes and odours.

4. Any of these classes of surface waters may have discharged into them a greater or less quantity of human sewage; leading, under certain circumstances, to very grave consequences.

In determining the quality of a given water supply, the proper method of procedure is as follows:—

1. To make a local examination of the water shed, in order that all probable sources of pollution may be discovered.

2. Then, if necessary, to have chemical analyses made of samples of the water, by which the nature of the contamination, and to a certain extent its amount and origin, may be ascertained.

3. To make a biological examination giving the number and species of the living organisms that may be present. This will be of assistance in interpreting the chemical analysis; and also in detecting the possible presence of organisms, which in themselves might constitute an element of danger.

Before discussing the results of these analyses, it may be stated in advance, that it is in connection with the *organic* matter in water, dissolved or suspended, visible or invisible, that serious pollution from a sanitary standpoint is to be apprehended. And it is in the information which they furnish on this point that the chief value of the analyses consists. But in order to interpret them properly it will be necessary to allude briefly to the constitution of organic matter and to the changes it is liable to undergo.

To begin with, it includes all those combinations of the chemical elements whose formation depends upon the processes of life; and which, therefore, occur either in plants or animals. Its history is cyclical, consisting of a *constructive* phase or period of growth, and a *destructive* phase or period of decay; the death of the plant or animal forming the dividing line between the two phases. The cycle begins by the appropriation of inert, purely mineral substances from the earth by the green plants, which derive the necessary energy from the sunlight; and ends with the complete disintegration of the more or less complex structures which constituted its organic character, and the return of the elements to the earth.

With regard to the nature of the changes it may have undergone, it is only with those in the second or destructive phase that we are concerned. At the beginning of this phase, at the death of the plant or animal, we find that all organic matter is composed mainly of carbon, oxygen, hydrogen, and nitrogen. The more nitrogen it contains, the more objectionable it is from a sanitary point of view. This destructive process is essentially one of oxidation. The first step is the oxidation of the carbon by the oxygen of the body itself, or by that from without forming carbonic acid gas, and leaving the nitrogen and hydrogen to unite to form ammonia. As decomposition proceeds, the ammonia is itself oxidized—the hydrogen to form water, and the nitrogen to form nitrous acid. The last step is the oxidation of the nitrous acid to nitric acid. The nitrous and nitric acids do not remain free but combine with some base present, as soda or potash, to form nitrites and nitrates, the latter being purely mineral substances; so that the final results of the decomposition process are carbonic acid, water, and nitrates. Thus the dead inorganic materials needed for the formation of organic structures are only borrowed; and ultimately are returned to the earth again as inert as when they were taken from it.

Returning now to the chemical analysis, we find the results given in some such form as the following, which is the one used by the Massachusetts State Board of Health:—*

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* The figures in this table indicate parts per 100,000.

There are also columns for the date of collection and examination, and for noting the colour, turbidity, etc.

Sample.	Residue on Evaporation.		Ammonia.			Chlorine.	Nitrogen as		Hardness.	
				Albuminoid.						
	Total.	Loss on Ignition.	Free.	Dissolved.	Suspended.		Nitrites.	Nitrates.		
A	3.85	1.00	.0002	.0048	.0012	.49	.0050	.0000	1.6	Average surface water.
B	40.25	—	.097	.0316	.0222	6.32	.3500	.0300	5.3	Private well.
C	10.50	2.40	.027	.0156	.0120	2.78	.1400	.013	3.6	Mystic Lake.

Now it has been found that a very accurate, and at the same time comparatively easy method of determining the organic matter in water by a chemical analysis is to determine the amount and condition of the nitrogen present. Thus, under the head of Albuminoid Ammonia, are entered amounts which are proportional to that part of the nitrogen which is derived from fresh organic matter, *i. e.*, from organic matter which has not yet begun to decompose. These columns, therefore, represent the possibilities of putrefaction still existing in the water. The amounts under Free Ammonia represent decay begun; under Nitrous Acids (or Nitrites) decay still further advanced; while under Nitrates the amounts entered represent the nitrogen derived from that portion of the original organic matter which has passed through all the stages of decay, and which has been converted into purely mineral matter again.

The importance of the determination of the chlorine is, that an excessive amount points to contamination by sewage which always contains a considerable proportion of common salt.

The actual amounts of the different substances as they occur in water supplies are exceedingly minute, as will be seen by referring to the above table of analysis, one of which samples (B) is a highly polluted one. Hence, in themselves these substances are of very little importance. It is in the history of the water which their presence indicates that their significance lies. Thus the chemical analysis can tell us not only what is in the water, but also a great deal about what is going on in it. It is only within recent years, however, that the methods of organic analysis have been capable of producing such results; when the first attempts at water purification were made, very little was known of the organic matter in solution, and the object aimed at was simply the *clarification* of the water, or the removal of suspended matter visible to the eye.

This was the condition of things when James Simpson, in 1839, constructed a sand filtration plant for one of the London water companies. Each of the beds of this system consisted of a broad shallow basin or reservoir with water-tight bottom and sides. The depth was about 12 feet, and it was filled to about half this depth with the filtering material, which consisted of uniform layers of small stones, gravel and sand, the stones on the bottom and the finest sand on the top. Through the bottom layer of stones and gravel extended a number of branch drains leading into a larger central drain which was connected to the outlet (Fig. 2). The inlet to the filter bed opened above the surface of the sand, and both it and the outlet were provided with gates. The process of filtering consisted in flooding this bed of sand and gravel, and drawing off the water from beneath by means of the system of underdrains, which were built with open joints. The rate could be regulated by the gates or other apparatus on the inlet and outlet pipes.

As filtration progressed, the surface of the sand became gradually choked up by the formation upon it of a layer composed of material removed from the water. When this layer became so impervious as to prevent the water passing in sufficient quantities, the filter was stopped, the water level drawn down below the surface of the bed, and the deposit layer removed, together with from ½ to 1 inch of sand. When the surface was smoothed and levelled, the bed was ready to be put in action again.

The frequency of the scrapings depended upon the condition of the water and the rate at which it was filtered; and when the sand layer had become reduced in thickness to what was considered a proper minimum, the whole amount removed was replaced at one time, either by new sand, or by the scrapings after they had been thoroughly washed.

The results from the use of these filters were so satisfactory according to the ideas of purified water then in vogue, that in the following years several others were built in England, and a little later on the continent, especially in Germany. Some of the most important of the continental filters built during this period wer designed by the English engineers Gill and Lindley. They were all built on the same general lines as the Simpson filter described above, the details varying somewhat with the individual notions of the designers.

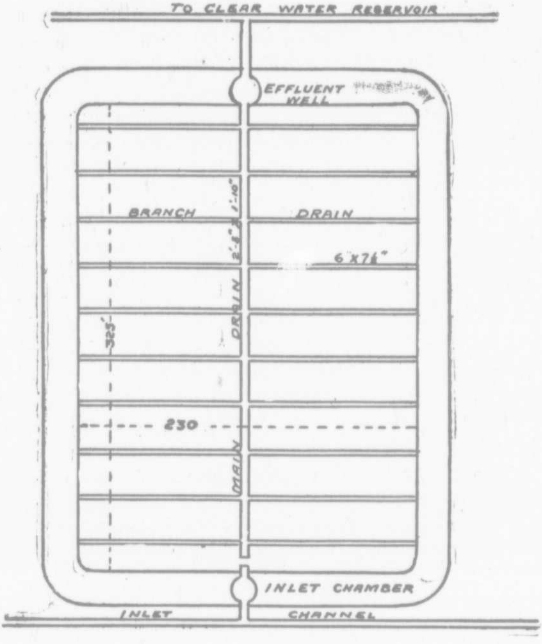


FIG. 2.

Plan of underdrains of Hamburg filters.

In America practically no attention was paid to the matter. In 1866 the late Jas. P. Kirkwood was employed by the city of St. Louis to report upon the condition of its water supply. His report included the result of his personal observations of the working of several European filters, and was translated and widely read on the continent of Europe. But his recommendations to St. Louis, so far as filter-beds were concerned, were not adopted. And between that time and 1892, only two plants were built in America, one at Poughkeepsie, N. Y., in 1872, the other in 1874 at Hudson, N. Y., both being after designs by Kirkwood.

A little earlier, in 1870, the English chemists Wanklyn and Frankland invented new and improved methods of organic analysis which led to more attention being paid to the organic matter in solution in water. A new importance was also attributed to it at this time by reason of the ideas which were then held concerning the processes of fermentation and decomposition. It was supposed that decay could be communicated to sound organic matter by contact with other organic matter already in process of decomposition; this being the theory advanced by the chemist Liebig, who held that ordinary alcoholic fermentations were produced by the dead and decaying yeast cells, instead of by the action of the living and growing cells as we know now. And so it was considered that the presence of decomposing vegetable or animal matter in water would tend to set up injurious putrefactive changes in the digestive organs and thus produce disease. Hence when analyses of the effluents from the sand filters showed only a moderate reduction of the organic matter—seldom as much as 50 per cent—the result was considered very disappointing, and as indicating that this method of filtration, while capable of improving the appearance and taste of the water, was of but slight hygienic value.

Not many years later, however, these ideas and theories were broken down by the researches of Pasteur, who demonstrated that the processes of fermentation and putrefaction were dependent upon the presence of living organisms; and that some of these organisms were capable of causing disease. A new view was now taken of organic matter in water, the presence of which was considered to be not necessarily dangerous in itself, except as indicating the probable presence of germs. Yet, while chemical purity was now deemed of much less importance than biological purity, the former remained the standard, owing to lack of satisfactory methods of prosecuting the study of these organisms.

Then, in 1881, came the famous discovery by Dr. Robert Koch of his "plate culture" method. Hitherto, owing to the extreme minuteness of the bacteria, and the enormous rate at which they increased in number under circumstances favourable to their growth, it was almost impossible, with the methods then available, to make much progress in the knowledge of the subject. But with the advent of Koch's invention these difficulties were to a great extent removed. It now became possible to determine the number of germs, to study their habits of life, functions, etc., and to classify them into species, in a manner which, considering the kind of creature dealt with, seems quite marvellous.

Besides placing the germ theory of disease on a firm basis, this discovery of Koch's marks the beginning of the period during which it has been possible to deal with the subjects of the purification of water and sewage in a rational and scientific way. Numerous investigators at once began the study of these questions under the new and vastly improved circumstances. Inasmuch as the results of many of their experiments have a direct bearing upon the subject under consideration, a brief description of the nature and some of the characteristics of the bacteria will be given before proceeding further.

BACTERIA.

They belong to the lowest and smallest forms of life. Structurally they are composed of a single cell with a wall, possibly of cellulose, and contents consisting of apparently structureless protoplasm and a nucleus; and are thus comparable to the bone, blood, nerve cells, etc., which represent the ultimate structural composition of the animal body.

They are of such extreme minuteness as to be visible only to high powers of the microscope. In their greatest dimensions they vary, from $\frac{1}{10}$ to 2 micro-millimetres (from $\frac{1}{250000}$ to $\frac{1}{12000}$ of an inch). A sphere $\frac{1}{25}$ of an inch in diameter could contain more than 500 millions of the larger ones, and it would take a thousand of them placed in a row to reach across the diameter; so that it is little wonder that their presence was, until a few years ago, scarcely suspected. They are generally transparent, but may be stained for purposes of study by some of the aniline dyes.

It was at first doubtful whether they should be classified as plants or animals; but it is now definitely decided that they are plants. Some of them have the power of motion, which appears to be by means of little hair-like appendages or cilia. They reproduce by fission,—a simple process by which a single bacterium divides itself in the middle, thus producing two. Under favourable conditions this multiplication can go on with incredible rapidity. They comprise a great number of species with definite characteristics and requirements for growth, etc. All these species are included in the general term *bacterium*, or *microbe*, or *germ*.

They may be classified in various ways, depending upon their form, the nature of their environment, the products of their action, etc.

According to its form a germ may belong to :—

1. The *micrococci*, or ball shaped.

2. The *bacilli*, or rod shaped.
3. The *spirilla*, or spiral shaped.

They occur usually as separate individuals, but may also occur in pairs, tetrads, or in a row like a chain. Besides these forms they are often found under certain circumstances in irregular groups or masses, held together by a transparent glutinous material which they secrete through their cell walls. These sticky, jelly-like masses are termed zöoglœa. Unlike the algæ and other green plants they cannot exist upon purely inorganic matter, but require for their nourishment matter already organized in some form. Moisture is also a necessity to their proper growth; and thus according to their habitat or preferred environment they are classified as:

1. *Saprophytes*, living on dead animal or vegetable matter, or on water containing these in solution.
2. *Parasites*, subsisting on a living host, in the body of which they grow and multiply, in some cases without any injurious effect, but in others causing disease and death. It is not known whether these results are produced by their action in obtaining their food or by the products which are thus set free. These injurious members of the parasitic class are the so-called pathogenic or disease-producing bacteria; such as the well-known germs of typhoid and cholera. Some species of bacteria are able to exist either as saprophytes or parasites, and are called *facultative.*

Another classification depends upon their ability to live in the presence or absence of oxygen, *e. g.*:

1. *Aerobic*, requiring the presence of oxygen.
2. *Anäerobic*, unable to exist in the presence of this gas.

Facultative anäerobics can live either with or without oxygen.

There are various other ways of classifying them which are of no special interest in this connection. The most important classification, from our point of view, is that which divides them into parasites and saprophytes. The great majority of bacteria belong to the latter class, and depend for their nourishment entirely upon lifeless animal or vegetable material. Their energies are thus devoted to the task of attacking dead and decaying organic matter, tearing it apart (in the chemical sense), breaking up its complex combinations, and ultimately reducing it to unobjectionable inorganic compounds. This is accomplished in many different ways, depending upon the attendant circumstances and the species of the dominating germ. But the final result is the same. All these destructive processes in the history of organic matter, which have been previously referred to, were formerly considered to be purely chemical; but it is now known that if the bacteria are absent or in any way rendered inactive, no decomposition of any kind can take place even in air. Hence, it is evident that the rôle they play in nature is, for the most part, a beneficent one. They are the universal scavengers, and but for them all organic growth would in time be overwhelmed by its own waste.

There are, however, also the pathogenic members of the parasitic class, which, though few in number when compared with the others, are yet possessed of the same capacity for multiplication when the conditions are favourable. But while the absence of such conditions will arrest their growth and development, it does not necessarily cause their death. For instance, the temperature most suitable to the typhoid germ is that of the human body, which is its natural habitat; yet it can exist for months in the middle of a block of ice, and then continue its normal career with undiminished energy and virulence. Hence, of the different kinds of water pollution, human sewage is the most to be feared, since it is at any time liable to contain such germs; and the method which can best ensure their removal is evidently the one best suited for domestic purification.

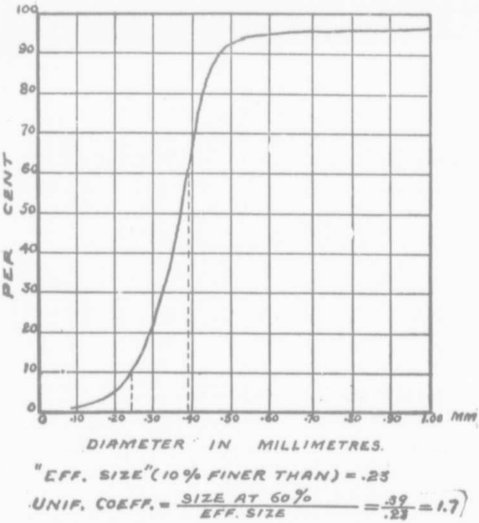
With the adoption of bacterial purity as a standard for water purification, it is no wonder that it was anticipated that the sand filter would prove even of less hygienic value than it did from the chemical point of view. Thus in a paper read before the Institute of Civil Engineers about this time the following statement occurs: "Filtration is another remedy put forward as infallible by those who have not grasped the subject. How can filtration affect substances dissolved in water? And as for the minute organisms found in putrescent bodies, they could pass a hundred or a thousand abreast through the interstitial spaces of ordinary sand as used for this purpose." Nevertheless, as experiments and tests multiplied, it soon became evident that these same clumsy contrivances were actually removing from 97 to 98 per cent. of all the germs contained in the water. Not only this, but continued study and experiment since then have resulted in such changes in the methods of building and operating these filters, that they can now be depended upon to remove from 99 to 100 per cent. of the bacteria, and although numerous other devices for filtering have been invented and tried, so far none have been shown to be equal in efficiency to the sand filter. Thus did these earlier engineers build better than they knew, and produce results whose excellence they did not even suspect.

Investigation into the manner in which it was possible for a comparatively porous material like the sand bed to hold back such infinitesimal bodies as the bacteria revealed a paradoxical condition of affairs, viz., that these germs, while constituting the most dangerous element in the pollution of drinking water, were at the same time the chief agents in its purification. It was found that the purifying action was partly mechanical and partly biological, the circumstances attending the latter not being very well understood. The manner in which it takes place and the means by which it may be enhanced, will be referred to while describing the construction and operation of a modern filtration plant.

In describing the materials of the bed and the best method of disposing them, we shall begin with the sand.

SAND.

It is in the sand layer that the actual purification takes place; and it is observed that the efficiency and economy of the process are dependent to a considerable extent upon the size of the sand grains



Graphical representation of a mechanical analysis of a sample of sand.

and the thickness of the bed. It is the smaller grains which determine the "effective size" of a sample of sand; since, by filling up the spaces between the larger ones, they fix the diameter and length of the channels through which the water must pass.

At Lawrence, as the result of experimenting on the rate at which water flows through various sizes of sand, the "effective size" is taken as that of the grain which has 10 per cent. by weight of the sample smaller than itself, and 90 per cent. larger. This size is obtained by a process of mechanical analysis described in the Report for 1892, which also gives what is termed the "uniformity co-efficient," the latter being the ratio of the size of the grain which has 60 per cent. smaller than itself to the "effective size." (See Fig.) If we look more closely into the purifying action of the sand, in order to be able to understand just how it is affected by difference in the "effective size," "uniformity co-efficient," thickness of the bed, etc., we shall see that what takes place is as follows:—

When water is first let in to the filter, it rises to a depth of 3 or 4 feet above the surface of the bed; and it is either held there for some hours, or filtration is allowed to proceed at once, the first part of the effluent being wasted. In either case, the sand grains at the surface soon become enveloped in a membranous film composed partly of the zöoglœa form of the bacteria, and partly of the more or less finely divided organic matter which the water holds in suspension. This sticky jelly-like substance, extending around and between the sand grains, entangles and holds back the smallest particles in the water, even the bacteria themselves. The latter are not only prevented from moving further, but are detained under such adverse circumstances as to not only arrest their growth and multiplication, but also to cause their death.

Naturally the larger suspended particles, water animalculæ, fragments of plants, etc., are stopped at the very surface of the sand, and a continuous mantle called by the Germans the *Schmutzdecke* is soon formed and covers the whole bed. Under certain circumstances, as for example when the water contains a large algæ growth, this layer forms a dark greenish carpet of a texture like felt, which when dry can be peeled off in flakes. Ordinarily, however, since it contains a certain quantity of silty matter, it penetrates the sand for a depth of half an inch or so. But even when formed in this way there is often almost a distinct plane of cleavage between it and the sand below, which makes it very easy to remove with broad square-cornered shovels.

This operation becomes necessary when the gradual thickening of the surface layer prevents the required quantity of water from passing.

It will thus be seen that the surface film forms by itself an exceedingly effective filtering material, but with a very delicate structure; and as such, should be carefully guarded against any influence which might cause its fracture. Several European engineers have concluded that it alone constitutes the actual filtering medium; and that the remainder of the sand bed serves merely for its support, and for steadying the flow of the water through the bed. But experiments made at the Lawrence Station do not by any means verify this view. Indeed they have shown that if great care is taken not to disturb the underlying sand, almost the whole of the surface layer may be removed without at all affecting the bacterial character of the effluent. It is also shown that a new filter does not arrive at what is called its "full bacterial efficiency" until it has been in use for a considerable time; even though in the meantime surface layers may have been formed of sufficient thickness as to completely clog the filters.

By examining the sand, it has been found that this sub-surface purification only occurs when the sand grains for a considerable depth below the surface have become coated with a film of the gelatinous organic material referred to above. It has also been shown that if, during scraping, the bed is subjected to any considerable mechanical disturbances, as by spading, by which these envelopes are broken and detached, the result is a decided inferiority in the quality of the effluent. It is a well-known fact, that the longer sand is in use the greater is its efficiency for filtering purposes.

All these considerations go to show that while undoubtedly most of the purification takes place in the surface layer, it is not absolutely essential. The facts stated are chiefly of importance in so far as they indicate the true principles upon which the process of filtration depends. They should by no means tend to lessen the care which ought always to be exercised to preserve the surface layer intact. The purifying power of the main body of the sand should be considered as a factor of safety, and as an additional guarantee of good results.

As to the influence of the size of the sand, it may be stated generally that the "uniformity co-efficient" should be as low as possible. Also that the smaller the "effective size" the more efficient is the filtration, the less liability is there to disturbing effects, and the sooner does the sand arrive at its full bacterial efficiency. At the same time it must be operated at a lower rate, becomes clogged more easily, and thus requires more frequent scraping. The latter performance, together with the periodic renewal of the sand, will form the principal part of the expense of operation. There is thus a minimum limit beyond which it would be uneconomical as well as unnecessary to go. The best size, taking everything into consideration, will evidently depend to a considerable extent on the quality of the water and other local circumstances.

The "effective size" of the sand used in the principal European filters varies, according to Mr. Allen Hazen, from .20 to .44 millimetres; and the "uniformity coefficient" from 1.5 to about 3.7.

As to the proper depth of the sand layer, there is even now considerable difference of opinion among engineers. The great variations in the depths of the sand in the older filters, shown by Fig. 1, are not surprising, considering the fact that when the most of them were built nothing was known of their biological action. If we adopt the view, that it is only the surface film which filters, the determination of the best thickness becomes merely a matter of comparing the extra operating expense due to the more frequent renewals of a thin bed, with the corresponding saving in first cost. In most of the European filters the renewal does not take place till the thickness of the bed has been reduced to from 12 to 24 inches. The former is the limit imposed by the Imperial Board of Health of Germany. It would seem to be better practice to require a minimum depth of from 2 to 3 feet, in order to have at all times the benefit of the steadying effect produced by depth of bed. Besides this there is the additional advantage of having a deep permanent layer, which is never disturbed, and which, therefore, causes the filter to increase instead of decrease in efficiency as it grows older.

GRAVEL.

The layer of gravel serves to support the sand and to conduct the water horizontally to the under-drains. The excessive thickness used in some of the old filter beds (see Fig. 1) is not at all necessary, 12 or 15 inches being quite sufficient. It should consist of 3 or 4 layers of graduated sizes, the top one being fine enough to support the sand without any liability of the layers getting mixed. Around the openings into the underdrains the separate stones should be carefully placed so as to avoid any possibility of movement when the water begins to flow. If necessary the gravel must be thoroughly washed before being put in place.

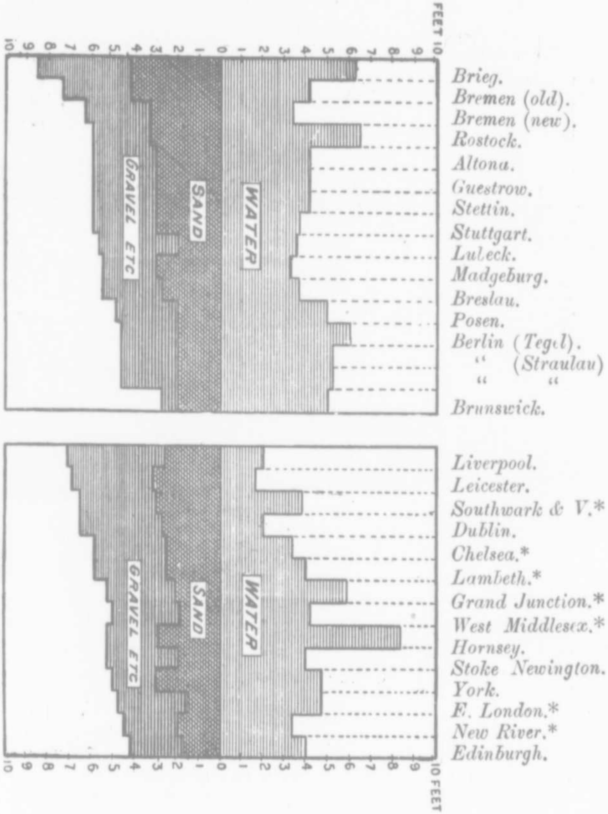


Fig. 1.—Diagram showing Depth of Materials in several European Filter Beds.

* London Water Companies.

UNDERDRAINS.

In arranging the underdrainage system of a filter, which includes the gravel bed, the object to be aimed at is to cause the water to sink vertically through the sand, and as nearly as possible at a uniform rate in all parts of the bed. In order to effect this it is evident that the resistance to horizontal motion in the underdraining system must be everywhere nearly the same. Attempts have been made to calculate the proper size of the underdrains, using formulæ for the flow of water through gravel and sand of various sizes. A discussion of the matter will be found in the Report of the Mass. State Board of Health for 1892, and also in Allen Hazen's book on the "Filtration of Public Water Supplies," p. 32-41. With round tile drains, and a daily filtration rate of 2.57 million gallons per acre, Mr. Hazen suggests the following limits to the area which pipes of the different sizes should be allowed to drain :

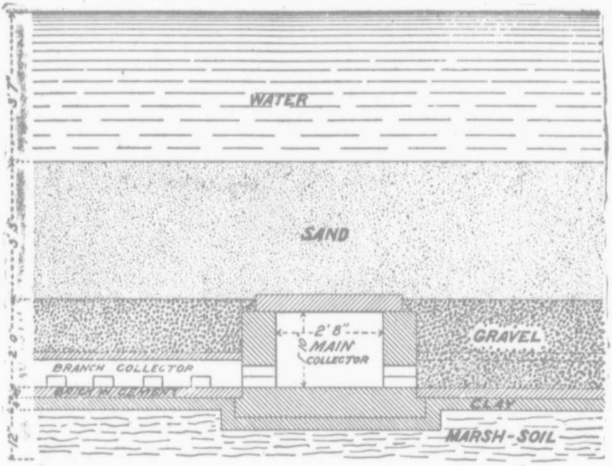


FIG. 3.—Section of Hamburg filter bed.

Diam. of drain.	To drain an area not exceeding	Corresponding velocity of water in drain.
4 inches.	290 square feet.	0.30 ft. per sec.
6 "	750 "	0.35 "
8 "	1530 "	0.40 "
10 "	2780 "	0.46 "
12 "	4400 "	0.51 "

and a cross-sectional area for the larger and main drains of at least $\frac{1}{6000}$ of the area drained. With the rate mentioned this would give a maximum velocity in the drain of 0.55 ft. per second.

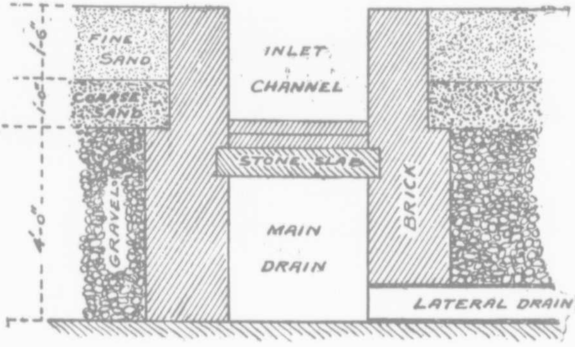


FIG. 4.—Section of filter bed proposed in 1866 by Kirkwood for St. Louis, Mo.

These underdrains are variously constructed of open jointed channels of stone or brickwork, or of tile pipes with perforations or open joints. (See Figs. 3, 4, 5, 6.) There is no advantage in spacing the laterals more than about 16 feet apart, as the extra quantity of coarse gravel necessary would cost more than the saving in the pipe. In some filters the underdraining has been accomplished by means of a double bottom of open brickwork supported on arches or other arrangements of the same material.

The lateral drains usually rest upon the bottom of the basin, but the main drain is often placed lower. (See Figs. 5 and 6.) If the top of the drain is higher than the coarsest layer of gravel, that part should be closed to prevent the entrance of the fine gravel.

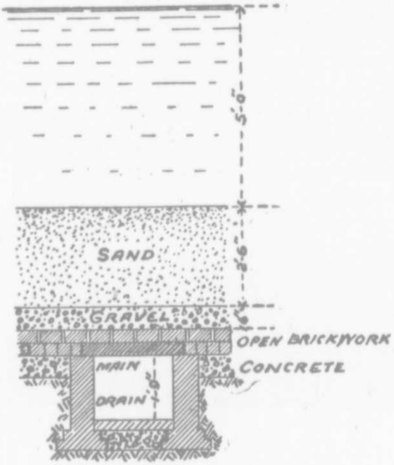


FIG. 5.—Section of filter bed New River Water Company (London).

In several of the old filters vertical ventilating pipes extend from the underdrains above the surface of the water on the bed. These are for the purpose of allowing the escape of air from below, so as not to cause disturbance by passing through the sand. They are not used in the latest filters, as it was found that they were of no advantage, but rather a source of trouble, through the formation of channels between them and the sand, which allowed water to pass without filtration.

BASIN.

The basin which encloses the filtering materials must of course be water-tight; and in that respect the same care must be exercised in its design and construction as would be necessary in the case of any reservoir for holding water. Its depth will depend upon the thickness of the bed and the height to which the water is to be allowed to rise, but does not usually exceed 10 or 12 feet. The bottom is usually level, or perhaps with slight depressions for the lateral drains. The walls

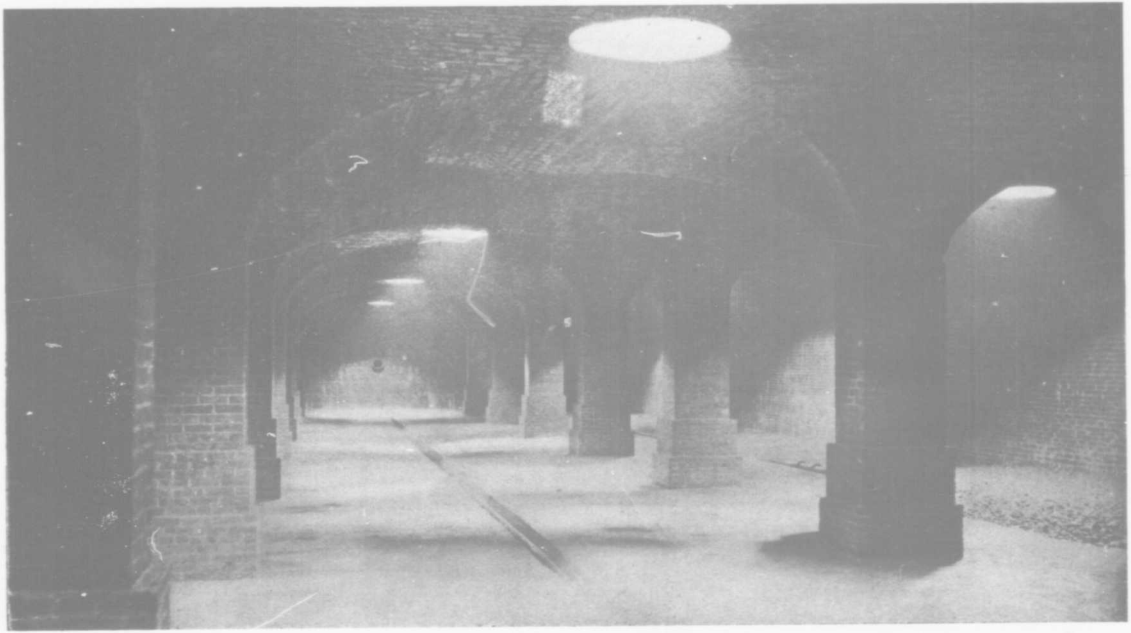
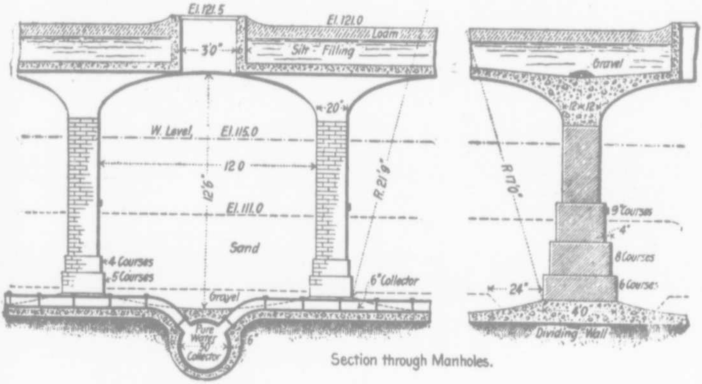


Fig. 8.—COVERED FILTER BED AT ASHLAND, WIS.

may be either vertical or sloping, depending upon the material used. Taking into account the necessity of uniformity in the filtration rate at different points of the bed, vertical sides are probably preferable to sloping. Local circumstances will as a rule determine the best method of construction and the material to be used. The latter may include stone masonry, brick, concrete, earth embankments, puddle, etc.



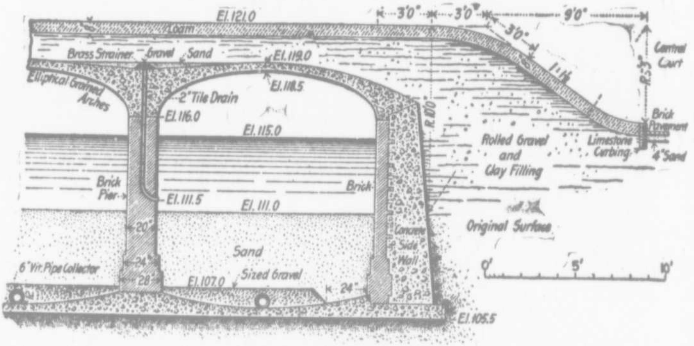
Section through Manholes.

FIG. 6.—Section of filter bed for Albany, N.Y. (From Engineering News.)

Concrete is a very satisfactory, and in most cases an economical material to use for any part of the structure.

If a roof is required it should consist of groined arches, supported on pillars, preferably of brick. (See Figs. 8, 9 and 10.) Care is necessary to obtain a solid foundation for the latter, as the form of roof will not admit of much unequal settlement. A good plan is to form the bottom of flat inverted arches which will give a firm and even support for all the pillars ; and the lateral underdrains will then lie along the hollows midway between the rows of piers. (See Figs. 6 and 7.) With a roof of this kind vertical side walls will be more economical than sloping ones. But the plane surface between the wall and the bed must be broken by projections, in order to prevent the liability of unfiltered water passing along the junction ; which remark also applies to the piers. It is to prevent this same contingency that the gravel layer is only carried to within 2 or 3 feet of the walls, its place being filled by the sand which here composes the whole depth of the bed.

(See Figs. 6 and 7.) Around the inlet and outlet chambers there should be no gravel within 5 or 6 feet of the walls.



Section through Piers.

FIG. 7.—Section of filter bed for Albany, N.Y. (From Engineering News.)

Manholes must be constructed in the roof for the admission of light and air. Also a "run" for entering and removing the sand scrapings, etc. With piers spaced 14 or 16 feet on centres a light and strong roof can be built of concrete at a very moderate cost. When the roof is finished it is covered to a depth of two or three feet with earth surmounted by a layer of loam, which may be seeded down or laid out in flower beds, etc.

For open filters the sides may be of earth embankments, made watertight by a layer of puddle or concrete. If of the former, a paving of brick is necessary, which must be of sufficient strength to withstand the action of the ice where it is exposed.

OPERATION.

Before proceeding with the methods of operating a filtration plant, reference will be made to Fig. 11, which shows diagrammatically a filter bed with inlet, outlet, underdrains, etc. With a given flow of water through the bed, the vertical distance H represents the head required to force this quantity through the surface film, the sand, gravel and underdrains. It is variously termed "loss of head," "head on the filter," "filtering head."

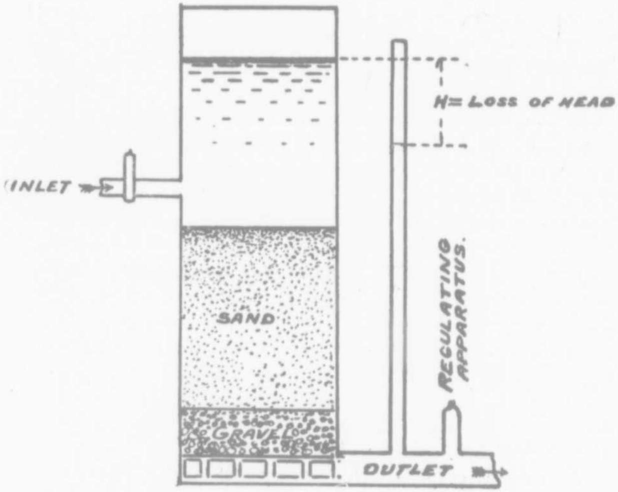


FIG. 11.—Diagram showing various parts of a filter bed.

The depth of water in the majority of European filter beds is usually from 3 to 4 feet, with the full depth of sand. In some of these filters, it was allowed to rise and fall according to fluctuations in the removal of the effluent. Such variations in depth, however, are found to have an injurious effect upon the surface layer, and on the efficiency of the filtering process; in the newer plants, therefore, they are provided against by an apparatus on the mouth of the inlet pipe by which the water when it reaches a certain height automatically closes the inlet. These consist usually of some form of balanced valve worked by a float. In connection with an open filter such an arrangement must of course be protected from frost.

The inlet opens into a small chamber at the side of the bed from which it is separated by a wall. The water flows over the wall on to the bed, and is prevented from disturbing the surface of the sand by paving it for a short distance from the chamber. Sometimes the water enters by overflowing an open masonry channel extending across the surface of the bed. (See Fig. 4.)

The loss of head, corresponding to a given rate of flow of water through the filter, will depend upon the extent to which the surface film has formed, and the friction in the sand, gravel and underdrains; but under any given conditions it varies (within practical limits) directly as the rate.

In some of the old filters, the outlet was connected directly to a clear water basin, or pump well; and the difference in level between the surface of the water in the filter and of that in the well was, of course, equal to the loss of head. Fluctuations in the draft upon the well produced corresponding fluctuations in the filtering head, and therefore in the rate which was thus automatically adjusted to the demand. In others, however, some sort of apparatus was placed between the filter and the clear water basin by which the rate could be kept constant. This is now considered to be of the greatest importance for the reason that bacterial tests of the effluents have shown that marked deterioration invariably follows fluctuation in the rates. This is probably caused by the mechanical disturbances produced in the sand bed and surface film. For details of such tests, see Report Mass. State Board of Health for 1894.

In the newest plants, therefore, some kind of an arrangement is always provided for the regulation of the flow, examples of which are shown in Figs. 12, 13 and 14. Since the rate varies directly as the loss of head, it is immaterial which is regulated. Some of these devices, therefore, regulate the flow directly, while others accomplish the same result by the indirect method of regulating the loss of head. In order that the former may be kept the same from one day to another, the latter must be gradually increased as the period of service of the bed extends, so as to correspond with the increasing resistance of the surface layer. This is effected automatically in the device shown in Fig. 12, which was designed by Lindley for the filters at Warsaw. The apparatus is contained in a water-tight chamber, connected on one side with the filter, and on the other with the clear water basin. The rate at which the water can pass from one to the other depends upon the depth to which the slits in the sliding pipe extend beneath the surface of the water. This is adjusted by weights at the other end of the chain which passes over a pulley. Thus the rate can be kept constant; and as the resistance of the bed increases the level of the water in the chamber will automatically adjust itself to produce the necessary differences in level or loss of head.

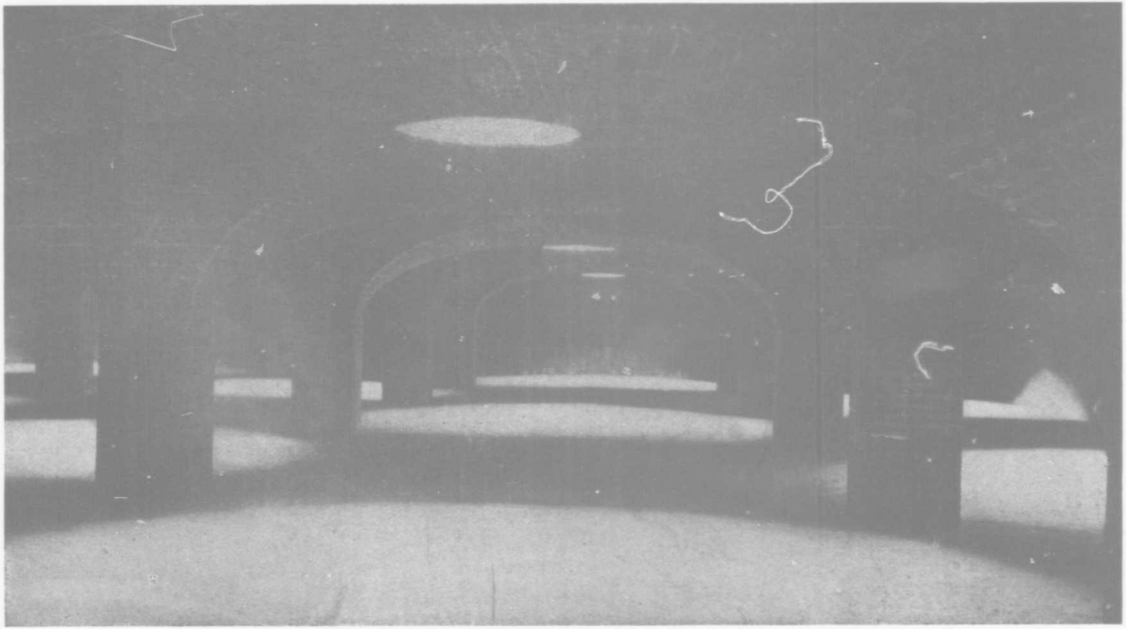


Fig. 9.—COVERED FILTER BED AT ASHLAND WIS., SAND IN PLACE.

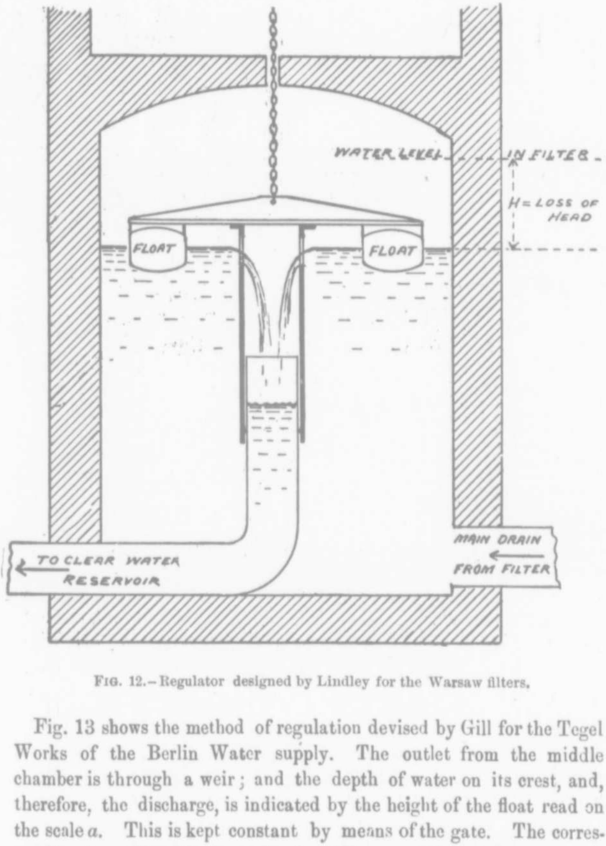


FIG. 12.—Regulator designed by Lindley for the Warsaw filters.

Fig. 13 shows the method of regulation devised by Gill for the Tegel Works of the Berlin Water supply. The outlet from the middle chamber is through a weir; and the depth of water on its crest, and, therefore, the discharge, is indicated by the height of the float read on the scale *a*. This is kept constant by means of the gate. The corresponding loss of head is shown by the difference of the readings on scale *b*. Keeping the water in the filter always at the same level, a constant rate can only be maintained by the gradual falling of the level in the right hand chamber and a consequent wider opening of the gate.

Fig. 14 shows the principle used in the new Hamburg filters. A similar method was recommended by Kirkwood for St. Louis. The

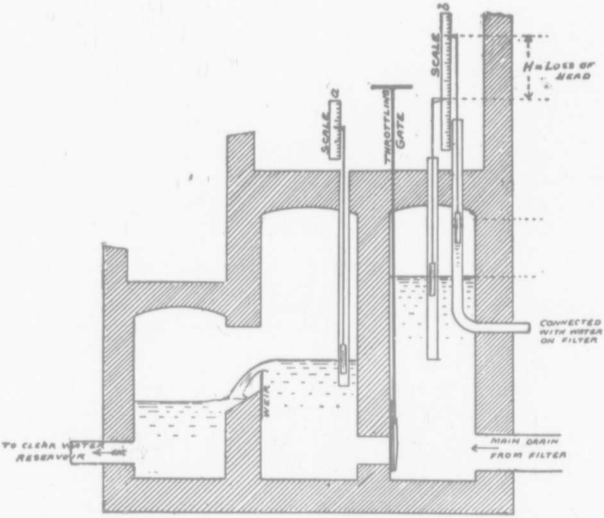


FIG. 13.—Regulator used in the Berlin (Tegel) works.

scale on the right reads downwards, and its zero corresponds to the level of the surface of the water on the filter, which must of course be kept constant. In the first chamber is a float with a pointer attached. The reading of this pointer on the right scale evidently gives the loss of head. The reading of the same pointer on the other scale gives the corresponding rate. This is accomplished in the following way: The outlet of the first chamber is through the weir, which is movable in a vertical direction. The smaller scale is fixed to this weir as shown in Fig. 14, so that the distance between the crest of the weir and the zero of the scale is the same as that between the pointer and the water line of the float. Both loss of head and the rate may therefore be regulated by lowering or raising the weir.

As to the limit beyond which the loss of head should not be allowed to go, the general opinion seems to be that it should not be greater than the depth of water on the bed, though the Lawrence experiments have not shown any bad effects from exceeding this limit.

As a general thing it may be stated that, everything else being equal,

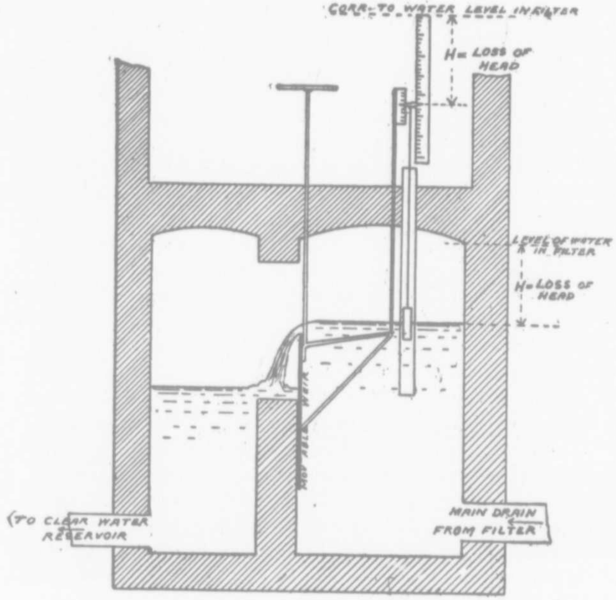


Fig. 14.—Regulating apparatus used in the new Hamburg filters.

the higher the rate the poorer the quality of the filtrate. But with fairly low rates this deterioration is slight, so that entirely satisfactory results can be obtained with rates up to 3 or $3\frac{1}{2}$ million gallons per acre per day. Probably higher rates could be safely employed if very great care were exercised in the operation of the filter. The relative effects of high and low rates from a financial point of view are discussed further on.

SCRAPING THE FILTER.

When the clogging of the filter bed has become such as to require a loss of head greater than the prescribed limit, the inlet is closed and the water allowed to drain away until it has sunk some distance below the surface of the sand. When this has become sufficiently firm, workmen enter the bed with planks, wheelbarrows and broad flat shovels. With these they carefully remove the surface layer and pile it up in little heaps, which they afterwards remove with the barrows. The depth removed varies from $\frac{1}{2}$ to 1 inch, and averages about $\frac{8}{10}$ of an inch. The surface of the sand is then raked to loosen up the packing caused by the boots of the workmen, and after smoothing down any irregularities the planks are removed and the filter is ready for another period of service.

The refilling begins from below by admitting through the underdrains filtered water from another bed in action. The object of this is to drive out the air from the pores of the sand, where its presence in the form of bubbles would cause considerable unnecessary friction. When the water has risen a few inches above the surface of the sand, the lower connection is shut off and the refilling is completed by means of the surface inlet.

Before filtration proper begins the water should be allowed to stand on the bed for several hours; or the first million gallons or so should be wasted. The amount wasted can be reduced by beginning the filtration at a low rate, and gradually increasing it to the maximum.

When the scrapings have reduced the sand-bed to the minimum allowable thickness, the total amount removed, which has in the meantime been thoroughly washed, is replaced at one time. Before doing so the surface of the permanent layer, which is never removed, should be loosened up by being spaded over to a depth of six inches or so. If this is not done, there is a liability of sub-surface clogging at its junction with the clean sand.

When the filter is started again, it is, except for the permanent layer, in the condition of a new filter, and so requires extra care in operating it, and the filtrate should be wasted for a much longer time than is required after the scrapings. Piefké of the Berlin Water Works places this period at six days.

Considering the labour necessary and the time the bed is out of use, this replacing of the sand is an expensive operation, and should not occur oftener than can be avoided. In most plants the usual period is about once a year.

SAND WASHING.

Sometimes it is possible to obtain new clean sand at less cost than is necessary to wash the old. But this is rarely the case; hence an important part of the equipment of a fair-sized filtration plant is the apparatus for the washing of the sand. The simplest of the methods employed for this purpose consists of a broad shallow box, which is set in an inclined position. The dirty sand is thrown into this box, and a jet of water played upon it from a hose. The water overflows from the lower end of the box and carries the dirt with it. This is continued until the water runs off clean.

The more elaborate methods employ mechanical means to force the water through the sand. Drum-washers, operated by horse or steam power, are largely used in Germany. They are set in an inclined position, and the sand, with streams of water playing upon it, is forced from the lower to the upper end by means of revolving spiral blades. Various other methods more or less on the same principle are employed. Fig. 15 shows the sand-washer used at Hudson, N. Y.

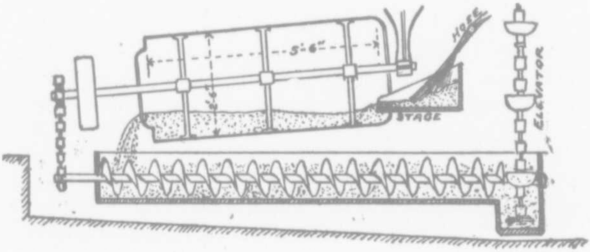


FIG. 15.—Sand washing apparatus used at Hudson, N.Y.

The dimensions are shown on the figure. The dirty sand is shovelled on to the stage, from which it is washed by a hose jet into the revolving cylinder. From the lower end of the latter it falls into a wooden trough 1 foot square in section and closed at both ends. The screw forces the sand into a pit at one end, from which it is elevated by buckets to the floor of the sand storehouse above. The water overflowing the box carries the dirt with it.

The "Ejector" washer is probably the most efficient of all the methods employed. It consists of a series of conical hoppers arranged in a row. At the bottom of each hopper is an ejector through which a stream of water passes under a pressure of 15 or 20 lbs. The dirty sand is thrown into the first and largest hopper. From this it is ejected through a vertical pipe into a trough, from which it falls into the next hopper. Here the same thing occurs; and the process is repeated until the water, which is continually overflowing from the hoppers, comes off clear. The whole arrangement must be enclosed in a masonry pit, from which the dirty water is conducted by drains. Six or eight hoppers are required for each machine, which will have a capacity of from 5 to 6 cubic yards per hour. Sand washers of this type are used in the new filters at Hamburg (Fig. 16); and are to be used in the plant now under construction at Albany, N. Y. Details of the latter are given in *Engineering News*, Feb. 10, 1898.

The volume of water required in sand-washing varies, according to the method used, from 12 to 20 times that of the sand; the ejector machines apparently requiring the most. The question of cost will be referred to under maintenance.

INTERMITTENT FILTRATION.

The operations which have been described in the foregoing pages are those connected with the carrying on of what is known as *continuous* sand filtration; and in determining what methods produce the best results, our only test has been the degree of bacterial purification effected. The reason of this is, as we have already seen, that in waters at all likely to be used as public supplies, the actual amount of organic matter is relatively so small as to be of little sanitary significance. Nevertheless, there is a certain degree of chemical purification effected by this process. Analyses of the effluents show a reduction of the dissolved organic matter of from 30 to 60 per cent. This is brought about by the action of the bacteria, which, though existing under adverse conditions, are yet capable of producing this result in the presence of the free oxygen in the water, the amount of which is usually quite sufficient for the purpose. Now, in the case of sewage, which is only very highly polluted water, the amount of free oxygen is very small in comparison with the organic matter present. And it was found, in making experiments on the purification of sewage by passing it through beds of sand, that if air were artificially introduced a very complete reduction of the organic matter would be effected by the bacteria. This was accomplished by working the bed intermittently; that is to say, at regular intervals of time the bed was allowed to drain, and fill its pores with the air drawn in after the sewage. After taking this breath the bed rested; then the sewage was again turned on to the surface, preventing the escape of the air which was necessary to provide oxygen for its purification. A similar method used in connection with water is what is termed *intermittent filtration.* The first filter of the kind was built at Lawrence, Mass., by H. F. Mills, C. E., member of the State Board of Health. Since then, small plants on the same principle have been built at Mt. Vernon, N.Y., and Grand Falls, North Dakota.

The results do not seem to indicate any necessity for their use, not being at all superior to those of continuous filters, while the method of operation is not suited to cold climates, and either requires a greater area of bed or a higher rate of filtration. A description of the Lawrence filter may be found in *Trans. Am. Soc. C. E.*, 1893, p. 350.

GENERAL ARRANGEMENT.

From what has been said, it will be evident that where the water is at any time liable to turbidity, a settling basin, capable of holding from 12 to 24 hours' supply at least, must be provided. Also, in order that the filter may be able to work continuously at a uniform rate, a clear water basin will be necessary of a capacity sufficient to cover the maximum fluctuations in the consumption. Fig. 17 indicates roughly the general arrangement of the parts of a complete system. If the supply is from a storage reservoir, the filters are placed below the dam, and are, of course, supplied by gravity. (See Fig. 18.) But even when the supply is from a river or lake, the topography of the ground often admits of the same economical arrangement. If this is not possible, the water must be pumped into the settling basin by a separate pump of the low lift variety. The extra expense of two pumpings may be almost eliminated if the same station, boiler plant, etc., can be made to serve for both pumps.

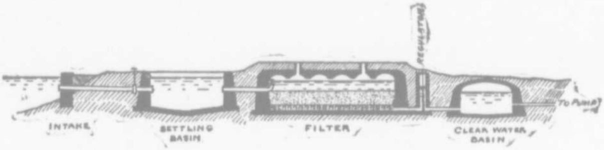


FIG. 17.—Sketch showing the relation of the parts of a filtration system.

The total area of filter beds required depends in the first place upon the maximum rate adopted; and, second, upon the area out of use while being scraped and refilled. The higher the rate of filtration the less the total area, and therefore the first cost of the plant. The principal item of expense connected with the operation of this plant is that for scraping; and it is found that the amount scraped for any given quantity of water filtered is independent of the rate. Also, the allowance for the area out of use will not vary with the rate to any extent. Hence an increase in the rate will not by any means produce a proportionate reduction in the cost of filtration. A rate of 3,000,000 gallons per acre of bed in use will give results entirely satisfactory from the standpoint of efficiency, and at a cost which is usually by no means excessive.

The size of the individual beds will depend in part upon the extent of the total area, the smaller plants having necessarily to use smaller beds. A large bed costs less per unit of area than a small one, on account of the proportionately greater length of wall in the latter case. With a large bed it is, however, probably more difficult to obtain a uniform rate of filtration over the whole area.

During the winter of cold climates the cost of maintenance is considerably increased by the expense of removing the ice which forms in the bed. It is also difficult to avoid injuriously disturbing the surface of the sand. Beside this when the water is drawn down, the surface sometimes freezes before it can be scraped. On account of such disadvantages as these, filter beds should be covered in all cold climates. The best method of constructing these roofs has already been referred to.

The proper number, shape, and area of the beds of a system can only be determined for any particular case by careful study of the local conditions, and by making comparative estimates of the different items of cost of construction, maintenance, etc. There will be opportunities for the exercise of considerable ingenuity in the general laying out of the system, the relative placing of its parts, the arrangement of the piping, drains, etc., in order that convenience and economy may be happily combined.

THE COST OF CONSTRUCTION.

This will of course depend on the local circumstances and the kind of materials used. As in all hydraulic work, great care is required in the construction, and the best quality of materials must be used. In the main, it is the same class of work as is required in the building of distributing reservoirs.

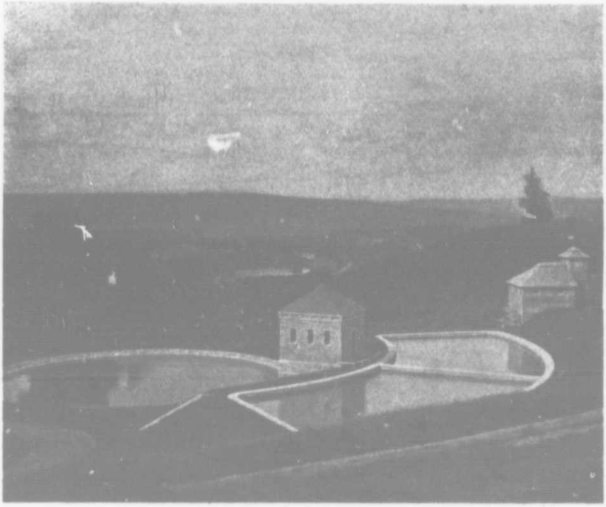


Fig. 10.--FILTER BEDS AND CLEAR WATER BASIN AT ILION, N.Y.

ELLEPTICAL GROINED ARCHES USED IN ROOF OF WELLESLEY, (MASS.) COVERED RESERVOIR.

The following table gives the cost of construction for several European and American filters :

Place.	Cost per Acre.	
	Covered.	Open.
London		$24,000—$40,000
Berlin (1884-87)	$66,000—$70,000	
Hamburg (1893)		30,500
Warsaw (1885)	78,000	
Zurich (1885)	86,000	
Nantucket, Mass. (1892).		45,500
Hudson, N.Y. (1874-88)		73,000
Ilion (1893)		96,700
Ashland, Wis., (1897)	80,000	
Somersworth, N.H. (1898)........	64.000	
Poughkeepsie, N.Y. (1872)		90,000
do do (1896)		41,000

Lindley gives the general cost of continental filters as $45,000 per acre for open, and $68,000 for covered.

The following figures, giving in detail the bids received Feb. 15th, 1898, for constructing the water filtration plant now in process of construction at Albany, N.Y., will be of more interest. When completed it will be by far the largest plant yet built in America ; and in general design and completeness of equipment it will be second to none.

It will consist of a settling basin of 16,000,000 gallons capacity, eight covered filter beds, each with $\frac{7}{10}$ of an acre of sand surface, and a clear water reservoir with a capacity of 600,000 gallons. There will also be provided an office building containing fully equipped chemical and bacteriological laboratories.

The price for the sand and gravel included the necessary screening, washing and putting in place

The sand washer is of the ejector type. Other details are shown in Figs.

The bids are as follows :

Material.	Quantities.	Prices of				Engineer's Estimates.
		Successful Bidder.	Other Bidders.			
Shale Rock Excavation	5,000 cu. yds.	$ 1.20	$ 0.30	to	$ 1.50	$ 0.80
Earth excavation (above grade)	60,000 "	.27	.13¼	"	.476	.20
Earth excavation (below grade)	3,000 "	.30	.20	"	.60	.40
Rolled clay and gravel embankments	21,000 "	.52	.45	"	.90	.50
Silt and loam filling	23,000 "	.15	.15	"	.50	.20
General filling (rolled)	18,000 "	.18	.07	"	.40	.20
Puddle in place	13,000 "	.71½	.67	"	1.07	1.00
Broken stone or gravel for lining	1,900 "	.85	.99	"	1.40	1.25
Sodding	3,000 sq. yds.	.15	.15	"	.60	.15
Seeding	8 acres	25.00	12.50	"	70.00	50.00
Gravel in roadway rolled	800 cu. yds.	.60	1.00	"	1.50	1.00
Vitrified brick laid as paving	120 M.	20.00	18.00	"	30.00	20.00
Stone curbing	800 lin. ft.	.60	.75	"	1.50	.50
Concrete in floors	11,000 cu. yds.	2.31	2.34	"	3.50	3.00
Concrete in vaulting	7,000 "	3.85	3.90	"	7.50	5.00
Other concrete	3,000 "	2.13	2.50	"	4.30	3.00
Brick work	4,500 "	8.12½	7.00	"	10.00	6.00
Imp'd Portland Cement	500 bbls.	3.12½	2.35	"	3.00	2.75
American do do	14,000 "	2.14½	1.90	"	2.21	2.15
Rosendale Cement	1,500 "	.97½	.85	"	1.95	1.00
Furnishing and placing 2″ drain pipe in piers.		525.00	300.00	"	1,318.00	700.00
2 in. agricultural drain pipe	2,000 lin. ft.	.04	.05	"	.10	.05
6 *ins. drain pipe open joints*	16,000 "	.11	.10	"	.12⅕	.10
Fur. and laying all vit. pipe cement joints		5,337.00	3,850.00	"	5,933.00	6,000.00
Placing all gates, etc. Fur. by board		1,140.00	700.00	"	2,000.00	470.00
Fur. and placing all cast iron pipe and specials		20,701.25	14,750.00	"	20,000.00	15,000.00
Iron filter covers	672 each	4.40	5.00	"	6.50	5.00
Sand washing apparatus	2 sets	393.00	250.00	"	1,000.00	800.00
Sand run fixtures	8 each	407.50	100.00	"	511.00	200.00
Regulator houses	8 each	862.24	175.00	"	900.00	500.00
Office and laboratory building		4,881.00	2,700.00	"	10,200.00	3,000.00
Filter gravel in place	7,000 cu. yds.	1.05	1.00	"	2.00	1.50
Filter sand in place	36,000 "	1.00	.90	"	1.78	1.25
Split stone lining	2,000 sq. yds.	.82	1.03	"	3.60	2.00
Rough stone paving	200 "	.82	.93	"	2.50	.80
Fasteners fur. and placed in concrete vaulting	3,000	200.00	150.00	"	225.00	100.00
Iron fence	850 lin. ft.	2.00	1.00	"	2.00	1.00
Connection with pump-well and closing old intake		3,000.00	1,000	"	4,000	3,500.00
Total		$309,866	$322,358	"	$387,345	$322,

The items of special interest are given in italics.

It will thus be seen that a covered filter plant of this area (5.6 acres), with settling basin, clear water basin, and all other appurtenances complete, can be built for less than $56,000 per acre.

For further details and information concerning this plant see *Engineering News*, Feb. 10th and Oct. 20th, 1898.

MAINTENANCE.

The total cost of maintenance of a filtration plant is made up of the operating expenses, and the interest and sinking fund charges.

The former—the operating expenses—comprise : —

(*a*) The cost of superintendence, and of attendants to look after the regulation, etc.

(*b*) The cost of scraping and removing the sand.

(*c*) The cost of washing the sand.

(*d*) The cost of replacing the washed sand when renewal of the bed becomes necessary.

It is only in very large plants that a special superintendent is required, so that the expense for that purpose would not form a very large part of the total cost. The proper handling of the gates, and the running of the plant in general requires a degree of intelligence considerably above that of the ordinary labourer. The wages of the gatemen therefore will be from $2.00 to $3.00 per day.

Scraping and removing the sand by wheelbarrows seems to cost, under ordinary circumstances, between $40 and $50 per acre, depending upon the wages paid. At Mount Vernon, N. Y., the shovellers and barrow wheelers are paid $1.10 per day, and the scrapers $1.25. Mr. Chas. Fowler, for many years in charge of the filters in Poughkeepsie, N.Y., says that one man working 1 hour is required for every 150 square foot of surface cleaned and removed. This would cost at $1.50 per day, about $43.50 per acre. Lindley gives 30 days at 10 hours each for every acre, which at the same rate is $45.00 per acre. In the small plants at Ilion, N.Y., and Ashland, Wisconsin, the cost is at the rate of about $50 per acre.

The cost of sand washing varies with the method employed. In Poughkeepsie, when they used a simple inclined trough and water jet, it cost as high as $1.50 per yard. By improving their methods they reduced this cost, till to-day it is only 27 cts. per yard. In Hudson, the cost is 20 cents per yard, and in Ilion 18. In Germany it varies from 14 to 20 cents per yard.

The periodical replacing of the sand in the bed must be done carefully of course, but should not cost, including whatever is necessary to be done to the permanent layer, more than 40 cts. per cu. yard.

The cost of these various operations will of course depend upon the scale on which they are carried on. It will obviously be easier to keep the price low with a large plant than a small one. In the case of the former a force of gatemen and labourers can be permanently employed. In the smaller plants the operations of scraping and sand washing only take place at intervals, and are performed by labourers hired temporarily for the purpose, or by employees from other parts of the water system.

In using the above data to make an estimate of the total operating expenses, we shall employ as a unit the cost per million gallons of water filtered.

Assuming an average yield of 50 million gallons per acre between scrapings, the total cost would be as follows :

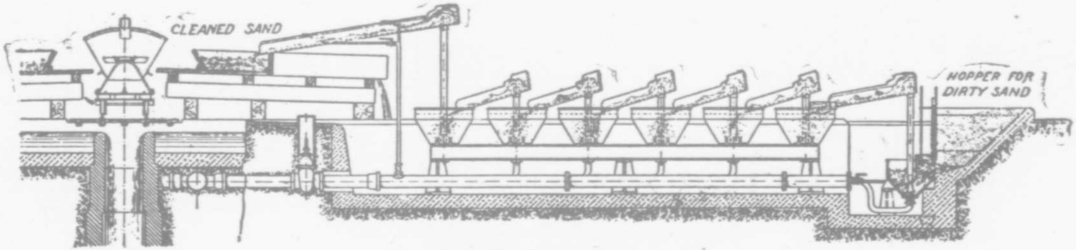
Scraping and removing @ $45 per ac.......	$0.90	per mill.	gals. filtered.
Washing 100 cu. yds. sand @ 25 cts. yd...	0.50	"	"
Replacing, etc., @ 40 cts " ...	0.80	"	"
Superintendence, etc..............................	0.25	"	"
Total................	$2.45	"	"

To this should be added the cost of bacterial analyses of the effluents, which should be made as frequently as possible in order to test the working of the filters. In many of the European plants a fully equipped laboratory is included in the equipment ; and some of the superintendents, like Piefké, Chief Engineer of the Berlin Works, are also expert bacteriologists.

The actual cost of the operations discussed above for some American filters is as follows :

Poughkeepsie, N.Y., for 20 years averaged	$2.90	per mill.	gals. filtered.
Hudson, N.Y., is given as	$1.38	"	"
Mount Vernon, N.Y., a little less than....	2.00	"	"
Ashland, Wisconsin, estimated to cost.....	2.25	"	"

The following table, furnished by W. B. Bryan, Esq., Chief Engineer East London Water Co., gives the yearly cost of filtration of the London Water Companies from 1880 to 1895.



SAND WASHING APPARATUS IN HAMBURG.

FIG. 16.

COST OF FILTRATION PER MILLION U.S. GALLONS—LONDON WATER COMPANIES.

Name of Company.	1880–1	1881–2	1882–3	1883–4	1884–5	1885–6	1886–7	1887–8	1888–9	1889–90	1890–1	1891–2	1892–3	1893–4	1894–5
	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
Chelsea	1.17	1.20	1.10	1.01	1.06	1.15	.80	1.08	.83	.66	.72	0.75	.62	1.16	.60
East London	1.17	1.40	1.24	1.06	1.06	1.17	.97	1.22	1.29	1.50	1.42	1.54	1.42	2.63	1.69
Grand Junction	1.01	.95	1.40	1.73	1.82	1.35	1.40	1.75	1.56	1.22	1.33	1.24	1.30	2.00	1.68
Lambeth	.83	.81	.96	.93	.90	.90	.87	.90	.95	.88	.86	1.01	1.20	1.46	2.54
New River	1.34	1.15	1.41	1.11	1.02	1.01	.98	.93	.98	.90	1.02	.93	1.17	1.43	1.03
Southwark and Vauxhall.	1.17	1.37	1.47	1.62	1.41	1.15	1.44	1.29	1.53	1.70	1.17	1.15	1.26	1.53	1.34
West Middlesex	1.67	1.54	1.74	1.67	1.30	1.07	1.70	1.01	.83	3.56	1.01	.97	1.42	.95	.96

To get the total cost of maintenance, we must include with the operating expenses the charges for interest and sinking funds. This will of course depend upon the cost of construction; and the latter will vary with the maximum rate of filtration adopted, and the proportion of the total area to be out of use while being cleaned. These being decided upon, it will then be easy to calculate the first cost per million gallons of daily yield. For example, if, with the rate chosen, the daily yield of the plant will be 2 million gallons per acre of the total area of beds, the first cost per million gallons will be half the cost of construction per acre, and so on. The diagram gives the cost per million gallons filtered, corresponding to different construction costs, which will pay the interest and sinking fund charges necessary to cancel the whole first cost with interest at the end of 40 years.

For example, with a first cost of $60,000 per acre, and a net yield of 2 million gallons per acre of total area, the cost per million gallons with interest at 4 per cent. would be $4.15.

The amounts taken from the diagrams added to the estimated cost of operation will give the total cost of maintenance per million gallons of water filtered. With interest at 4½ per cent. and a first cost of $80,000 per acre, this would amount to about $6. Add to this $2.50 for the expense of operation and we should have $8.50 as the total cost of filtering 1 million gallons of water, or 1,000 gallons for less than $\frac{9}{10}$ of a cent. With open filters, or more favourable local conditions, this charge would be considerably reduced.

RESULTS.

Having now discussed the method and cost of sand filtration, the next and last question to be considered is the nature of the results which this process can be depended upon to produce. There can be no question as to its efficiency from an æsthetic point of view. The complete removal of even the most minute particles in suspension, together with a large part of the dissolved organic matter, ensures the entire elimination of any characteristics the water may possess which would be disagreeable to sight, taste or smell. Yet it is because of the effectiveness of the purification from a sanitary standpoint that this system is especially noted. This is due, as we have seen, to its destructive effect upon the bacteria, which is almost sufficient to cause their entire disappearance during the passage of the water through the filter. The average reduction in a well designed and well managed plant will be as great as 98 or 99 per cent., as shown by comparing the number of germs in the effluent with that

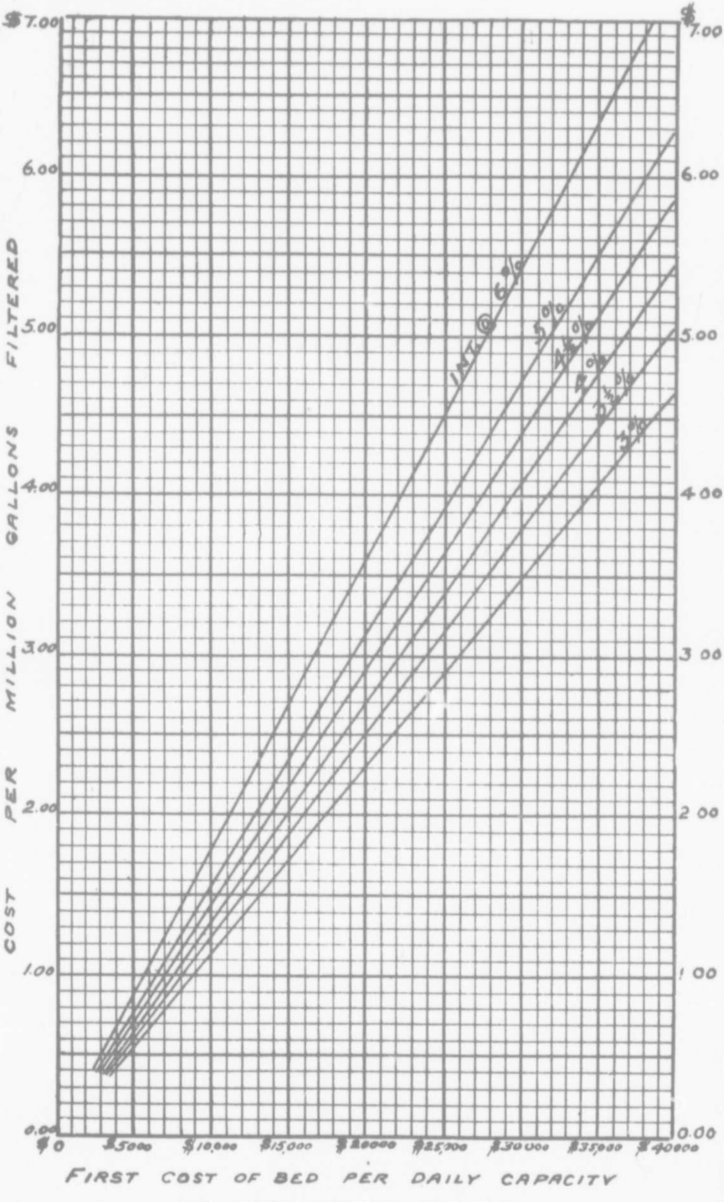


DIAGRAM GIVING THAT PORTION OF THE COST OF FILLING A MILLION GALLONS OF WATER WHICH IS NECESSARY TO PROVIDE FOR INTEREST AND 40 YEARS SINKING FUND.

in the applied water. But in reality it is even greater than this. For it has been shown that of the few bacteria which are present in the effluent, a certain number come from the underdrains, and have therefore not passed through the filter at all. These belong to some of the species of water bacteria, and, consequently, will be quite harmless. From tests made on the experimental filters at Lawrence with an easily recognized and hardy species, the actual reduction was found to be from 99.9 to 100 per cent. Now, when it is considered the filter is capable of producing such effects upon bacteria which exist normally in water, it will be evident that the effect upon the pathogenic or disease germs, which are out of their natural habitat and in a decidedly unfavourable environment, will be much greater. Thus what may be called the "hygienic efficiency" of this system must be remarkably high. The process is comparable to nature's method of purifying the surface water which furnishes the underground supplies; and if properly carried out, the water produced is probably of almost equal wholesomeness. The continued experience of places where sand filtration plants have been in operation for some time only goes to strengthen this conclusion.

In America the method is only just beginning to be employed. Up to the year 1892 there were but two plants of this description in the country, viz., those at Hudson and Poughkeepsie, which have been already referred to. Since that time 14 new ones have been completed and three others are under construction, the latter including the large plant at Albany. The experience to be derived from these plants is too limited to be of much value for some time to come; but the officials connected with the majority of them have invariably expressed their entire satisfaction with the method of working and with the results obtained.

In England and the continent, however, the experience of many years is available, this method, as we have seen, having been used long before the *rationale* of the process was understood. In England particularly, many of the supplies are from surface waters made available by means of large storage reservoirs; and in nearly every instance the stored water is filtered before being supplied to the consumers. The new supply for Liverpool, which was put into operation in 1892, comes from an artificial lake formed by damming the Vyrnwy River in Wales. This lake is 68 miles from Liverpool, and lies in a sparsely inhabited district remote from railways or towns. Yet the water from this source, safe as it may appear, is also made to pass through a sand filter before being allowed to enter the distribution pipes. In Germany the use of any surface water without filtration is prohibited by law.

But in addition to the high esteem in which the method is held wherever it has been used, there are certain health and mortality statistics which are perhaps of even greater significance. The typhoid fever death rate is now considered to be a pretty good index of the purity of a city's water supply. Keeping this in mind the following * tables prepared by John W. Hill, M.Am.Soc.C.E., will be found to furnish interesting information in this connection.

TABLE I.—TYPHOID FEVER DEATH RATE.

CLASS I.—10 or less per 100,000 of Population.

CITY	SOURCE OF WATER SUPPLY.	1890	1891	1892	1893	1894	Average for Five Yrs.
The Hague	Filtered from sand dunes	3	12	4	2	3.4	4.9
Rotterdam	Filtered from River Mease	6	4	6	5	4.8	5.2
Christiania		12	9	4	6	3	6.8
Dresden	Filter Gallery by River Elbe	9	8	5	4.5	8.2	6.9
Vienna	Springs in the Schneeberg	9	6	8	7	5	7.0
Munich	Spring Water from Mangfall Valley	8	7	3	15	2.5	7.1
Copenhagen		9	8	7	9	6.7	7.9
Berlin	Filtered from L. Tegel and River Spree.	9	10	8	9	4	8.0
CLASS II.—10 20 per 100,000 of Population.							
Breslau	Filtered Water from River Oder	15	12	15	10	6.1	11.6
Amsterdam	Filtered from Haarlam Dunes	19	11	15	16	8.5	13.9
Stockholm		18	18	19	8	8.3	14.3
Brisbane		....	....	....	19	9.6	14.3
London	Kent Wells, 17%. Filtered from Thames and Lea, 83%	16	15	11	16	15	14.6
Edinburgh	Filtered from Reservoir in Pentland Hills	19	18	13	14	15	15.8
Trieste		12	11	26	17	19	17
Brooklyn	Impounded and Well Water	26	20	17	17	15	19
CLASS III.—20-30 per 100,000 of Population.							
New York	Impounded from Croton and Bronx Rivers	21	22	22	20	17	20.4
Davenport	Filtered from Mississippi River	19	10.8	34.6	16.7	26	21.4
New Orleans	Rainwater from Tanks and Cistern	20	23	21	15	28	21.4
Sydney, N.S.W	Impounded from Upper Nepean	....	....	20	19	29	21.6
Hamburg	From River Elbe, filtered since May, 1893	28	23	34	18	6	21.8
Buda Pesth	Ground Water from Wells	34	23	26	15	14	22.4
Glasgow	Lake Katrine	26	31	18	20	24	23.8
Brussels		26	41	23	27	14	26.2
Paris	Rivers Seine, Marne, Vanne, Ourqc Canal, Art. Wells and Springs	30	20	28	25	29	26.4
Manchester	Lake Thirlmere	31	39	25	25	18	27.6

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* From an address on "Water Supply for Cities," given by J. W. Hill, C E., before the Faculty and Students of the University of Illinois, Jan. 21, 1896.

TABLE I—*Continued.*

CLASS IV.—30-40 per 100,000 of Population.

Venice		44	33	30	26	18	30.2
Milwaukee	Lake Michigan	33	33	31	37	26	32.0
Rome	Fontanadi Trevi, Aqua Felice & Paoli	35	36	26	34	30	32.2
Boston	Lake Cochituate and Sudbury River	43	33	29	30	28	32 6
Detroit	Detroit River	18	13	51	61	26	33.8
Dayton, O	Driven Wells	20	32	44	64	20	36.0
Turin		46	41	44	29	24	36.8
Liverpool	Lake Vyrnwy	24	25	25	53	58	37.0
Buffalo.	Niagara River	....	50	34	37	36	39.2
Providence	Pawtuxet River	29	47	39	34	47	39.2
Covington	Ohio River	43	45	40	27	42	39.4

CLASS V.—40-50 per 100,000 of Population.

S. Francisco	Impounded from Mountain Streams	59	41	34	32	35	40.2
Prague		33	37	53	36	57	43.2
Minneapolis	Mississippi River	81	45	36	60	45	45.4
Baltimore	Lake Roland, Gunpowder River	57	34	42	47	49	45.8
Newark	Impounded from Pequannock River since April, 1892	60	81	45	28	15	45.8
St. Louis	Mississippi River	34	30	37	103	31	47.0
Newport, Ky	Ohio River	....	....	...	58	37	47.5
Philadelphia	Schuylkill and Delaware River	64	64	40	41	32	48.2
Denver	South Platte River	....	....	53	57	35	48.3
Cleveland	Lake Erie	66	52	54	47	27	49.2

CLASS VI.—50-60 per 100,000 of Population.

St. Petersburg.	Filtered from River Neva	57	....	....	51	49	52.3
Cincinnati	Ohio River	67	62	40	43	50	52.4
Moscow	Springs, Ponds, Moscov and Yanza Rivers	73	75	68	40	29	57.
Toronto	Lake Ontario	93	94	43	42	17	57.8
Quincy, Ill	Filtered from Mississippi River	76	28	48	58	79	58.
Dublin	Filtered from River Vartry	62	58	39	87	48	58.8

CLASS VII.—Over 60 per 100,000 of Population.

Knoxville	Filtered from Tennessee River	101.5	45	36	67	59	61.9
Milan, Italy		.....	....	62	62	....	62.
Jersey City	Passaic River	91	95	53	60	76	75.
Washington	Potomac River	83	83	70	66	71	76.6
Louisville, Ky.	Ohio River	83	81	72	84	72	79.4
Chattanooga	Tennessee River	145	66	55	86	48	80.
Chicago	Lake Michigan	83	160	104	42	31	84.
Pittsburgh	Alleghany River	.....	100	100	111	56	91.7
Lowell, Mass.	Driven Wells, Merrimac River	158	98	90	61	55	92.4
Atlanta, Ga.	Filtered from Chattahootchie River	149	119	87	66	43	92.8
Lawrence, Mass	Filtered from Merrimac River	123	115	102	93	48	96.2
Alexandria, Eg't	River Nile	208	348	77	79	100	162.4
Cairo, Egypt	River Nile	260	233	163	154	135	189.4

TABLE II.—TYPHOID FEVER DEATH RATE.

Death Rate per 100,000 of Population, arranged upon Basis of Death Rates for 1894.

CLASS I.—Less than 10.		CLASS II.—10-20.		CLASS III.—20-30.	
Munich	2.5	Brussels	14	Dayton, O	20
Christiania	3.0	Buda-Pesth	14	Turin	24
The Hague	3.4	London	15	Glasgow	24
Berlin	4.0	Edinburgh	15	Milwaukee	26
Rotterdam	4.8	Brooklyn	15	*Davenport	26
Vienna	5.0	Newark	15	Detroit	26
Hamburg	6.0	New York	17	Cleveland	27
Breslau	6.1	Toronto	17	Boston	28
Copenhagen	6.7	Manchester	18	New Orleans	28
Dresden	8.2	Venice	18	Moscow	29
Stockholm	8.3	Trieste	19	Sydney, N.S.W.	29
Amsterdam	8.5			Paris	29
Brisbane	9.6				
CLASS IV.—30-40.		**CLASS V.—40-50.**		**CLASS VI.—50-60.**	
Rome	30	Covington, Ky	42	Cincinnati	50
St. Louis	31	*Atlanta, Ga	43	Lowell, Mass	55
Chicago	31	Providence, R.I.	47	Pittsburgh	56
Philadelphia	32	Lawrence, Mass	48	Prague	57
Denver	35	*Chattanooga, Tenn.	48	*Knoxville	59
San Francisco	35	Dublin, Ireland	48		
Buffalo	36	Baltimore	49		
Newport, Ky	37	St. Petersburg	49		
CLASS VII.—Over 60.					
Milan	62				
Washington City	71				
Louisville	72				
Jersey City	76				
*Quincy, Ill	79				
Alexandria, Egypt	100				
Cairo, Egypt	135				

*Mechanical filters.

These figures show that the lowest rates are for those cities deriving their supply either from springs or from surface waters which have been subjected to sand filtration carried out in accordance with the strictest modern requirements. They also indicate the general inferiority of the water supplied to American cities when compared with European supplies. Chicago and Berlin have about the same population, yet the typhoid death rate of the former is more than ten times that of the latter; or, in other words, the chances of contracting typhoid fever in Chicago are ten times as great as in Berlin.

Out of the many instances showing the beneficial effect of filtration with regard to the prevalence of certain infectious diseases, two of the most noted will be cited, one in Europe and the other in America.

Hamburg and Altona, though under separate governments, practically form one continuous city with a joint population of about 800,000. They both draw their water supplies from the sewage polluted Elbe River upon which they are situated. Altona is the nearest to the mouth of the river, and its water intake being three or four miles further down is below the outfall of both its own sewers and those of Hamburg. The Hamburg intake is about two miles above the city. In 1892 an epidemic of cholera occurred, during which Hamburg, with a population of 622,530, had 17,975 cases with 7,611 deaths, while Altona, with 143,000 population, had during the same time 562 cases and 328 deaths, and in many of the cases credited to Altona the disease was contracted in Hamburg. Wandsbeck (20,000), just across the river from Hamburg, enjoyed the same immunity as Altona. Both of these places purify their water supplies by sand filtration, while in Hamburg the only attempt in that direction was the employment of settling basins. A filtration plant was, however, in process of construction at that time, and was put in operation in May, 1893, since when the typhoid rate has diminished from about 30 to 6 per 100,000.

The other case is that of Lawrence, Massachusetts, which is situated on the Merrimac River, a few miles below Lowell. In spite of the great dilution, the water of this river which supplies both cities is seriously polluted by the sewage draining into it from the towns built along its banks; and as a consequence the typhoid fever rates in both places were unusually high.

In Sept., 1893, a system of intermittent sand filtration was completed. The effect upon the health of the citizens is shown in the following figures:

Year.	Deaths from Typhoid Fever per 100,000 Population.	
1887	114	
1888	114	
1889	127	
1890	134	
1891	119	
1892	105	
1893	80	
1894	47	(23)
1895	31	(17)
1896	19	(4)
1897	16	

For the last four years the figures in the brackets represent the number of deaths among people (principally mill operatives) who were accustomed to drink canal water without filtration ; so that the actual reduction in the death rate which should be credited to the filters is much greater even than the figures indicate.

Many attempts have been made during the last 12 or 15 years to improve upon the sand filter, but so far without success. Some of the methods invented involve less expense for construction or give better chemical results ; but the thoroughness of the bacterial purification effected by the sand bed has not been equalled by any.

The only one of these methods which has been used to any considerable extent is the American cr Mechanical System of Filtration, which is employed in several places in the United States. Sand is the material used in this process also, but it is contained in cylindrical wooden or iron tanks. The water enters the tanks, sometimes under pressure, and is driven through the sand at a rate 50 times as great as the maximum allowed in the case of the filter bed. For this reason the latter method is sometimes referred to as Slow Sand Filtration. With such a high rate the surface film must be formed artificially; and this is done by adding a solution of alum to the water, which forms with the carbonates present a white flocculent precipitate. Such a filter will, of course, soon become clogged ; but it can be quickly and easily cleaned without removing any of the sand from the tank. The results produced, under test conditions at least, are undoubtedly good ; and it has the advantage over the filter bed of somewhat lower first cost. On the other hand, the charges necessary for repairs and depreciation will be considerably higher on account of the less permanent character of its construction ; so that if proper allowance could be made for this, the difference in the actual cost of filtering a given quantity of water by either process would not be very great. In any case it will probably not involve an addition of more than 10 per cent. to the ordinary cost of the water. Indeed, calculations have been made showing that if a proper valuation is put upon the lives saved by its use, the construction of a filtration plant is often in the long run a source of economy. Such considerations, however, seem quite unnecessary. A city's water supply should be pure, wholesome, and attractive in appearance, just as the streets should be clean and well paved, and the public buildings architecturally beautiful. Besides, having gone to the expense of obtaining a public water supply, indifference with regard to its purity or unwillingness to provide for it would seem to be utterly unreasonable; especially when it can be secured for such a comparatively small increase in the total cost as sand filtration involves.

It would be much cheaper, of course, to purify only that part of the supply which is used for purely domestic purposes. But that would require a double set of distribution pipes; and we should also lose the satisfaction of knowing that the whole of the public supply could be used for any purpose with perfect impunity so far as health is concerned. And when we consider that the expense of filtering the whole supply at the most only amounts to two or three cents per month for each consumer, it will scarcely be considered excessive.

In conclusion, the author wishes to acknowledge his obligation to Messrs. Chas. R. Bettes, Ch. Engr., Queen's Co. Water Co., Far Rockaway, N. Y.; A. N. Russell, Secretary Water Commissioners, Ilion, N. Y.; G. E. Hoffmaster, Mgr. Suburban Water Co., Mount Vernon, N. Y.; Sam. Wheeler, Superintendent, Ashland, Wisconsin, for their courtesy in furnishing him with valuable data and information; also, to W. B. Bryan, M.I.C.E., Ch. Engr. of the East London Water Co., for the opportunity to make personal observations of the working of the large plant under his control.

CORRESPONDENCE.

Mr. E. Marceau. Although having no personal experience in water purification, the writer may be permitted to say a few words in connection with the very interesting paper of Mr. Lea. The question of pure drinking water is one of general interest, and one upon which engineers especially should endeavour to inform themselves.

During the latter part of last year the writer happened to read a most valuable paper on the subject, published in "Engineering," by Mr. Henry E. P. Cottrell, A.M.I.C.E., and the following are a series of notes taken down at the time, which the writer has tried to put in presentable form :—

In 1894 the Municipal Council of Paris inaugurated a competition on a working state between inventors of various systems of water purification. Some 148 different processes were submitted to a committee of experts. Of these 29 only were reserved for experiment, the others being rejected as unsuitable. The 29 proposals contemplated either sterilization by heat or filtration by means of sand, charcoal, cellulose, asbestos, pottery composition, centrifugal machinery, etc., or chemical purification by lime, iron, baryta and iron, sulphate of alumina and sand, etc.

The conclusions of the Committee's report, presented by Dr. A. J. Marten, Sanitary Inspector General of Paris, were : 1st. That none of the systems experimented upon attained the required standard on a working scale, and that, from the Seine River water used, all alike gave an insufficient supply of purified water ; 2nd, that sterilization by heat or by purely chemical treatment is not to be recommended, the former process giving very uncertain results and the latter being too expensive ; 3rd, that simple filtering did not effect a reduction of salts of lime in the water, and that, while this method more or less reduces the quantity of organic matter in the water, it very often produces a loss of oxygen in solution.

The commissioners finally stated that, if any preference could be given to any of the systems experimented upon, they inclined to the mixed processes all alone applicable to the purification of the drinking water of a city like Paris. These processes consist in the filtration by sand and in the subsequent use of inoffensive re-agents acting by the oxidation of organic substances, etc. Their objection to sterilization by sand filtration alone is, that, under the best conditions, the water thus treated still contains a certain number of germs, and is not therefore above suspicion.

This, it will be seen, is not an absolute condemnation of the sand filter, but it shows where the weak point of it is. Sand filters, the writer may state, have been in use in many small French towns for a number of years, and have been found to give a supply of fairly pure water. What the commissioners seemed to wish to put in evidence is that the sand filter cannot be relied upon as a perfect destroyer of germs.

Since the above-mentioned report was written more satisfactory processes of water purification have been discovered. One of these consists in the filtering of water through an ordinary sand filter and afterwards treating it by ozone.

The method was first applied at Oudshoorn, Holland, on a working scale, and the results obtained with Old Rhine water, which is very impure, show conclusively that, by the ozonizing process, all water microbes, usually present in river water, and all pathogenic varieties, if present, are absolutely destroyed. Moreover, the sterilization is obtained in a constant and regular manner throughout the prolonged use of the plant in question, a description of which may be found in the paper referred to.

The cost of purifying water by this process was at first very high. Experiments conducted at the Hygienic Exhibition at Paris show that it would amount to about $6.80 per million gallons. Taking the average daily consumption of water in Montreal at 20,000,000 gallons, the working of a plant similar to that at Oudshoorn, and of sufficient capacity to treat that volume of water, would entail a yearly expenditure of about $50,000, which, not to speak of the original cost and maintenance of the plant, would, the writer is afraid, be a too heavy tax on the City's treasury.

It may be stated, however, that the cost of the production of ozone has lately been considerably reduced owing to improvements in electrical machinery, and that the cost of water purification by this reagent must have fallen in consequence.

At the present day a portion of the water supply of Paris, some 22,000,000 gallons daily, delivered by the works at St. Maur, near the city, is being purified by the ozonizing process. The water is allowed to descend slowly into large cast iron cylinders of special construction where it is brought to a state of fine division. Ozonized air, produced by the discharge of an electric current of 50,000 to 100,000 volts, is pumped into the cylinders, and the water into long and perfect contact with it; all the dead and organic matter, as well as all the living germs which it contains, are completely destroyed. The writer has no data as to the cost of the plant or of its working.

But, if all or half of what is told by Mr. Cottrell of a newly invented process of water sterilization be true, perfectly pure water will in the near future be procurable everywhere and at hardly any cost. The new method is the invention of Professor Henry Bergé, and of his son, Dr. Albert Bergé, both of the University of Brussels; it is called the "Polozone process."

Polozone is the gaseous product of the combination of two volumes of oxygen and one volume of chlorine ($C l O_2$). Its preparation is simplicity itself. It may be employed either in the gaseous form or in the solution, and is a more powerful oxidizer than ozone. Although a perfect destroyer of microbe life, it does not affect men or animals.

The process is equally satisfactory in point of cost. The sterilization of one million gallons of the worst river water by polozone does not cost over 90 cents, and its application to the comparatively pure waters of the St. Lawrence or Ottawa rivers would not come nearly so high. Finally, if the water be first passed through a good sand filter, the quantity of polozone required to perfectly sterilize 1,000,000 gallon would not exceed 10 cents.

But this is not all. In the form of a solution, polozone can be applied to the purification of water in large reservoirs, in distribution mains, and even in the glass on the table. Travellers may carry it with them and have their pure water wherever they go.

The above results seem almost too good to be true, but the tables in Mr. Cottrell's paper, giving analyses made by several specialists, appear to leave no doubt as to their correctness.

It is the intention of the writer to communicate at an early date with the Messrs. Bergé, and to ask them for more ample information on the matter. The writer will be glad to communicate their answer to the Society.

In conclusion the writer wishes to state that the reading of Mr. Cottrell's paper will be found very interesting to all the members.

Mr. C. H. Keefer. The writer is sure that all the members are indebted to Mr. Lea for having contributed a paper containing so much valuable information.

Though there are cases where mechanical filtration can be used to advantage, there seems no doubt that, in the majority of cases, and wherever practicable, the natural process of slow sand filtration is the best to adopt. Slow sand filtration not only closely approximates natural filtration under the best conditions, but has the practical test of European experience of nearly fifty years, and is still the system used in new and important works. The writer knows the objection can be raised of the expense of cleaning uncovered filter beds in our climate in the winter. This, however, he hardly thinks is enough to prevent their use, as in both European and American plants they have the same difficulty to contend with though in a lesser degree. The objection to the extra cost of clearing in the winter could be removed and the advantage of covered storage obtained where it was possible to go to the expense of covering the filter beds. This might be done at a reasonable first cost by making the beds long and narrow in parallel series. These might be cheaply covered with timber for a time, or until the expense of concrete or brick could be afforded.

Mr. Rudolph Hering.

Mr. Lea's paper should, in the opinion of the writer, receive much commendation, because it takes up the entire subject of sand filtration of public water-supplies, and discusses it rather fully within a brief compass, and states what are now known to be the essential and most important facts relating to the subject. Our literature is, unfortunately, filled with a good many opinions which were formed before a sufficient number of facts were known, upon which a science of sand filtration could be developed, and it is refreshing to read a paper which seems to be devoid of unsubstantiated opinions.

It seems quite probable that we shall more and more come to recognize that, besides water purified in a laboratory, there is no purer water than that which has passed through either a natural or an artificial filter. By the natural filter the writer would understand the soil, the sand or porous rock, in its natural state, through which the rain water percolates, and from which it issues as springs. Artificially purified water is such as issues from filters which have been specially prepared for the purpose. Rain water, which was formerly supposed to be especially pure, is known to be often polluted by the effluvia rising from a city, and by the fact that the drops of rain, as it were, wash the air in descending, and free it from much of its finely divided organic matter, bacteria, etc.

The writer was pleased to see that Mr. Lea, when enumerating the methods of procedure in determining the quality of a given water-supply, puts at the head of his list a local examination of the water-shed instead of a chemical or biological examination of the same. It may be that both of the latter analyses are misleading. The cause of an apparent objectionable result may be entirely local, and due to a discharge from a single establishment carrying on an offensive trade. While the analyses might condemn such a supply, a local examination of the water would not condemn it, but cause the removal of the single objectionable establishment, and thus remove the source of an objectionable analysis. It is, of course, well to make all three examinations, but, if the writer had to choose, most weight would be given to Mr. Lea's first item, namely, to make a local examination of the watershed. Then the writer would have a biological examination made, and finally a chemical analysis, which latter can then be understood far better than if the old method is followed, by making *only* a chemical analysis.

Not the least interesting part of Mr. Lea's treatment of the subject is the historic part, and the writer is pleased to see that he gives proper credit to Mr. John Simpson as being the first engineer to introduce the method of sand filtration for water purification in 1839. While Mr. Simpson's name was mentioned many years ago, it is hardly ever mentioned now when the progress of water purification is discussed. The proper position of M. Pasteur and Dr. Koch, with reference to water purification, is also correctly given. Mr. Lea's description of executed works, and particularly of the maintenance thereof, will tend to adjust the general opinions held on this subject to a more correct basis, upon which future progress will have to be built.

C. Coffin. There is perhaps no subject which has at the present time greater interest for those connected in any way with the construction or management of water works than that of the filtration of water. The past ten or fifteen years have seen an advance in the knowledge of this subject and its laws, which, while not attracting so much attention from the general public as some of the remarkable and widely advertised discoveries of that period, may produce as important and valuable results in the well-being of the people. Every year adds to the difficulty of procuring potable water for public supplies, and of guarding present supplies from pollution. New enemies to the purity or the attractiveness of water seem to be constantly appearing, although this may be only seeming, and they are new to us only because we are new to experience; yet the fact remains that serious trouble may suddenly appear in a supply which has till then been free from that particular form of trouble.

Although ground waters are not entirely free from this experience, it is much more common in surface waters, and frequently comes in the form of vegetable micro organisms which make the water very disagreeable to the senses, for the time at least, and cause a greater popular outcry than serious pollution by sewage would do unless the latter were followed by and directly connected with an epidemic of disease.

The possibility of successfully purifying water either by sand or mechanical filtration promises an avenue of escape from the evils of polluted or inferior water at moderate cost. Mr. Lea's paper on Sand Filtration of Public Water Supplies is very interesting and valuable, and an excellent summary of the progress made in this subject to the present time; it describes very clearly and concisely the evils that may affect a water supply, the causes of its pollution, the natural processes by which the offensive organic matter is changed to inoffensive mineral matter, and the modern methods of purification by the removal of matter objectionable to the senses, and, more important still, the wonderful reduction of the excessive numbers of bacteria that are present in polluted water, and among which there may be the germs of disease.

The writer does not intend to discuss the methods or details of filtration, but rather to emphasize the very general need that really exists for the filtration of water supplies. It may be that the day is distant when all surface supplies will be filtered, but that an enlightened public opinion will some time demand water for domestic purposes that is as clear and wholesome as unpolluted spring water the writer has no doubt. It will then be necessary in all properly managed water systems to place the protection of a suitable filter between the unavoidable contaminations of the water shed and the consumer. It is not in the engineer's power to arbitrarily introduce improvements however necessary he may consider them, nor is it his duty to force them upon an unwilling public, but it certainly is his privilege to keep well in advance, and while doing the best that he can with the means at his disposal, endeavour to lead the way to better things.

The last two decades have seen a wonderful increase in the number of water works both in the United States and Canada, especially in the smaller cities and towns. It is now possible to supply small villages, even where the water must be pumped, at less cost than it can be obtained from individual wells. During this time the standard of design and construction, on what may be called the mechanical side, has been raised, very largely by the efforts of engineers, until now many of the works built by municipalities are, measured by present knowledge, almost perfect machines for the collection and distribution of water and for the extinguishment of fires. Much less attention has, however, been given to the sanitary side of the subject. An engineer, who was a thorough and consistent advocate of mechanical perfection and efficiency, was accustomed to say that he did not believe in all of this talk about the purity of water, that in his opinion a little foreign matter in the water only made it so much the more nutritious. Although this was not a serious statement of opinion, it represented roughly the rather contemptuous attitude of too many otherwise good engineers toward what they considered over-refinements in water supply. A great change has taken place within a comparatively short time.

Less than fifteen years ago the Engineering Department of the State Board of Health of Massachusetts was organized, and an act passed that required all plans for water supply and sewage disposal to be submitted to the Board before their final adoption. The work of this Board led to a great sanitary improvement in the condition of water supplies throughout the State, and it is perhaps not too much to say that the water works practice of Massachusetts is the standard for the country.

The value of the studies of the Board are generally recognized, and its experiments on the filtration of water and sewage which are the most complete yet made, at least on this side of the water, have given a great impetus to the practice of filtration, and placed in the hands of engineers the knowledge necessary to enable them to construct and operate filters on correct principles.

For some time it is likely that the greatest obstacle to the adoption of filtration of water supplies will be its cost, or supposed cost, and this will probably be the basis of the strongest opposition. When, however, this question is examined rationally, and in its relation to the cost of other factors of a water supply, and to expenses that people are quite willing to bear for other things that give them satisfaction, it will be seen that it is a small affair to put into the balance against a clean, wholesome water supply.

The average cost of construction of water works, as shown by the statistics of fifty-two places ranging in population from 1,000 to 85,000, was about $38.50 per consumer.*

Mr. Clark, the chemist of the Massachusetts Board of Health, states,

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* See paper on Financial Management of Water Works, Jour. N.E.W.W. Assoc., Vol. XI, No. 1, Table B.

as the result of his experience in charge of the experiment station at Lawrence that, with water as badly polluted as that of the Merrimac River, a safe rate of filtration is 3,000,000 gallons per acre daily.*

Assuming, however, an average rate of but 2,500,000 gallons, and a per capita consumption of 60 gallons per day and the cost of the filters at $75,000 per acre, the construction cost of the filters would be $1.80 per consumer, or 5.20 p.c. of the average cost of the other parts of the system ($38.50).

Note.—Reference is made in the above computation to "slow sand filters" only, but the cost of mechanical filters would not exceed the figures given. The comparative cost of the two types will no doubt largely depend upon local conditions.

No hesitation is now felt in spending from 25 p.c. to 50 p.c. of the whole cost of works in providing fire protection when a domestic supply alone could be obtained for from 50 p.c. to 75 p.c. of the cost, and little objection is made to increasing the cost 5 p c. to 10 p.c. for increased efficiency in the fire service. If so much can be wisely spent, as undoubtedly it can, to protect our property, why is it not equally wise and prudent to make the smaller expenditure to protect our health?

If it be urged that the expenditure for fire protection is off set by the saving in insurance premiums, which is quite true, is it not equally true that there is a saving in doctors' bills and in time by the greater degree of health in the community?

So much for the first cost or cost of construction; the annual expense is, however, the real measure of cost. On the same bases of computation as before, and allowing $2.50 per million gallons for operating the filters, interest upon the first cost at 4 p.c. and depreciation on the plant at 2 p.c. on the cost, we have as follows for the annual cost per consumer.

Annual consumption per consumer = 60 × 365 = 21,900 gall.
Annual cost of operation per consumer = $\frac{21,900}{1,000,000} \times \$2.50 = \$0.0548$
Annual interest charge per consumer = $1.80 × 4 % = .072
Annual depreciation per consumer = $1.80 × 2 % = .036

Total annual expense per consumer for filtration $0.1628

In the statistics already referred to it is shown that the average annual expense of maintaining water works, including operation, interest

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* See Jour. N.E.W.W. Assoc., Vol. XII, page 241.

and depreciation, is about $2.60 per consumer, therefore estimated expense of filtration is less than 6½ p.c. of the average of the total expenses in existing works. The percentages given above being based upon averages would not exactly apply to any particular works, but show approximately the relation of the expense of filtration to the other expenses. The above annual expense of filtration, which is perhaps as fair an estimate as can be made for general application, is practically 16 cents per consumer; the increased cost of water, due to filtration, is therefore about one dollar a year for a family of six persons. A man who smokes one cigar a day cannot secure a great improvement in the brand by the expenditure of an extra ⅓ of a cent daily, neither can the quality of the family tea, molasses, flour or butter be much improved by the addition of one dollar to the annual grocery bill, yet most people consider it highly important that the quality of such things shall be good. Many families pay more than one dollar a month in addition to their water rates for spring water, often of doubtful quality.

It may be said that, in making an allowance of 60 gallons per consumer, the consumption has been under-rated. It can be said in reply that, if in any place of less than 50,000 inhabitants the use or rather the waste of water is allowed to continue at a greater rate, then that place is in no position to criticise a reasonable expenditure for filtration. Larger places may, perhaps, have a larger rate without incurring the charge of extravagant waste, but it is probable that the cost of filtration will be less than that estimated per million gallons in the larger places. Furthermore, the adoption of filtration would have a great tendency to promote a reform that is perhaps more sadly needed in American waterworks than any other. The writer refers to the prevention of the waste of water. This waste is a crying evil in the majority of our works, and it is a reform in which it is extremely difficult to awaken any interest in the public, or among those intrusted with the control of works. The writer does not refer to the Superintendents, many of whom are alive to its importance, but to those higher in authority. Those who readily appreciate the economy of an expenditure for a "high duty" pump, which by its increased efficiency will reduce the coal bill, cannot be persuaded that an outlay for meters will reduce the consumption, and thus also reduce the coal bill. While they are willing to pay for an additional supply, they will not introduce meters and thus render the present one sufficient. To such the filter would be a powerful advocate of water waste prevention and the necessity of keeping the consumption within reasonable limits.

Mr. John W Hill.

Two conditions of modern city life have combined to bring the subject of "Quality of Public Water Supplies" forcibly to the front, and these conditions will keep it there until satisfactory remedies, generally applicable, have been devised to overcome the serious difficulties which now surround the water supplies of many large and small cities. One of these conditions is the rapid growth in population of cities and towns, and the other the positive proof of the transmission of certain dangerous diseases by sewage polluted waters.

Considering the large amount of untreated sewage and surface drainage which flows into many rivers and lakes, which are drawn upon for public water supply, it is evident that such water in its natural condition is not suitable for domestic uses, particularly for drinking and culinary purposes. The chief objection to any sewage pulluted water is the possibility, indeed, the probability, of its being the carrier from the sick to the well of the specific organisms productive of typhoid fever and other water-borne diseases, and so thoroughly grounded is this belief in connection with some public water supplies that law-suits involving large sums of money, based on inferior quality of the public water, are now progressing in several cities of the United States.

The objection to polluted water supplies is sometimes overcome by the substitution of water from mountain springs and deep wells in the drift or in the rock ; but these sources, especially wells, do not always furnish satisfactory water, neither are they generally applicable. Few cities can look to undefiled mountain sources for a water supply, and the large satisfactory supplies from deep wells are limited in number. In fact, the location and development of cities conform to the laws of commerce rather than to the laws of health, and artificial works must be devised to overcome the difficulties due to the location and unfavourable environment of many communities.

The remedy which will give relief in one case will not always be applicable or perhaps the best in another, but, by proper study of the local conditions and available sources of water, material improvement in each instance can be had, which will go far toward mitigating the evils due to the present polluted public water supplies.

Thus, in one city of the United States, the substitution of water from one river for that of another river has reduced the typhoid fever rates of that city by upwards of 90 per cent. In a certain city of Germany, by substituting mountain spring water for the water previously used from a sewage polluted river, the typhoid fever rates have sunk to the lowest of any large city in the world—so low indeed that in that city it is difficult to obtain typhoid cases sufficient to illustrate in the medical clinics the characteristic symptoms and progress of this disease. In another city of Germany, by the substitution of plain sand-filtered water for the unfiltered water from a river carrying the sewage and land drainage from several millions of population, the typhoid fever rates have so declined that in the opinion of the medical officers of health all the evidences of this disease which now remain in that city can be traced to the careless use of the unfiltered river water or to infected food brought into the local markets. In a large city of England, where the water is chiefly obtained from two small rivers, both polluted with surface wash and land drainage, by the application of the highest skill and vigilance in the operation of plain sand filters, the typhoid fever death rates within 20 years have been reduced from 90 to 13 or 14 per 100,000 of population living.

Instances showing the advantage to the health of a community by water supplies of great purity may be multiplied to a limited extent; but the great majority of the cities outside of Europe are still to be awakened to their dangers from polluted water supplies; and no field in engineering offers greater opportunities to contribute to the welfare of mankind than that which embraces the quality of the water supplied daily to any community, and no public improvement can confer greater benefits upon the population of any city than that which accomplishes a marked reduction in the typhoid fever rates.

We are thus brought to the threshhold of the problem. How shall cities not favourably situated with reference to natural sources of pure water be supplied? Cities like London, Berlin, Paris, Boston, Montreal, Chicago and many of lesser note have no sources of water supply which will compare with the water from some deep wells or mountain springs, and it would be barbarous to assume that the people of these cities should be compelled to subsist upon water lower in quality or less beneficial to health than that of the most favoured community in the world.

Two practical remedies are always open to cities such as are by geographical location prevented from enjoying water from satisfactory natural sources. One, the purification by artificial means of *all* the water which may be drawn for public uses, and the other by creating a dual water supply, one branch of which will furnish either naturally pure or artificially purified water for drinking and culinary purposes.

Experience has abundantly shown that Plain Slow Sand Filtration is capable of converting a polluted water into a safe drinking water, and without in any manner imparting other properties to the water which may be only less objectionable than the pathogenic and other sewage organisms which filtration chiefly aims to remove. By Plain Sand Filtration is used one mode of nature for the production of pure water. The same results are accomplished by the Sand Filter as by the slow percolation of a polluted water through great depths of soil, sand and pervious rocks to the porous strata where it is tapped by artesian and non-flowing driven wells; and water properly filtered should equal in point of purity deep well or spring water.

The Plain Slow Sand Filters as found in the cities of London, Berlin and Hamburg, have demonstrated an ability to deal with polluted river waters in a way which should satisfy any reasonable demand, and at a cost per million gallons of water treated within the reach of any Municipal Corporation which values the health of its people.

Aside from the fact that Plain Sand Filtration without coagulants has demonstrated as high or higher bacterial efficiency than mechanical filtration with alum, or some other coagulant, is the important consideration that with Plain Sand Filtration there is no chance that the last condition of the filtered water may become worse than the first. Plain Sand Filtration, like Mechanical Filtration with alum, may not always remove the objectionable elements from sewage polluted waters, but with the first system the danger ends in imperfect filtration, while by Mechanical Filtration with alum or some other chemical as a coagulant, a new danger may be imparted to the water.

By the use of a chemical, such as alum or sulphate of alumina, for the purification of water, it is possible, indeed probable, that under the ordinary conditions of use the filtered water will contain some undecomposed chemical or be deficient in respect to purity. The proper adaptation of a chemical to Water Purification supposes a pre-existing knowledge of the natural condition of the water before the chemical is applied. This knowledge is very difficult, if not in some situations impossible of attainment, and, excepting it is known, chemicals cannot successfully be applied to the purification of water.

If it were possible to obtain to-day a sample of the water which will come to the filter to-morrow, the regulation of the alum would be much easier and less liable to cause injury to the filtrate. But from several causes the condition of the raw water is varying from day to day, and sometimes from hour to hour, and by what means a mechanical contrivance for feeding the alum solution to the water can take cognizance of these changes and proportion the amount of solution accordingly, has thus far not come within the writer's knowledge.

The Plain Sand Filter when properly built and operated after a simple system, which requires no foreknowledge of the varying condition of the raw water from day to day, will produce a satisfactory filtered water, and without imparting to it either acidity or astringency.

Whenever mechanical filtration with alum is suggested, the statement is always made that by the *judicious application* of the chemical, no danger need be apprehended from its use. The same may be said of many chemicals stronger than sulphate of alumina, but the very use of a reagent as powerful as alum involves an element of danger, which in injudicious hands may do much harm, at least to those afflicted with tender digestive apparatus; and at least one-half of all the adult people of the civilized world have impaired organs of digestion. To such persons waters containing measurable amounts of undecomposed sulphate of alumina will be positively hurtful. While alum tinctured waters are sometimes recommended by physicians for special organic difficulties, it is not known that the continued use of such waters has ever been of benefit, except perhaps in special instances.

To show how the United States government officials view the use of chemicals in the artificial production of potable water, the following excerpt is taken from from the *Engineering News* of Feb. 23rd, 1899:

" Two Water Filtration Plants for the U. S. Capitol building at Washington are proposed. An Act now before Congress authorizes the architect of the Capitol building to contract with a filter company for two plants, one at each end of the building, of 350,000 gallons each. The effluent must be "bright, clear water." The water " shall be double filtered through two separate filter beds at a rate of not more than 5 gallons per square foot of bed per minute, *without the use of alum or other chemicals*," and " a thorough and efficient method of cleaning and aerating the filter beds shall be employed."

(The italics are the writer's.)

One of the most potent arguments offered by the champions of Mechanical Filtration with alum as a coagulant is the smaller area required, and lower first cost of works, but this is usually more than offset by the increased cost of chemicals, labour and repairs of machinery over the relatively low cost of operation of Plain Sand Filters; and as a general rule the cost per million gallons of water filtered, including operating expenses and fixed charges on the cost of works of filtration and land required, will be in favour of Plain Slow Sand Filtration.

With reference to a double water supply, the percentage of water used for drinking and culinary purposes by any city is quite small, and this really is the only water which is especially liable to be the carrier of disease organisms. Now, if this proportion of the public water supply is of undoubted purity, and all people will confine themselves to its use for all dietetic purposes, it will meet the requirements of sanitation as fully as if the whole supply was rendered pure, or was naturally of good quality. At least 98 per cent. of the whole public water supply is applied to uses which are unaffected by the bacteriac condition of the water, and to some able investigators of this problem it seems unreasonable that all the water supplied to a city should be of high quality in order to meet the very small real requirements for purl-water.

In many localities an amount of water from unexceptional sources can be obtained sufficient to meet the consumption for drinking and dietetic purposes, but the availability of this better water depends upon a separate system of small mains to distribute it to the householders, and on separate services and independent plumbing to each premises, and to avoid an unwarranted application of the water of high quality to the coarser uses of a household, each of such services should be metered.

Even in localities where the better water was to be had only by methods of purification, this purification of the small quantity of water required could then at moderate cost be carried to the highest state attainable by artificial methods.

The dual system of water supply was presented and discussed in two papers by the writer ; one to the American Society of Civil Engineers, June, 1894, and the other to the Eighth International Congress of Hygiene and Demography, Buda-Pest, September, 1894, and many practical men, especially physicians, were found who favoured this method of supplying water of high hygienic quality for dietetic purposes.

The author of the paper has endeavoured to present on page 70, and by the diagram which follows, the cost of filters and filtration. Necessarily, the factors which affect the cost of other engineering structures in different localities apply to works of water purification. The writer has seen very excellent sand filters in Holland, which have cost only $14,200 per acre, operating successfully at the rate of 3,200,000 U. S. gallons per acre per day, or the cost of these filters was less than $5,000 per one million gallons of daily capacity. This, however, is no criterion of cost, because the raw water which is put on the filters in that country as a rule is better than waters which some communities on this side of the Atlantic often consider quite good enough without filtration. Upon the other hand, some of the filters at Zurich cost $70,857 per acre and deal with 5,850,000 U. S. gallons per acre per day, or the cost of construction was over $12,000 per million gallons of daily capacity.

The author's proposition of $60,000 per acre and 2 millions daily capacity is very high, and there will be few situations which will require a cost of works equal to $30,000 per million gallons of daily capacity.

With reference to the value of the typhoid fever statistics of large cities as a measure of the quality of the public water supply, upon a separate sheet herewith the writer has shown the typhoid mortality statistics from 36 of the principal cities of America, and 34 of the principal cities of Europe, Australia and Egypt, compiled to Dec. 31st, 1897, which confirm the good opinion previously entertained for the water supplies of Vienna, Munich, Hamburg, Berlin, London and the Dutch cities abroad, and of Newark, N.J., Lawrence, Mass., and a few of the larger cities of the United States. These statistics also show a gradual reduction in the typhoid fever rates in cities like Chicago, Baltimore, Philadelphia and Cincinnati, which have made no improvement in the quality of their public water supplies, but are indebted for typhoid fever reduction to the sale and use of bottled spring and distilled water, which has largely increased of late years, as well as to the use on some lines of the Pullman and Wagner Sleeping, Parlor and Dining Cars of the best water which is attainable along their routes.

The subject of water filtration, in all instances where the public supply is exposed to sewage contamination is no longer a theory, but a condition which cities will in due time be compelled to meet as a requirement of law; and so well is this recognised that certain cities, as for example Philadelphia, Boston, Albany, Cincinnati, Louisville, and many smaller towns in the United States, either have already introduced, or are engaged on projected works of water purification.

At all events, whatever the remedy to be adopted, no city is now justified on the ground of impracticability, or cost, of rejecting modern methods of purifying the whole supply of water, or of devising a dual system, one branch of which will carry to every premises a water of unquestioned purity.

Dr. Andrew **MacPhail.** It is a hard saying of science that there is nothing common or unclean. Bacteria, as well as men, have their work to do, but the business of the bacteria is more important than ours. The world could do without us; without the bacteria it would soon be stifled under its own waste, and all life, even bacteria life, would cease.

S.

JOHN W. HILL,
Consulting Engineer,
Cincinnati, Ohio.

	1896.		1897.		1898.	
Death Rate.	Population.	Death Rate.	Population.	Death Rate.	Population,	Death Rate.
17	1,934,077	16	1,990,562	15	....	....
32	1,619,226	46	1,750,000	25	....	....
40	1,188,793	34	1,200,000	33	....	....
16	1,140,000	15	1,160,000	15	....	....
19	570,000	19	623,000	20	....	....
33	508,694	32	528,912	33	....	....
39	507,398	37	506,398	37	....	....
37	330,000	31	360,000	17	....	....
36	341,000	48	360,000	28	....	....
36	330,279	43	350,000	21	....	....
29	350,000	20	360,000	17.5	....	....
41	275,000	33	275,000	51	....	....
74	278,150	51	280,250	43	....	....
77	280,000	61	287,500	64	....	...
22	279,000	20	275,000	19	....	....
27	257,500	18	275,000	33	....	....
17	230,000	21	230,000	14	....	....
71	187,098	61-62	191,841	21	....	....
77	211,100	45	222,223	36	....	....
32	150,000	27	154,000	16	....	....
97	165,000	41	180,000	30	....	....
39	85,700	42	87,000	21	....	....
31	55,000	15	55,510	18	....	....
47	87.754	55	87,754	64	....	....
47	85,000	25	85,000	21	....	....
27	50,000	32	....	......	....	....
73	30,000	63	....	......	....	....
30	150,000	61	155,000	40	....	....
70	110,000	60	100,000	54	....	....
47-48	40,000	30	40,000	42.5	....	....
......	(1) 37,000 (2 8,000	32 125	45,000	33	....	....
59	42,000	26	44,000	34	....	....
31	35.000	20	36,500	19	....	....
28	196,666	28-29	195,997	12	....	....
18	256,470	21	264,165	24	....	....
......	....	......	30,000	20	....	....

Compiled from the
OFFICIAL REPORTS OF HEALTH DEPARTMENTS.
January, 1897.

TYPHOID FEVER STATISTICS.

FROM THE PRINCIPAL CITIES OF NORTH AMERICA AND EUROPE.

DEATH RATE PER 100,000 OF POPULATION LIVING.

JOHN W. HILL,
Consulting Engineer,
Cincinnati, Ohio.

CITY.	SOURCE OF SUPPLY.	1890.		1891.		1892.		1893.		1894.		1895.		1896.		1897.		1898.	
		Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.
New York City, N.Y.	Imp'd water from Croton & Bronx Rivers	1,705,980	21	1,765,645	22	,827.396	22	1,891,306	20	1,957,452	17	1,879,195	17	1,934,077	16	1,990,562	15	....	....
Chicago, Ill.	Lake Michigan	1,208664	83	1,250,000	160	,438,010	104	1,600.000	42	1,567,727	31	1,600,000	32	1,619,226	46	1,750,000	25	....	....
Philadelphia, Pa.	Schuylkill & Delaware Rivers	1,046,964	64	1,069,264	64	1,092,168	40	1,115,562	41	1,146,000	32	1,163,864	40	1,188,793	34	1,200,000	33	....	....
Brooklyn, N.Y.	Imp'd. water from driven and open wells.	854,945	26	880,780	20	962,530	17	990,891	17	1,045,000	15	1,090,000	16	1,140,000	15	1,160,000	15	....	....
St. Louis, Mo.	Mississippi River	450,000	34	452,000	30	460,000	37	500,000	103	540,000	31	560 000	19	570,000	19	623,000	20	....	....
Boston, Mass.	Lake Cochituate & Sudbury River.	437,245	43	461,093	33	474,063	29	487,397	30	501,107	28	496,920	33	508,694	32	528,912	33	....	....
Baltimore, Md.	Lake Roland & Gunpowder River.	434,151	57	445,853	34	458,350	42	473,193	47	455,427	49	496,315	39	507,398	37	506,398	37	....	....
San Francisco, Cal.	Imp'd. water from mountain streams.	300,000	59	330,000	41	330,000	34	330,000	32	330,000	35	330,000	37	330,000	31	360,000	17	....	....
Cincinnati, Ohio	Ohio River	296,000	67	300.000	62	305,000	40	310 000	43	336,000	50	336,000	36	341,000	48	360,000	28	....	....
Cleveland, Ohio.	Lake Erie	277,488	66	299,475	52	309,243	54	322,932	47	325,000	27	325.000	36	330,279	43	350,000	21	....	....
Buffalo, N.Y.	Niagara River at head	....	......	255,664	50	285,000	34	300,000	37	315,000	36	335,709	29	350,000	20	360,000	17.5	....	....
New Orleans, La.	Drinking water from tanks and cisterns.	254,000	20	254,000	23	254,000	21	254,000	15	275,000	28	275,000	41	275,000	33	275,000	51	....	....
Washington, D.C.	Potomac River	250,000	83	250,000	83	260,000	70	285,000	66	270,514	71	271,000	74	278,150	51	280,250	43	....	....
Pittsburgh, Pa.	Alleghany River	....	......	247,000	100	255,000	100	264,000	111	272,000	56	275,000	77	280,000	61	287,500	64	....	...
Detroit, Mich.	Detroit River.	230,000	18	230,000	13	230,000	51	230,000	61	250,000	26	280,000	22	279,000	20	275,000	19	....	....
Milwaukee, Wis.	Lake Michigan	220,000	33	233,333	33	245,000	31	260,000	37	267,500	26	260,000	27	257,500	18	275,000	33	....	....
*Newark, N.J.	Imp'd water from Paquannock River.	181,830	60	187,108	81	192,531	45	198,115	28	203,861	15	215,725	17	230,000	21	230,000	14	....	....
Jersey City, N.J.	Passaic & Paquannock Rivers.	163,003	91	167,237	95	171,471	53	175,000	60	179,939	76	184,173	71	187,098	61-62	191,841	21	....	....
Louisville, Ky.	Ohio River	161,000	88	161,000	81	161,000	72	161.000	84	200,000	72	205,000	77	211,100	45	222,223	36	....	....
Providence, R.I.	Pawtucket River	132,146	29	132,146	47	132,146	39	148,944	34	153,000	47	145,472	32	150,000	27	154,000	16	....	....
Indianapolis, Ind.	Driven wells.	....	......	120,000	36	125,000	52	125,000	106	125,000	55	125,000	97	165,000	41	180,000	30	....	....
Lowell, Mass.	Merrimac River & driven wells.	77,696	158	80,400	98	83,200	90	87,191	61	90,613	55	84,367	39	85,700	42	87,000	21	....	....
Lawrence, Mass.	Filtered from Merrimac River.	44,654	123	45,911	115	47,204	102	48,355	93	49,900	48	52,164	31	55,000	15	55,510	18	....	....
Nashville, Tenn.	Filter Gallery, Cumberland River.	77,000	46	80,000	56	83,000	53	85.000	24	87,000	32	87,500	47	87.754	55	87,754	64	....	....
Dayton, Ohio	Driven wells	60,000	20	60,000	32	63,000	44	75,000	64	85,000	20	80,000	47	85,000	25	85,000	21	....	....
Covington, Ky.	Ohio River	37,400	43	40,000	45	42,500	40	45,000	27	48,000	42	48,000	27	50,000	32	....	......	....	....
†Newport, Ky.	Ohio River	.....	.....	....	......	....	......	27,500	58	30,000	37	30,000	73	30,000	63	....	......	....	....
Denver, Col.	South Platte & Marston Lake.	....	......	....	......	120,000	53	125,000	57	140,000	35	145,000	30	150,000	61	155,000	40	....	....
Atlanta, Ga.	Mech. Filter, Chattahootchie River	65,533	151	75,000	119	85,000	87	95,000	66	108,000	43	100,000	70	110.000	60	100,000	54	....	....
Chattanooga, Tenn.	Mech. Filter, Tennessee River	29,109	145	34,900	66	40,000	55	36,000	86	35,751	48	40,400	47-48	40,000	30	40,000	42.5	....	....
‡Knoxville, Tenn.	Mech. Filter, Tennessee River.	40,600	101	40,385	45	40,385	37	40,385	67	40,385	59	....	......	(1) 37,000 (2 8,000	32 125	45,000	33	....	....
Quincy, Ill.	Mech. Filter, Mississippi River	31,500	83	34,000	32	36,000	50	37,500	48	39,000	77	40,500	59	42,000	26	44,000	34	....	....
Davenport, Iowa.	Mech. Filter, Mississippi River	30,000	50	30,000	30	30,600	16	30,900	35	34,000	18	35,000	31	35.000	20	36,500	19	....	....
Toronto, Ont.	Lake Ontario	167,439	93	181,220	94	184,000	43	188,333	42	196,666	17	196,666	28	196,666	28-29	195,997	12	....	....
Montreal, Que.	St. Lawrence River	216,300	29	218,268	30	224,816	22	231,560	21	241,748	17	249,000	18	256,470	21	264,165	24	....	....
Oskosh, Wis.	Mech. Filter, Lake Winnebago	....	......	....	......	....	......	....	......	....	......	....	......	....	......	30,000	20	....	....

* East Jersey Water Co., established 15th April, 1892.

‡ (1) City proper. (2) Suburbs.

† Health Department, established 1893.

TYPHOID FEVER STATISTICS.—*Continued.*

FROM THE PRINCIPAL CITIES OF NORTH AMERICA AND EUROPE.

DEATH RATE PER 100,000 OF POPULATION LIVING.

CITY	SOURCE OF SUPPLY.	1890.		1891.		1892.		1893.		1894.		1895.		1896.		1897.		1898.	
		Population.	Death Rate.	Population.	Death Rate	Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.	Population.	Death Rate.
London, Eng	From Kent wells and filtered water from Thames & Lea Rivers	4,180,654	16	4,222,157	15	4,264,076	11	4,306,411	16	4,349,166	15	4,392,346	14	4,421,955	14	4,463,169	13	....	....
Liverpool, Eng	Lake Vyrnwy (Wales)	513,493	24	517,116	25	513,790	25	510,514	53	507,230	58	503,967	37	632,512	32	633,078	26.5	....	....
Manchester, Eng	Lake Thirlmere (Cumberland)	379,437	31	506,469	39	510,898	25	515,598	25	520,211	18	524,865	19	529,561	23	534,299	19	....	....
Edinburgh, Scot	Imp'd. water from Pentland Hills.	271,135	19	261,970	18	264,787	13	267,261	14	270,588	15	273,535	20	276,514	16	292,364	12	....	....
Glasgow, Scot	Lock Katrine	530,208	26	567,143	31	669,059	18	677,883	20	686,820	24	695,876	19	705,052	23	714,919	25	....	....
Dublin, Ireland	Imp'd. water filtered from River Yartry, Ourucq Canal, Artesian Well, springs..	353,082	62	347,312	58	349,594	39	349,594	87	349,594	48	349,594	27	349,594	45	349,594	58	....	....
Paris, France	Rivers Seine, Marne and Yanne	2,260,945	30	2,424,705	20	2,424,705	28	2,424,705	25	2,424,705	29	2,424,705	11	2,511,629	11	2,571,629	10	....	....
Brussels (with suburbs) Bel.	....	477,288	26	465,517	41	476,862	23	488,188	27	498,400	14	507,985	16	518,387	18	531,024	18	....	....
Amsterdam, Hol	Harrlen Dunes	406,302	19	417.539	11	426,914	15	437,892	16	446,295	8-9	451,493	11	489,496	3	500,091	7	....	....
Rotterdam, Hol	Filtered water from River Mease	203,486	6	209.136	4	216,679	6	222,233	5	228,597	5	272,042	2	276,338	12	290,004	12	....	....
The Hague, Hol	From Sand Dunes	156,497	3	160,531	12	165,560	4	169,828	2	174,790	3	180,455	5	187,545	4	191,529	5	....	....
Copenhagen, Den	Driven wells	312,387	9	320,000	8	330,000	7	337,500	9	341.000	7	333,714	16	333,714	7	340,500	6	....	....
Stockholm, Sweden	Lake and well water	236,350	18	245,317	18	248,051	19	249,246	8	252,937	8	259,304	9	267,100	6	274,611	7	....	....
Christiana, Nor	....	143,300	12	151,130	9	156,535	4	161,151	6	167,583	3	174,717	7	182,856	33	192,141	15	....	....
St. Petersburg, Rus	Filtered water from Neave River, Mytschia Springs & Ponds	842,000	57	....	......	....	......	954,400	51	954,400	49	954,400	87	954,400	142	954,400	100	....	....
Moscow, Rus	Moscov & Yanza Rivers	753,469	73	753,469	75	753,469	68	753,469	40	753,469	29	753,469	50	753,469	46	988,610	35	....	....
Berlin, Ger	Filtered water from Lake Tegel & River Spree	1,548,279	9	1,601,327	10	1,662,237	8	1,714,938	9	1,701,643	4	1,734,492	5	1,695,313	5	1,726 098	4	....	....
Hamburg (State), Ger.	Filtered water from River Elbe	591,647	28	622,530	23	637,686	34	634,878	18	598,372	6	608,710	9	625,552	6	661,015	7	....	....
Altoona, Ger	Filter Gallery by River Elbe	143,249	19	144,388	64	145,527	43	146,667	15	147,807	7	148,934	13	....	......	....	.....	....	....
Dresden, Ger	Filter Gallery by River Elbe	269,250	9	276,523	8	301,400	5	308,930	4–5	316,600	8	324,341	5	342,340	4	347,485	3	....	....
Breslau, Ger	Filtered water from River Odor	324,400	15	339,000	12	346,442	15	353,551	10	360,660	6	367,769	9	377,062	8	385,198	11	....	...
Munich, Ger	Spring water from Mangpau Valley	298,000	8	357,000	7	373,000	3	385,000	15	393,000	2-3	396,000	3	406,000	3	430,000	5	....	....
Vienna(with suburbs), Aust-Hungary	Springs in the Schneeberg	822,176	9	1,378,530	6	1,406,933	8	1,435,931	7	1,465,537	5	1,495,764	6	1,526,623	5	1,574,129	5	....	....
Prague, Aust.-Hung.	....	314,425	33	310,485	37	321,167	53	327,953	36	339,172	57	351,478	46	364,632	28	377,109	36	....	....
Buda-Pest, Aust.-Hung	Ground water from wells	463,017	34	513,010	23	526,263	26	539,516	15	552,769	14	566,022	20	579,275	29	629,486	19	....	....
Trieste, Aust.-Hung	....	160,092	12	156,190	11	157,343	26	158,314	17	159,739	19	160,825	5	161,886	13	164,491	26	....	....
Rome, Italy	Fontanadi, Trevi, Aqua Felice & Paoli..	417,392	35	427,684	36	438,123	26	449,430	34	456,777	30	465,563	62	473,296	27	483,560	18	....	....
Milan, Italy	....	....	......	....	......	424,887	62	430,829	62	....	......	441,948	56	....	......	....	..	....	....
Turin, Italy	....	314,827	46	320,808	41	329,724	44	334,090	29	335,957	24	344,203	32	344,203	24	344,203	19	....	....
Venice, Italy	7 Springs in the Mountains, 15 miles distant—cast iron conduit.	156,800	44	158,288	33	162,664	30	163,601	26	158,187	18	158,159	23	163,254	27	166,069	32	....	....
Cairo, Egypt	River Nile by Canal	374,838	260	374,838	235	374,838	163	374,838	154	374,838	135	374,838	90	374,838	141	570,062	55	....	....
Alexandria, Egypt	River Nile by Canal	231,396	208	231,396	348	231,396	77	231,396	79	231,396	100	231,396	103	231,396	89	319,766	59	....	....
Sidney (with suburbs). Austr	Imp'd. water from Upper Nepean River..	....	......	....	......	406,480	20	411,710	19	421,030	29	423,600	20	....	......	....	......	....	....
Brisbane " Austr.	....	....	......	....	......	....	......	93,657	19	93,657	10	93,657	60	....	......	....	......	....	....

The tubercle bacillus which ravages a degenerate lung is diligently and innocently reducing organic or inorganic matter. It is a mere accident that this process of reduction takes place before the corporal death of the organism. Nature works in a blind way, and what we call disease is merely one of the ways by which she works. Disease is only a manifestation of her activity, just as inflammation signifies that she is working in a hurry and getting hot over it.

There is a continual warfare between the bacteria and the flesh; we are the enemy, not the bacteria. They are impassive; it does not matter to them whether they live or die, but we refuse to accept Nature's judgment. We cannot win. We can, however, delay the issue. It is in this way sanitary science can help us.

It teaches us not to allow the bacteria to gain a foothold; it shows us how to prevent their entrance. Medical science teaches us how to be strong against them, how to keep in health. It goes a step further, it teaches us how to stifle them and to cast them off. Nature has not left us naked, but it is only now we are learning how to use the weapons she has placed in our hands. This learning and teaching is the work of science in the present generation.

The paper under discussion—The Purification of the Water we drink—deals with one of the most rudimentary processes of civilized life, and yet most communities are as oblivious as savages as to its necessity. We do not catch diseases. We drink them, and we eat them. We have solved the question of drinking, and need not suffer from typhoid fever or other filth diseases any more. The problem we are now working upon is the food supply and the prevention of consumption. That will come in time.

The bacteriologist is a scientist merely; a sanitary engineer is something more; he is the man of affairs as well. He translates the formula of the laboratory into plain language and applies it for the safeguarding of the people. Municipal authorities are only wasting their time discussing the value of filtration *per se* that was settled long ago.

Yet it may be worth while drawing an illustration from very near home.

Newark and New Jersey had the same water supply till 1892, and a typhoidal mortality of 90 per 100,000. Newark changed its supply in that year, and its mortality fell to 45, 28, 15, 17, 21 per 1,000 per year. New Jersey's rate remained from 91 to 95 per 100,000 till 1897, when it too changed its source of supply. Next year the typhoid mortality dropped 78 per cent.

Under proper hygienic precautions typhoid fever will become as rare as leprosy; already the tendency is all that way, as the English record shows. The mortality in England and Wales was 32 per 100,000 in the eighth decade, 19 in the ninth decade and 17 these ten years.

In Munich the rate is one-third that for the whole of England, or ten to fourteen deaths per year in a city of 400,000.

It is the engineers as much as the doctors who have accomplished this work.

Typhoid is only taken as a type of these diseases, but there are many others which are water-borne, viz.: all those accompanied by diarrhœal symptoms, cholera, typhus, dysentery, and the remedy for one and all is filtration.

It is quite true that these diseases are carried other ways than by water, viz., by flies, by dust, and from earth closets, but, if it is checked at the source by the purification of the water, all these subsidiary causes will disappear.

The tendency is towards municipal ownership and public control of water supplies, but the time is not far distant when purveyors of water, public or private, will be held as strictly accountable for its absolute purity as dealers in any other public commodity.

What the bacteriologists have proved is this: typhoid fever is always due to a bacillus; the disease germs are carried abroad in the water; they will cause the disease in those who drink the water. You engineers have accepted this as true; you have acted upon it; you have purified the water; you have saved more lives than a generation of doctors. You have much still to do, and your work will not be done till you have provided purified water for everybody to drink.

It is for you and not for the doctors to decide how that shall be done.

Mr. Lewis Skaife. As a contribution to the discussion on Mr. Lea's paper on "Sand Filtration of Public Water Supplies," Mr. Skaife wished to submit the following description of a system of filtration which Mr. Lea had not touched upon in this paper, and which he believed to be quite new. The filtering plant is installed at Louisville, Ky., and is the design of Mr. McDougall, a former resident of Montreal. The following description of the system has been abstracted from a Louisville paper;—

The system consists in passing the water, first through what is called a "Clarifier," and then through a "Polarite Filter," as follows:

The clarifier, which takes the place of sedimentation basins (which have the great disadvantage of requiring a large area of ground), consists of two large steel tanks, having a layer of selected sand at the bottom. The water in passing through this clarifier becomes so clear and bright that it would seem from its appearance that no further purification was necessary. A small quantity of lime water is added to the water as it enters the clarifier, to precipitate matter held in suspension in the water. This lime water acts also as a germ destroyer to a large extent.

From the clarifier the water passes through the polarite filter, which consists of a layer of specially prepared magnetic oxide of iron (called "polarite"), placed in an ordinary filter bed, and covered with a layer of sand. This polarite is porous and indestructible; it has been used in filter beds in Europe for over ten years, and was then as fresh as ever.

The water receives its final purification by both filtration and oxidation, and it comes out clear and sparkling. Analysis of 1,000,000 parts of water before filtration gave 250 parts of matter held in suspension. After passing through the clarifier, only 5 or 6 parts of suspended matter remained. A cubic centimeter of water before filtration showed between 3,000 and 4,000 bacteria, after passing through the clarifier only between 50 and 75, and after passing through the polarite filter there were practically none.

It is claimed for this system that it can be operated without the use of sedimentation basins, thus saving their large initial cost and the further cost of their operation, which is stated to be much less than that of slow filtration through large areas of sand filter beds.

The use of lime as a precipitant is found to give better results than the use of alum as a coagulant, and at the same time it is very much cheaper. Alum, which is used in operating the so-called "American" filters, has the great disadvantage of hardening the water when carbonate of lime is present. It has been contended that the use of lime would harden the water. The experiments on which this contention was based did not prove anything against the use of lime by itself, as they were made with water treated with lime and alum together. The sulphuric acid in the alum at once combined with the lime, forming a soluble sulphate of lime, hardening the water co-ordinately with the amount in solution. Lime by itself will really soften water, by causing a precipitation of the bicarbonates which are held in solution. This precipitation is in the form of an insoluble carbonate, and co-ordinately with the precipitation the water is softened. Besides this, lime is a disinfectant, a deodorant and a germ killer.

The advantages of the system may be summed up as follows:—

Cheapness of installation. Small area of ground required. Simplicity and ease of operation. Large saving in the use of lime instead of alum or sulphate of iron. Saving in the quantity of water required to wash the beds and tanks of 80 per cent. over other systems.

The Louisville plant has a capacity of 250,000 gallons per day, with a filter of only 230 square feet.

REPLY TO THE DISCUSSION.

Mr. R. S. Lea

With regard to the paper by Mr. Cottrell, an abstract of which has been presented by Mr. Marceau, it may be said that, though nominally upon the general subject of the "Purification of Drinking Water," it is largely devoted to a description of a single process, which is so far only in the experimental stage. Its bearing upon the writer's paper upon sand filtration of water lies in the assertions it contains regarding the unsatisfactory degree of bacterial purity effected by that process. The Examining Board of the Paris Municipal Council did, it is true, condemn this process in common with all the others examined, as being incapable of producing what the Board considered to be a sufficiently high degree of bacterial purity. The standard required was, however, remarkably high, if not unnecessarily so, and so far has not been definitely shown to be possible of attainment on a large scale and under practical conditions. If, however, Dr. Bergé's Polozone process should prove successful in practice, it will be able to fulfil these requirements to the extent of furnishing a water absolutely sterile and of fairly high chemical purity.

Since the discovery some 15 or 18 years ago of the germ-removing properties of sand filters, a succession of new inventions for the purification of water have been put forward with claims of superior efficiency; but one by one when put to the test of actual practice these claims have been shown to be unfounded. On the other hand, the Sand Filtration process has steadily risen in the estimation of those who have studied and investigated it with reference to the quality of the water it produces as determined by analysis, and by its effect upon the health of the people who drink this water. Bacteria are undoubtedly present in small numbers in the effluent from such filters; but it is believed (and the reasons for this belief become of greater force as investigation is carried further) that the greater number, if not all of these, are from the underdrains, and have not come through the filter at all; and also that those which may have come through are not dangerous germs, but belong to some of the species of harmless water bacteria. Very much more of this nature can be said of the efficiency of sand filtration, but that is no reason why we should not welcome a process capable of producing the results expected of Dr. Bergé's; and it is to be hoped that the claims for it may be justified.

In the meantime it will be very interesting to learn more of the process from the correspondence with the inventors, which Mr. Marceau has promised to communicate to the Society.

The above remarks apply also to Mr. Skaife's description of the Polarite Filter. The tests of this process as reported seem to show a rather greater reduction of the percentage of the albuminoid ammonia in the water than is effected by the sand filter.

The writer agrees with Mr. Keefer that the covering of filter beds has advantages apart from the necessary protection against frost, which help to offset the extra expense. There would not seem to be any economy, however, in building long and narrow beds, as a wooden roof could rest upon piers which would of course be cheaper to construct than division walls, and which would later serve to support the permanent masonry cover.

With regard to Mr. Hering's reference to the proper method of determining the quality of a given water supply, there is no doubt that the information furnished by chemical and bacteriological analysis, in the absence of expert local examination of the watershed, cannot be depended upon. Which of these analyses is of relatively greater importance will depend upon circumstances. Often one is necessary for the proper interpretation of the other. In any case the data they furnish will enable the engineer, after personally examining the watershed, to form sound conclusions as to the fitness of the source for a public supply.

Mr. Coffin points out very clearly and conclusively how small relatively is the additional expense necessary to secure that characteristic which, in water for domestic use, is surely the most desirable, viz., its purity. He shows that while a demand for drinking water which can be guaranteed not to contain disease germs can scarcely be considered luxurious, yet people hesitate or refuse altogether to devote to the attainment of this object a sum ridiculously insignificant in comparison with what they are quite willing to expend for many other less important purposes, and, in the absurd waste of water which is allowed to go on in many places in America, enough money is being thrown away to purify the water many times over.

Mr. Hill's remarks are of great interest in view of his long and intimate acquaintance with the various phases of the subject. With regard to the relative advantage of slow sand and mechanical systems of filtration, the recent investigations which have been made at Louisville, Pittsburg and Cincinnati indicate that, with waters carrying large quantities of fine particles in suspension, the latter may be the more satisfactory method.

The estimates of the cost of filtering, including capital charges, etc., show very little difference in favour of this process.

As to the objection to the use of the alum which is necessary to form the coagulent, it is probable that the danger lies in the possibility of imperfect purification, due to an interrupted supply rather than in any injurious effect which an overcharge might have on the health of the consumers. There is no doubt, however, that the latter possibility might form in the opinion of some a serious objection.

Mr. Hill characterizes the writer's estimate of $60,000 per acre and 2,000,000 gallons daily capacity as very high, which no doubt it is, especially for large plants. It was given, however, less as an estimate than as an example to show how small is the actual cost of filtration even under unfavourable circumstances. Nevertheless, for small places where the beds must be small and few in number, it does not seem likely that covered filters could be built for much less than $50,000 per acre at least. The 2,000,000 gallon capacity is, of course, per acre of total area of beds, including those out of use for cleaning and removing, which will be necessarily larger with the small plants.

Mr. Hill's remarks regarding typhoid mortality statistics are very interesting, and the tables of rates of a great number of places in different parts of the world up to the end of 1897 are exceedingly valuable and complete.

Thursday, 2nd February.

P. W. St. George, Vice-President, in the Chair.

On motion by Mr. W. McNab, seconded by Mr. T. W. Lesage, the following resolution was carried: "That the money over from the sale of the dinner tickets should be expended in the improvement of the social part of the Rooms."

It was moved by Mr. L. Skaife, seconded by Mr. Stuart Howard: "That a special general meeting be called to transfer the admission fees, less the examination expenses, to the building fund."

The discussion of Mr. Irwin's paper on "Disputed Points in Connection with the Construction and Maintenance of Macadamized Roads" occupied the remainder of the evening.

Thursday, 16th February.

ERNEST MARCEAU, Member of Council, in the Chair.

Paper No. 141.

PAVEMENTS IN VANCOUVER, B.C.

By A. K. STUART, A.M.CAN.SOC.C.E.

When brought into comparison with other coast cities, Vancouver, British Columbia, young as it is, has gained for itself a reputation for its paved streets. Although only twelve years old, Vancouver can boast of nearly all of its central business streets being paved with either bituminous rock or wood blocks, the first of these pavements being laid in 1893 and the whole of the work being carried out under the Local Improvement system.

The object of this paper is to compare the two kinds of pavements and discuss their relative merits and adaptability to the well-known humidity of the climate of this portion of the Pacific Coast, and in order to do this it will probably be advisable to deal with each pavement as it was laid.

STREETS PAVED WITH BITUMINOUS ROCK IN 1893.

The by-law for this work was actually passed on the 11th of July, 1892, and came into operation on the 14th of August, 1892, the debentures being for 20 years. The rate per foot included interest at five per cent., the sinking fund being four per cent. for the repayment of the loan in twenty years. The total sum raised under this by-law was $111,100. The contract was let in July, 1892, to Contractor D. McGillivray, but by the time all the details were arranged it became so late in the fall that, owing to continued wet weather, it was deemed advisable to withhold the commencement of the work until the summer of 1893. In the meantime, Colonel Tracy, City Engineer, and the then Chairman of the Board of Works, went early in March of 1893 to Portland, Oregon, and Seattle and Tacoma, and on the 16th of March, 1893, reported to the City Council as follows:

" Having examined the different forms of rails in use on street railways in Seattle, Tacoma and Portland, on streets which have been paved with bituminous rock, and also on streets paved with stone, plank and macadam, we report as follows:

"1st. Owing to the gauge of the railway in these cities being 3 ft. 6 inches, while those of Vancouver are of the standard gauge, 4 feet 8½ inches, the conditions are considerably different, as it is not possible for vehicles to travel within the tracks in these cities. None of the tracks examined have been properly put down, they in nearly every case having settled and become uneven. With the timber set in concrete as provided for in our contract, this will be obviated, and the track should keep in good condition. The portion of the street occupied by the street railway is the weak point in all pavements. A good job cannot be made with rails set on the tie direct unless with a grooved girder rail at least 7 inches deep. The paving along the outside of the rails was in the best condition where the bituminous rock covering was carried up close to the rail without any stone courses. The only question on which there can be any doubt is as to the method of finishing on the inside of the rail and the form of the rail at that side. Most of the girder rails examined have narrow flanges on the inside (1½ inches), which for the traffic of vehicles are practically useless, as they allow neither sufficient width nor play for the wheels which would travel partly on iron and partly on the pavement. Girder rails with a wide flange for the wheels were in use on one street, but did not appear to answer any better, as the weight of heavy wagons on one side appeared to twist the rails out of shape. For the purposes of the street railway and its passengers, we believe the "T" rail to be the most advantageous. A fairly good and lasting job of paving can be made with the "T" rail, but, with a deep girder rail grooved with a flange for wheels, there would be no doubt of the security of the pavement. This would be the most expensive, and the question of the best rail under the circumstances (for Vancouver) will depend on how the Street Railway Company will keep up their share of the roadway when completed, that is 8 inches on each side of the rail."

The girder rail recommended could not be obtained, and the Street Railway Company were allowed by the corporation to put down a light "T" rail, which since, in many respects, has proved to be very unsatisfactory.

The total cost of the 1893 pavement was $101,667.94. Details as to the prices of the tender will be seen in "Table A."

The sand and gravel required for the concrete, and also the cement, were all supplied by the contractor, but the Corporation furnished the contractor with crushed rock for the concrete at cost price, namely $1.50 per cubic yard.

CONSTRUCTION.

Early in May of 1893 the work was commenced, and completed in October of that year, the total length of streets paved being 1.18 miles. All the work in connection with the laying of the double track was done under a separate contract between the contractor and the Street Railway Company, under the direction of the City Engineer, the same method of tamping round the ties with concrete being adopted as shewn in diagrams.

The old planking having been removed, the street was first graded to the required contour. All roots, rotten wood, vegetable mould or soft soil were removed, and replaced by good dry sand and gravel or broken rock. The surface of the ground having being brought to the proper level, it was well wetted and rolled, and where directed well rammed until brought to an even and smooth surface, the contractor being required to take proper care of, and provide for all gas, water and other pipes, and also all poles, to shore them up carefully, the contractor being held responsible for all damage to same in carrying out the work, the contractor also excavating for and setting the curbstones to the true line and grade, the curbing being well rammed, especially next to the footwall.

Concrete.—The concrete was composed of four parts of broken stone, two of clean gravel and three of clean coarse sand to one of the best English Portland cement, the quality and brand being approved by the City Engineer, with whom rested the power to reject any which did not fulfil the tests which he deemed sufficient. From careful experiments this proportion was found to be exceptionally good. The depth of the concrete was six inches. All materials were required to be thoroughly dry, and then wetted sufficiently and rammed in place to the proper shape, where it was protected until properly set, and kept clean until the bituminous rock covering was placed on it. In places where it was found necessary or expedient to have the concrete a little deeper than six inches, the extra quantity was figured and allowed the contractor. The broken stone used was of such sizes as would pass through a two-inch ring, and was supplied by the city on scows at the city landing, foot of Gore avenue, at the rate of $1.50 per cubic yard, the contractor being required to unload and haul the same. The work of grading, concreting and setting the curbstones was kept sufficiently in advance of the covering to allow the concrete to set properly.

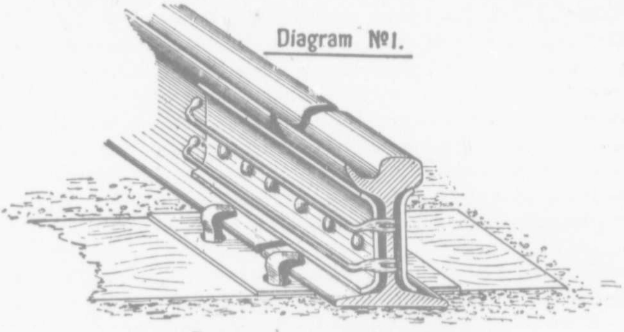
Stone Curbing.—The curbing used was of granite, and was six inches thick, twenty inches deep, and in lengths not less than three feet. The top surface was dressed evenly with a slight round on the outer edge, the joints throughout being kept as square and true as possible so as to make a close fit in order that they might be pointed and made water tight. The curbing at the street intersections was rounded to a two foot radius.

Gutters.—The stones for gutters were of granite, eight inch courses, eight inches deep and averaging twelve inches in length, the top surface being cut true to a reasonably smooth face, and the sides and ends, so that when laid there were not spaces of more than half an inch between any two courses. The spaces afterwards were floated with pure cement. It may be stated, however, that these stone gutters were only put in where the fall was slight.

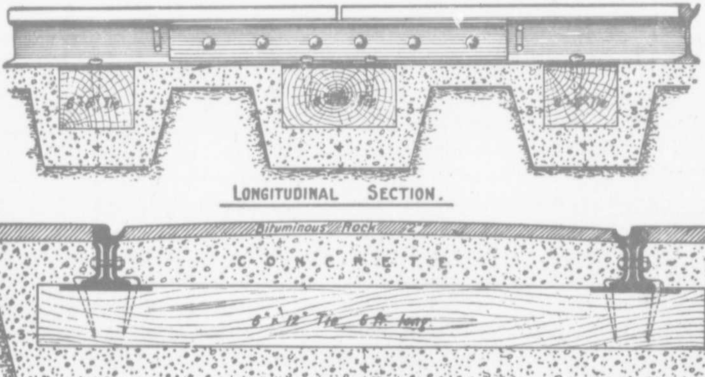
Bituminous Rock Covering.—The best quality of bituminous rock covering obtainable from San Luis Obispo, California, was used, containing not less than fifteen per cent. of bitumen. This was broken up and then disintegrated by steaming in a tight kettle under a pressure of not less than sixty pounds, and after being taken out of the kettle was dried in a pan heated by steam and placed while hot on the road, then raked to an even surface and rolled with a heavy hot roller until thoroughly compacted. This bituminous rock cost the contractor laid down in the yard at Vancouver not less than $10 per ton. The rolling had to be done to the satisfaction of the City Engineer, and, when completed, the surface was required to be smooth and even, and the bituminous rock not less than two inches in thickness or weigh less than twenty pounds per square foot. The work was required to be carefully and neatly finished around the gutters, and where not accessible to the roller was rammed with a hot iron. The whole work had to be guaranteed and kept in repair by the contractor for one year, the contractor furnishing a suitable bond to that effect.

No. 2.—Bituminous Rock Paving of 1895.

The bituminous rock pavement commenced in 1894, and finished in 1895, consisted of .61 of a mile in length, the work being carried out under a new contract, but by the same contractor, the main difference being the work in connection with the heavy girder rail laid (shewn in Diagram No. 1). In the case of this contract, however, the contractor



DETAIL SHEWING RAIL BOND



LONGITUDINAL SECTION.

CROSS SECTION.

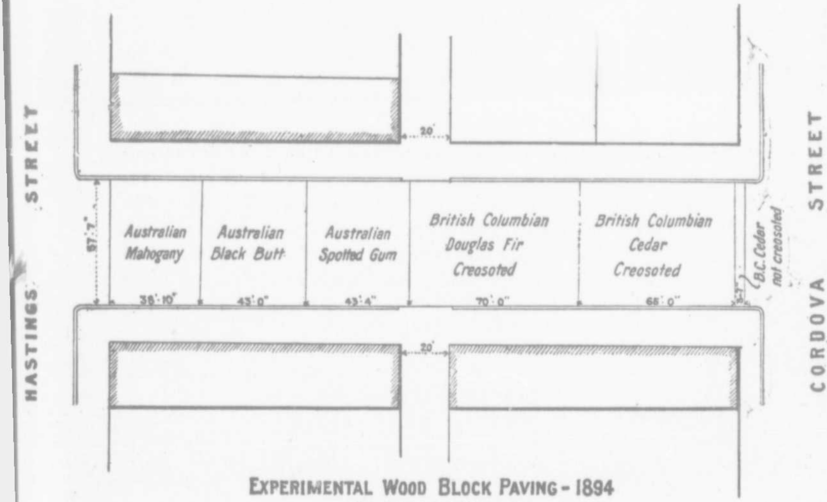
DIAGRAM SHEWING METHOD ADOPTED OF TAMPING CONCRETE AROUND TIES.

HASTINGS STREET

was required to give a two years' guarantee instead of only one, as in the contract of 1892-3.

No. 3.—Wood Block Paving of 1894.

This was only a short piece, .05 of a mile in length, and was laid on Granville st., at its approach to the Canadian Pacific Railway Company's depot, as an experiment, and in order to compare a sample shipment of Australian mahogany, black butt and spotted gum, which had been presented to the city by J. C. Rounding, Esq., of Sydney, with the local fir and cedar. These were put down as shewn in Diagrams Nos. 2 and 4. The conditions as to grading, concreting and granite



EXPERIMENTAL WOOD BLOCK PAVING - 1894
GRANVILLE STREET.

Diagram No 2

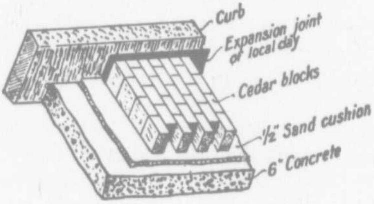
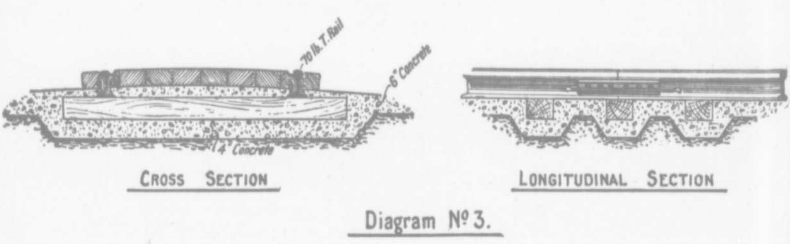


Diagram Nº 4

curb were the same as in the former pavement, and need not be enlarged upon. The contractors were Messrs. Armstrong and Morrison. The work was commenced in November, 1894, and finished at the end of December, taking about a month to complete, the work being carried out under trying atmospheric conditions, the contractors, nevertheless, doing their work very well. As to the block paving, the contractors were called upon to furnish good sound fir and cedar free from defects of any kind. The blocks were sawn 9 inches long, 3 inches wide, 5 inches deep, squarely and perfectly uniform in size and surfaced. The fir and cedar were well creosoted under pressure to the satisfaction of the City Engineer before being laid. The Australian woods were hauled and sawn by the contractor, and all the different kinds of wood were kept separate on the street. One little strip of uncreosoted cedar was put down where shewn on Diagram 2. The



CROSS SECTION

LONGITUDINAL SECTION

Diagram Nº 3.

blocks were laid with one quarter inch space between each row, the gradient of the street being over 5 per cent. The blocks were laid in rows running across the street, the contractor doing all the cutting and trimming necessary to break joints. After the blocks had been laid sufficiently ahead, a mixture of coal tar pitch and asphalt was poured into the joints. The joints were then filled with fine gravel well pounded in with a special tool and saturated with the asphalt mixture until filled compactly to the top of the blocks, which then received a coating of liquid asphalt and tar put on hot, the whole being covered with finely broken granite which was supplied by the city. An expansion joint of well-tempered clay was put in next each curb to allow for the expansion of the blocks. It may be remarked that, for this work, the city supplied the Portland cement used by the contractor at the rate of $2.90 per barrel. On this contract the contractor was required to give a written guarantee for one year, and to make all necessary repairs during that period. As a matter of fact, no repairs to speak of have been necessary to this pavement, and the City Engineer was so pleased with the results achieved from this pavement, especially the local fir and cedar, and more particularly the latter, both creosoted and uncreosoted, that, when the matter came up early in 1898 of the desirability of further extending the system of paved streets, he recommended the use of local cedar blocks as a test on a larger scale.

WOOD BLOCK PAVING OF 1898.

The chief points of difference between this wood block pavement, which was commenced in July, 1898, and completed at the close of the year, and the wood pavement of 1894, may be said to be that a good deal of the work entailed the fitting in of the blocks along the heavy 70 lb. "T" rail put down on Hastings street and Westminster avenue, and also that in this contract the specifications required the wood blocks to be laid with close joints instead of the quarter inch space as before, except on Richards and Seymour streets, where the gradient was sufficient to require a quarter inch space being left. In this contract, the contractors, Messrs. Campbell, Rannie & Co., were required to give a two years' guarantee to keep the pavement in proper repair. In connection with this pavement, the granite curb at street intersections was put in with 8 ft. radius instead of 2 ft., and found to make a much more satisfactory job.

COMPARISONS.

By way of general comparison, table "B" was prepared touching on the principal points. However, it will not be amiss to enlarge on some of the main features.

Referring first to the question of repairs, it will be seen by reference to Table "A" that the repairs to the bituminous rock pavement, especially that of 1893, have been very extensive, more so than was anticipated at the time it was put down. The greatest trouble has been along the 40-lb. "T" rail on Hastings, Cordova, Cambie and Carrall streets. The disintegration caused by urine from the horses and mineral oils caused Colonel Tracy, City Engineer, to have analyses of samples of the pavement made by Herbert Carmichael, Esq., Public Analyst and Assayer for the Province of British Columbia, early in March, 1898. The samples were taken by the City Engineer and numbered. The results were as follows —

Sample	I.	II.	III.	IV.	V.
Moisture...	·52%	·58%	·4%	·45%	·61%
Min. matter...........	81·55	85·28	81·84	84·45	86·45
Veg. matter............	·40	1·40	·57	·78	·30
Asp. cement..........	18·05	13·32	17·59	14·77	13·25

Writing to the City Engineer on the subject, Mr. Carmichael said: "The analysis of your samples of Bituminous Rock Pavement compared with the analysis of similar material appears to show that you have the necessary amount of bituminous cement in the composition of your paving mixture, but there is a considerable difference in the composition of the asphalts from different localities, and it is generally admitted that the bituminous rock from California does not make nearly so good a pavement as the Trinidad asphalt. A mineral oil would undoubtedly dissolve or partly dissolve asphalt cement, and would so disintegrate it that it would easily wear away.

There is no method that I know of that would get rid of the oil in a sample except by heating it to a fairly high temperature, and I doubt if even this would be entirely successful."

There can be no question that the humidity of the Vancouver climate, especially at certain seasons of the year, when there is a great deal of moisture and very little sun, is very detrimental to the wearing qualities of the bituminous rock pavement. The bituminous rock kept close to the *light* "T" rail has suffered very much from the vibration of the rail. On Granville st., however, where a 70-lb. girder rail was used and the bituminous rock and concrete built up clean to the rail, no trouble of this kind has been experienced, and neither the pavement on Granville st. nor the portion alongside the girder rail have required any very material repairs.

In frosty weather this pavement has proved slippery for horses, but it has been found that a little sand sprinkled over it has remedied this defect, especially salt water sand, of which any quantity can be obtained here, the salt in the sand appearing almost immediately to thaw out the frost from the surface.

The relative defects or merits of the wood block paving can be compared to a certain extent by reference to Table "B." The wood block paving put down at the close of 1894 as an experiment has certainly stood the traffic very well. This piece, however, has not been exposed to the very heavy traffic, and in frosty weather it has proved slippery, but a little sifted sand, as before remarked, has been found very effectual in remedying this defect. The local fir and cedar have proved just as satisfactory as the Australian woods so far.

It may be remarked, as to all these pavements, that, wherever it has been found necessary at any time to remove the covering for the purposes of repairs, the concrete exposed in each case has been found to be in a first-class condition, and to have set exceedingly hard and solid. It is evident that no pavement worthy of the name can be laid satisfactorily without a good foundation of Portland cement concrete.

As to the form of rail, so far as traffic is concerned, the experience at Vancouver is that a heavy grooved girder rail is the best. So far as the Street Railway Company is concerned, a "T" rail is best for their purposes. It would appear, in order to make the best and most lasting job, the rails should be set in concrete with iron cross-ties to hold them in place, avoiding the use of wood altogether. Judging by experience, it would appear that, *where a proper rigid track is put down*, it is best to lay the bituminous rock or asphalt right close up to the rail.

As to the wood block paving, there may be objections to it on sanitary grounds, but, owing very largely to the great clamor here for the use of local materials, it was determined early in 1898, when extensions to the paved streets were contemplated, to give it a test on a somewhat considerable scale.

The object of dipping the blocks in the mixture of coal tar and asphaltum was not so much with a view to preserving the wood as to prevent absorption and to make the pavement as far as possible impervious to moisture, it not being intended that the surface water should penetrate it. With this end in view, the blocks were laid close where the gradient would admit of it.

The advantage of the city owning its own plant for repairs, instead of doing the repairs by contract, will at once be evident by a reference to Table "A."

Diagram 4 will give an idea of the method of laying the blocks.

COMPARATIVE TABLE "A."

Description.	Miles.	Width of pavement between curbs in feet.	Nature of Pavement.	Rate per foot frontage to property owners.	How carried out.	Estimated life of pavement.	Length of Debentures.	Contract prices.
		ft.		$ c.		Years.	Years.	
Streets paved in 1893 (contract let in July, '92, work completed October, 1893).	1.18	Carrall, 43 Cordova, 43 Hastings, 51 Cambie, 43 Abbott, 43	Bituminous rock from California 6" concrete foundations, granite curbs.	Carrall, 6 99 Cordova, 6 99 Hastings. 8 50 Abbott, 6 99 Cambie, 6 99	Local improvement by-law, property owners paid ⅔ of cost, city ⅓.	20	20	Granite curb cost 75c. per lin. ft. laid. Gr. gutter cost 50c.do. Excav'n and concrete, $1.17 per sq. yd. Bit. rock. cov.$1.26 do
Streets paved in 1895 (contract commenced in April, 1894, work finished September, 1895).	.61	Granville, 51 Hastings, 51	Do	Granville, 8 50 Hastings, 8 00	Do	20	20	Granite curb, 87c. per lin. ft. laid. Do gutter, 50c. do Excav'n and concrete $1.33 per sq. yard. Bit. rock cov'ng $1.35
Street paved in 1894, commenced in November, finished in December.	.05	Granville, 51	Wood block, samples of Australian wood and local fir and cedar 6" concrete found'n granite curbs	Granville, 5.55⅝	Do	20	20	Granite curb, 85c. per lin. ft. laid. No gutter stones. Ex'n and concrete, 90c per sq. yard. Austral. wood blocks laid only, 54c p. sq.yd. B.C. fir and cedar supplied and creosoted, $1.44 per sq. yard. B.C. cedar supplied and *not* creosoted, 54c. per sq. yd.
Streets paved in 1898, commenced in July and completed Dec., 1898.	.98	Water, 41 Alexander, 41 Richards, 41 Seymour, 41 Hastings, 62 W'minster, 62	Wood Block, local cedar 6" concrete foundation granite curbs	Yrs. Yrs 40 12 Water, 3.64 2.44 Alx'der, 3.32 2.22 Rich'ds, 3.24 2.16 Seym'r, 3.24 2.16 Hast'gs, 5.00 3.34 W'nster, 4.98 3.32	Do	Curbs & concrete foundation 40 yrs; wood blocks, 12 yrs.	Curbs & concrete foundation 40 years; wood blocks, 12 years.	Gr. curb laid average 98½c per lin. ft. No granite gutters. Exc. and concrete average, $1.01¼ p. sq. yd Cedar blocks tarred and laid, $1.20½ do

COMPARATIVE TABLE "A"—*Continued.*

Description.	Cost to complete.	Repairs since have cost the city.	Repairs since have cost the Street Ry. Co., 8 in. each side of rails.	Cost of repairs per sq. foot.	REMARKS.
Streets paved in 1893 (contract let in July, '92, work completed October, 1893).	$101,667.94	* $3,033 from 1895 to end of 1898. This includes the streets paved with bituminous rock in 1895, although the repairs on these have been inconsiderable, compared with the streets originally paved.	$977	From 1895 to 1898, done by contract, cost 19c. per sq. ft. In 1898, done by City's own plant, cost 12c. per sq. ft. In 1898, done by City's own plant, cost 10c. per sq. ft.	*During 1895, 1896 and 1897 the repairs were done by contract, price 19c per sq. yard. In 1898, however, the City did the repairs itself, having bought out the plant at the close of 1897. The difference in cost will be apparent by reference to the column of cost of repairs per sq. ft. Probably 80 p.c. of the repairs have been made on No. 1 pavement.
Streets paved in 1895 (contract commenced in April, 1894, work finished September, 1895).	$54,004.50				
Street paved in 1894, commenced in November, finished in December.	$3,504	None.	None.	None.	
Streets paved in 1898, commenced in July and completed Dec., 1898.	$89,016.00	Only just completed; still under contractor's guarantee for 2 years.	Only just completed; nothing yet.	Only just completed; cannot be estimated yet.	

COMPARATIVE TABLE "B."

Description of Pavement.	Imperviousness to water.	Hardness.	Kind of footing in frosty weather.	Resistance to heavy traffic.	Noiselessness.	Capability of being easily cleaned.	Adaptability to steep grades.
No. 1. Bituminous rock pavement of 1893, and No. 2, Bituminous rock pavement of 1895.	Practically impervious	Hard, but gets elastic in hot weather.	Gets very slippery. Easily remedied by sifting salt-water sand over it.	Almost nil.	More noisy than the wood block paving.	Easier to keep clean than the wood block paving.	Adaptable to almost any grade, not steeper than 5 per cent.
No. 3. Wood Block Pavement of 1894, and No. 4, Wood block pavement of 1898.	Absorbs the water and retains it to a certain extent.	Not nearly as hard. Seems to be as easy on horses as the bituminous rock.	Slippery, but not as bad as the bituminous rock.	Compares favourably with the bituminous rock.	Less noisy.	Not as easily cleaned, more inclined to gather mud.	Can be made to suit almost any grade below 5 p.c.

Description of Pavement.	Cleanliness and sanitary qualities.	Costliness.	Wear and Durability.	Cost of Maintenance.	Adaptability to B.C. climate.	Convexity.	Form of rail in use on streets.
No. 1. Bituminous rock Pavement of 1893, and No. 2, Bituminous rock pavement of 1895.	Excellent.	More costly than the wood block paving. (See Table "A.")	Has not proved very good.	Much greater than that of the wood block paving (See Table "A.")	Has not proved as suitable as was expected.	6″ crown for 66 ft. streets. 8″ crown on wider streets.	No. 1. 40 lb. "T" rail spiked to stringer resting on ties bedded in concrete. No. 2. 70-lb. grooved girder rail (See dia.)
No. 3. Wood Block Pavement of 1894, and No. 4, Wood Block Pavement of 1898.	Not as clean or sanitary as the bituminous rock paving.	Less costly. (See prices Table "A.")	No. 3. Excellent. No. 4. Remains to be seen.	So far the maintenance has cost nothing to speak of.	No. 3. More so than the bitum's.rock. No. 4. Has to be proved.	7″ crown for 66 ft. streets. 8½″ crn. on wider sts. A little more crown would be all the better.	No. 3. No rails. No. 4. 70 lb. "T" rail. (See diagram.)

DISCUSSION.

Mr. J. Kerry. Mr. Kerry said that he did not think there could be any necessity for an expansion joint being laid between the curb and the blocks, as he had always understood that there was no expansion in creosoted blocks.

Mr. L. Skaife. Mr. Skaife said that the blocks might have expanded somewhat from the weight on them.

Mr. J. S. Vindin. Mr. Vindin said the "T" rail was certainly the worst possible to use. The Montreal Street Railway first used a 72 lb. girder rail with 4½ inches base, since then increasing the weight year by year. At the present time they have an 83 lb. girder rail with 6 inches base. They also found that the asphalt laid right up against the rail was the worst possible thing that could be done. They were now welding their rails, making a continuous rail with a joint about every 1,200 feet with an allowance of ½ inch for expansion in that length. This has been found very satisfactory, about 500 joints having been laid and only one having given out up to the present time, and that was an imperfect joint.

Mr. R. S. Lea. Mr. Lea asked if any one had ever seen clay used as mentioned in the paper and, if so, how did they keep it from washing out?

Prof. McLeod. Professor McLeod asked Mr. Vindin at what temperature the rails were laid, allowing ½ inch for expansion to every 1,200 feet. The range of temperature would no doubt be small owing to the uniformity of the temperature of the ground.

Mr. J. S. Vindin. Mr. Vindin replied that the rails were laid in the summer, and there was no noticeable expansion in the paved streets.

Mr. R. S. Lea. Mr. Lea said that expansion joints used to be put in large water pipes in California, but they are not put in now, and it is found that the whole tendency to expand is taken up by the friction of the earth. The result of a change of temperature is simply to strain the metal.

Mr. C. Leprohon. Referring to Diagram No. 1, longitudinal section, Mr. Leprohon thought it would have been easier to excavate the whole of it than to have the mounds standing there.

Mr. J. S. Vindin. Mr. Vindin said the heaviest rail used by the Montreal Street Railway Company was 89 lbs., that is, with the guard rail. The very heavy rails are imported, and are 9-16 inches in height.

Mr. T. W. Lesage. Mr. Lesage said, in connection with asphalt being laid close to the rail, asphalt deteriorates with the vibration of the rail. It is very hard to make a proper joint, because the asphalt close to the stone or rail does not get sufficient rolling. When the Street Railway Company double tracked St James Street, they cut out the old asphalt, leaving about ½ inch joint. There was no artificial joint made, and the asphalt is well worn. He thought the trouble was that the vibration of the rail disintegrated the asphalt. It was found, when blocks beside the rail were used, that two blocks were not sufficient, and three blocks 13½ or 14 inches were used. The asphalt next to the blocks will hold them against the rails and diminish the vibration.

Mr. W. J. Sproule. Mr. Sproule asked if the blocks were asphalt, or if the joint was filled up with asphalt or something else. He thought that if the stone was against the rail and the asphalt at the other side, the vibration would be communicated to the asphalt. He also asked as to the action of the wagon wheels running along the rail affecting the joint.

Mr. E. Marceau. Mr. Marceau thought that the wheels might have some effect on the joint between the rail and the asphalt, but not with three blocks laid longitudinally.

Mr. T. W. Lesage. Mr. Lesage said that that system of laying blocks was not at all satisfactory; the asphalt between them was constantly wearing out.

Mr. H. Irwin. Mr. Irwin said that, in making repairs and in laying asphalt alongside the rails, it would be a good protection to lay the asphalt at least ¼ of an inch higher than the ordinary surface, and that would leave the finished surface flush or almost flush.

Mr. L. Skaife. Mr. Skaife said it would not make a satisfactory job to lay the asphalt higher than the rail, as it could not be properly tamped.

Mr. H. Irwin. Mr. Irwin said that if that was the only trouble it should be within the reach of mechanical contrivances to make a perfectly smooth edge.

Mr. C. Leprohon. Mr. Leprohon said that, according to the paper, it would not seem that compression is required altogether. On page 4 it is stated that rolling had to be done with a heavy hot roller. We have to use tamping with very heavy weights, about 56 lbs., and the men go over it three or four times. The same result seemed to be obtained.

Mr. L. Skaife. Mr. Skaife thought that the author must have forgotten to say that the asphalt was tamped, as it could not possibly be rolled without being tamped first.

Mr. J. Kerry. Mr. Kerry said that it would be desirable to ask the author what filling composition was used. In uncreosoted blocks the expansion is very great, and it is necessary to make some provision for it.

Mr. L. Skaife. Mr. Skaife asked that the author be requested to say how the present pavements are wearing.

Mr. A. K. Stuart.

In reply, Mr. Stuart said that the bituminous rock was tamped with hot irons, and well raked before being rolled with hot rollers. There was no composition used where the blocks were laid close. The blocks were dipped in a mixture of coal tar and asphalt, and the same mixture poured on afterwards. Where the blocks were laid with strips between (which was only on steep grades), the interstices were well filled with fine gravel, tamped in with a special tool, and hot tar and asphalt poured in.

So far there cannot be said to be any perceptible wear to the most recent wood block pavement laid down in 1898. Where laid close-jointed the surface is remarkably smooth, and, in fact, almost as smooth as that of the bituminous rock when first laid down.

CORRESPONDENCE.

Mr. M. J. Butler.

The writer proposes to confine his remarks to the concrete or rather to that part of the specification defining the quality of the cement, "the best English Portland cement, the quality and brand being approved by the City Engineer." Surely it is high time to drop this clause; it has done duty long enough. It would seem an easy enough task to write a specification of requirements as to fineness, tensile strength, neat and with standard sand, and as to constant volume by the well-known Fajias' apparatus. It is really a matter of very little consequence whether the cement is made in England or Timbuctoo, provided it has the requisite qualities; "*the best English Portland*" unfortunately is seldom or never found in Canada.

Mr. W. T. Jennings.

The writer agrees with Mr. Stuart that a first-class pavement should be laid on a substantial well-founded concrete base, but, if Canadian Portland cement can be laid down in Vancover for even the same price as English brands, it should have the preference.

It has been satisfactorily tested. Even Battles-Thorold cement, which is not nearly as expensive, has given perfect satisfaction on Bay street, south of King street, Toronto.

Provision should be made in cold and variable climates for the contraction and expansion of the concrete base of pavements, especially on streets occupied by railway tracks as evidenced by sections observed on Yonge street, Toronto.

The same provision should be made for the wearing surface of all asphalt pavements. The writer is also of the opinion that railway tracks on first-class streets should be laid on ample longitudinal beds of concrete, and steel spacer bars should be used instead of wooden ties. Stone or hard brick toothed setting should be placed next the rails, as otherwise the mineral oils dropping from the car boxes, etc., and the vibration rapidly soften and assist in the disintegration of an asphalt pavement.

Thursday, 2nd March.

P. W. St. George, Vice-President, in the Chair.

It was moved by Mr. L. Skaife, seconded by Mr. T. W. Lesage, and carried: "That a Committee, consisting of Messrs. Stuart Howard, J. Vindin and C. deB. Leprohon, be authorized to expend the balance arising from the Dinner Fund."

The discussion of Mr. Lea's paper on "Sand Filtration of Public Water Supplies" occupied the evening.

Thursday, 16th March.

P. W. St. George, Vice-President, in the Chair.

A special general meeting of the Society was held in connection with the proposal to purchase the property No. 877 Dorchester street.

The following resolution was proposed by Mr. C. H. Rust, seconded by Mr. J. R. Barlow, and carried unanimously: "That the Council be and is hereby instructed to purchase the property, No. 877 Dorchester street, making use of the Building Fund, amounting to $4,500, for this purpose, and also to raise $6,500 by mortgage on the property in order to complete the purchase price of $8,000 with an additional sum of $3 000 for repairs and improvements."

The following resolution, of which notice had been given, was then proposed by Mr. L. Skaife, seconded by Mr. L. G. Papineau, and carried: "That the fund arising from entrance fees, less the examination expenses, be credited to the Building Fund until the building is complete."

Messrs. H. Irwin, J. S. Vindin, J. R. Barlow, L. G. Papineau, J. W. Heckman and J. G. Kerry, having been appointed scrutineers of the ballot for the election of members, declared the following elected:

MEMBERS.

Conway Edward Cartwright,
Henry W. Johnston, Jr.

ASSOCIATE MEMBERS.

Arthur Wm. Connor,
L. Ernest F. Fusey,
Joseph A. G. Goulet,
Gordon Grant,
Jos. Pierre Piche,
Frs. Charles Laberge,
Henry John Lamb,
John Hugh Sullivan.
Godfroy E. Labreche-Viger.

ASSOCIATES.

Owen Norton Evans,
Edward J. Fetherstonhaugh,
Albert J. de B. Corriveau,
A. V. Ramachandra Aiyar.

Transferred from the class of Associate Member to the class of Member:

B. Johnston Saunders.

Transferred from the class of Student to the class of Associate Member:

Walter W. Colpitts,
Charles H. Ellacott,
Hamilton Lindsay,
Arthur L. Mudge,
George A. McCarthy,
Robert F. Ogilvy,
Paul Etienne Parent,
Kenneth B. Thornton.

STUDENTS.

John Lorn Allan,
Samuel James Allen,
James Penrose Anglin,
Augustus R. Archer,
Lorne McKenzie Arkley,
Claude V. C. Austin,
Reginald H. Balfour,
Guy Ralston Balloch,
Stanislas Albert Baulne,
Alfred E. Beck,
Alexandre Belanger,
Thompson T. Black,
Archibald A. Bowman,
Hugh Harkness Boyd,
Fitz-Herbert P. Buchanan,
Aaron Forsey Buffett,
Stanley J. Burgoyne,
Archibald Burnett,
Herbert A. Burson,
E. Victor Burwell,
Archibald E. Byers,
Hugh Donald Cameron,
Geo. A. S. Campbell,
Edmund G. M. Cape,
Geo. Marcus Cary,
Sheldon B. Clement,
Thomas J. Colwill,
Louis E. Cote,
Onesiphore Horace Cote,
H. A. Coussirat,

Frederick Cowans,
Wm. Currie, Jr.,
Jas. S. Dargavel,
Wm. A. Davidson,
Wm. H. DeBlois,
Leopold Denis,
Valmore Denis,
Auguste Dostert,
Arthur E. Dubuc,
J. Duchastel de Montrouge,
G. Rupert Duncan,
Herbert M. Ewan,
Edward P. Fetherstonhaugh,
H. J. Wadsworth Finch,
Geo. Edgar Fiset,
Wm. G. Flint,
Andrew S. Forman,
Chas. Edward Fraser,
Donald Cameron Fraser,
Jas. Wm. Fraser,
John Wm. Fraser,
David Merner Fry,
Ernest E. Gagnon,
R. Hampson Gillean,
Lionel L. Gisborne,
Arthur Gordon Grier,
Geo. Milne Hamilton,
E. Greville Hampson,
M. J. Edmond Hardy,
John V. Hickey,
Ormond Higman, Jr.,
Rupert F. Howard,
Geo. Taylor Hyde,
Jas. Clark Hyde,
Frederick R. Judah,
Alison P. R. Kerr,
Jos. Lamoureux,
Warden K. Lowden,
Samuel B. McConnell,
Wm. B. McLean,
Norman M. McLeod,
Arthur W. McMaster,
Euclide Malo,
Angus K. Miller,
James L. F. Millar,
Geo. A. Montgomery,
Geo. J. Nelson,
Jas. E. K. Osborne,
Owen O'Sullivan,
Ernest E. Palmer,
Chas. S. Paterson,
Frank Peden,
H. Meredith Percy,
Geo. S. Proctor,
Gordon McT. Pyke,
Philip W. K. Robertson,
Henry P. Rust,
Thos. H. Schwitzer,
John A. Shaw,
Henry Lawrence Shepherd,
Henry B. Sims,
Paul F. Sise,
Geo. B. Smith,
Arthur Surveyer,
Richard B. Van Horne,
Frank W. Walker,
Edgar I. Wenger,
Frank Herbert White,
Gerald V. White,
Herbert A. Whitley,
John S. Whyte,
Robert M. Wilson,
Louis Yorston,
Wm. McG. Young.

Paper No. 142.

THE COMPRESSIVE STRENGTH OF CONCRETE.

As determined by tests made at McGill University.

By W. B. Anderson, Stud. Can. Soc. C. E.

Concrete, especially in the construction of piers and foundations, is coming every year into more extensive use. It is therefore desirable to determine its strength, and more particularly its resistance to crushing, as it is to a compressive force that it is most often subjected. The results of very few tests with this end in view are given in any of the treatises on Concrete or Building Materials, or in the Engineering Journals. A few results may be found, but they are scattered and very irregular, and little information can be obtained from them.

During the past three years a few tests have been carried on by the students of Civil Engineering at McGill University. The first series, two years ago, was to determine the effect of different percentages of water upon the strength, and the best percentage to use. This was found to be about 20 per cent. of the sand and cement. Last year tests were made comparing the strengths of concretes made respectively from an English Portland and a German one. This year tests were made upon sand cement in order to compare it with the Portlands, and also to determine the best proportions in which to mix it in making concretes.

This cement was "Cathedral" brand sand cement, made by the "St. Lawrence Portland Cement Co.," of Montreal. It is made of equal parts of Portland cement and kiln-dried pump sand. These are run together into a revolving cylinder half full of flint pebbles, where they are thoroughly mixed and ground to an impalpable powder.

The conditions under which the tests were made this year were the same as those of the first series (published in paper No. 117, Trans. Can. Soc. C. E.), except that the blocks were made 9x9x12-in. instead of 12-in. cubes, as the cubes were found, in some cases, to be too strong for the testing machine to break. The blocks were tested with their long edges vertical, and rested on a steel plate which was on a ball and socket joint, the plate above the block being fixed. Sheets of rubber were inserted above and below the block to give a more uniform distribution of the load. The blocks were allowed to stand in the moulds for about two days, and were then removed and placed in water, where they were kept until the time of testing.

The results of all the tests made in 1898, and the more striking ones of other years, are here presented in tabular form:—

RESULTS OF EXPERIMENTS ON THE COMPRESSIVE STRENGTH OF CONCRETE.

No. of Test.	Date of Test.	Brand of Cement.	MIXTURE.			Percentage of Water.	Weight in lbs. per cu.ft.	Breaking Load lbs. per sq. in.			Proportion of mortar to broken stone.	Relative amounts of Cement.	Relative Costs.	
			Cement.	Sand.	Broken Stone.			One week.	Four weeks.	Two months.			First Assumption.	Second Assumption.
1	1896	German Portland “Hemmoor” Brand.	1	2	4	20	139.5	746	626	507	60-80	157	174	126
2	“		1	2	5	“	......	...	703	....	-100	137	152	121
3	“		1	2	6	“	......	....	728	....	-120	122	135	116
4	1897		1	1	1	22½	142.3	×	×	....	60-30	367	407	206
5	“		1	1	2	“	146.7	1037	×	....	-60	275	305	175
6	“		1	1	3	“	148.0	×	×	....	-90	220	244	156
7	“		1	1	4	“	153.3	×	×	....	-120	183	204	144
8	“		1	1	5	“	151.2	×	×	....	-150	157	174	135
9	“	English Portland “Anchor” Brand.	1	2	2	20	143.5	494	565	....	60-40	220	259	150
10	“		1	2	3	“	146.0	611	555	....	-60	183	216	139
11	“		1	2	4	“	148.5	819	613	....	-80	157	185	131
12	“		1	2	5	“	150.5	581	680	..	-100	137	162	124
13	“		1	2	6	“	150.0	500	698	....	-120	122	143	120
14	“		1	3	3	“	139.5	333	205	....	60-45	157	185	122
15	“		1	3	4	“	139.0	....	366	....	-60	137	162	117
16	“		1	3	5	“	145.0	...	386	....	-75	122	143	113
17	“		1	3	6	“	147.0	....	357	...	-90	110	129	110
18	1898	Sand Cement “Cathedral” Brand.	1	3	5	“	146.5	144	274	400	-75	122	122	104
19	“		1	3	6	“	146.4	110	182	218	-90	110	110	102
20	“		1	3	7	“	150.3	210	322	....	-105	100	100	100
21	“		1	2	4	“	150.6	316	441	....	60-80	157	157	119
22	“		1	2	5	22	148.5	275	477	494	-100	137	137	114
23	“		1	2	6	20	154.0	521	639	670	-120	122	122	111
24	“		1	1½	3	“	149.8	412	490	....	60-72	200	200	134
25	“		1	1½	4	“	151.5	446	679	....	-96	169	169	126
26	“		1	1½	4½	“	153.5	536	741	....	-108	157	157	123
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Blocks marked thus (×) remained unbroken under a load of 1,950 lbs. per square inch

Column 13 shows the relative quantities of cement in the different mixtures, and some attempt has been made to estimate the cost of the different mixtures on this basis. The relative costs are compared on the following two different assumptions:—

First assumption:—Column 14 shown the relative costs if it is assumed that the sand and stone can be secured on the spot and their cost ignored. The cost of different brands of cement is taken as below.

Second assumption:—Column 15 shown the relative costs of the different mixtures and brands on the following assumed costs per cubic foot of materials.

English Portland..	.53	cents.
German Portland..	.50	"
Sand cement..	.45	"
Broken stone..	8	"
Sand..	2	"

The cost of labour is not taken into account, as it will be the same in every case, and these costs can at best be only a rough approximation.

The main requisite for an economic and good concrete is to have just enough cement to completely surround every grain of sand, and just enough of this mortar to fill every interstice between stones. Column 12 gives the proportion of mortar to stone, and it will be seen that with each different mortar the strength increases as the proportion of stone increases, or as the volume of interstices between the stones decreases, because the mortar is not so strong as the stone. The strength also increases with the richness of the mortar in cement, so that the strongest concrete will be one with very little sand and a great deal of stone. Those with the 1-1 mixtures of mortar are very much stronger, though also more expensive than the others. The sand cements are found to be weaker than similar mixtures of Portlands by from 12 per cent. to 40 per cent. The manufacturers claim that with a mortar, such as a 1-10, with a great deal of sand, this cement is stronger than the Portland. This remains to be determined.

If the concrete is desired to have very great strength, a Portland cement and a rich mortar might be used, but if weight is the main consideration, with only moderate strength required, a concrete of sand cement will be much cheaper and quite efficient. Of course, much cheaper mixtures than the ones tested can be made, but they will be weaker accordingly after a certain limit is passed, which limit has not been reached in these experiments. One of the cheapest and a fairly strong concrete is No. 23. This mixture would seem to be the best one to use if excessive strength were not required.

The loads given in the table are the actual crushing loads. The blocks showed cracks or signs of failure before this load was reached, but it was thought better to make the comparison on this basis.

For purposes of comparison it is best to take the results of the four-week tests, as the concretes then show more uniform results than at one week, and the two-month tests are not complete.

These tests are still very incomplete, and it might be profitable to make further tests with concretes containing more stone. The strongest of the sand cement mixtures is No. 26, and with this rich mortar it looks as if it would stand a good deal more stone, thus increasing both the strength and weight, and reducing the cost. Tests of this nature will likely be carried out at McGill University in future years.

DISCUSSION.

Mr. H. Irwin.

Mr. Irwin said that tests on the compressive strength of concrete were interesting, especially as concrete was so often used in foundations, though even where used for that purpose it was seldom subjected to its full capacity for resistance to compression except on rock.

There were some instances in the paper where a fuller explanation would save trouble in getting at its exact meaning.

For instance, the method of measuring the proportions of the cement, sand and stone should be given; and, in the column headed "Percentage of Water," it should be stated whether this percentage is of weight or volume.

As regards the "first assumption," the cost of sand and stone could hardly be ignored under any conditions, since the sand would have to be handled, and the stone, if broken, could not well cost less than 3½ cents per cubic foot, or 95 cents per cubic yard.

The marked decrease in strength of the samples with 3 of sand to 1 of cement must be noted; as the voids in sand amount to about half its volume, such a result is to be expected.

It does not seem quite clear that the compressive strength increases as the proportion of stone increases beyond the proportion of 1 of cement to 5 of stone to such an extent as to warrant adding more stone to get greater strength. In test 12, it will be seen that with proportions of 1 : 2 : 5 the strength after four weeks is 680 lbs. per square inch, while with 1 : 2 : 6 the strength after four weeks is 698 lbs., an increase of barely 3 per cent. Also from tests 16 and 17, with proportions 1 : 3 : 5 and 1 : 3 : 6, the respective strengths were 386 and 357 lbs. per square inch, showing a loss of over 7 per cent. for the larger proportion of stone.

Since the voids in broken stone amount to from 40 to 50 per cent., it is to be expected that, where the volume of the mortar is less than 40 per cent. of the broken stone, there will be voids, and consequent loss of strength in the concrete.

As no engineer would like to strain concrete up to the cracking or yielding point, it would be more interesting to give the load at this point also.

Mr. W. B. Anderson.

In reply, Mr. Anderson said that the proportions of cement, sand and stone were determined by weight, and the water is a percentage by weight of the sand and cement. This was explained, together with all conditions of mixing, in paper No. 117, to which reference was made.

As regards the "first assumption," cases might occur in which the sand and suitable stone or gravel would be found on the spot, and the labour being the same in every case, these items are ignored as stated; even if taken into account they would make very little or no difference in the *relative* costs of the concretes.

The actual crushing load is taken for purposes of comparison because it is considered more reliable than any indication of cracking. It is very hard to say whether a crack is merely a surface flaw or a break in the body of the block, while the testing machine indicates the moment the crushing load has been reached.

The pressure at the time of the first crack was noted, and is given below; but the results are open to the objections described.

PRESSURE AT THE TIME OF FIRST CRACK.

In lbs. per square inch.

No. of test.	One week.	Four weeks.	Two months.
18	133	167	300
19	73	154	183
20	122	137	..
21	296	388	..
22	188	379	44
23	416	584	548
24	405	294	..
25	385	613	..
26	438	679	..

Thursday, 30th March.

DUNCAN MACPHERSON, Member of Council, in the Chair.

Paper No. 143.

THE CONSTRUCTION OF THE MAIN INTERCEPTING SEWERS OF THE CITY OF LONDON, ONT.

By W. T. ASHBRIDGE, A. M. Can. Soc. C. E.

Introductory.—The initial steps leading towards a decided improvement in the sewerage of the City of London consisted in the construction of intercepting sewers designed to carry the present and future sewage flow to filtration beds for purification. The greater portion of this construction having been completed, the present time is a suitable one for its description.

As in many other cities and towns, the demand for the improvement was not spontaneous, and its necessity was emphasized very largely by damage-verdicts and suspended judgments against the corporation for nuisances caused by the pollution of the River Thames and various watercourses.

The main sewers at present and previously existing on King, Dundas and Wellington Streets are of brick, and intercept a large portion of the present sewage of the city. The branch sewers are chiefly of glazed tile, many of which are jointed with clay, and considerable trouble has been caused by tree roots penetrating and expanding inside in their own peculiar fashion. Until within a few years, the sewers were but poorly provided with ventilation, and where manholes were built they were usually found at from one to three feet below the road surface.

That in some cases there has been positive danger from this source is shown in the fact that, some years ago, while cleaning the King Street sewer, two workmen were overcome, and one of them died from the effects of gas (supposed to be illuminating). The men seem to have inhaled the gas at a closed manhole shaft.

As will be seen by examining the map accompanying the paper, two of the old main sewer outlets (discharging about 25 per cent. of the total sewage flow) empty into the South branch of the river above a mill dam, while the third, viz., King Street, enters the river just above the forks. When the splash boards are in position on the Waterworks Dam (situated about three and one-half miles below the forks), the river water is backed nearly level to this point. This condition lasts throughout the summer months. During the winter the boards are taken off, thus increasing the fall in that distance by four feet. In London South, nuisances were caused by sewers discharging into watercourses, and also a similar condition existed along the Carling's creek, which received the contents of several street sewers, as also the sewage of the barracks. To remedy this state of affairs, various reports were presented, and on September 2nd, 1896, the ratepayers voted the sum of $150,000, to be applied to the work. This, with some $55,000 (otherwise provided), was the amount believed to be requisite to construct the sewers, purchase the necessary land, and set in operation filtration beds below the Coves, practically as outlined by Mr. Willis Chipman, who was retained as Consulting Engineer.

The writer, as assistant to the City Engineer, Mr. A. O. Graydon, had charge of the work of designing the details, and of superintending the construction.

The system is practically a "separate" one. Cellar, roof and closet drainage will be accommodated, but from the portion of the city now sewered, surface water will also be taken. The regulation as to the amount to be carried during the rainstorms is to be made in "overflow" manholes, which will be described further on.

The admission of the surface water as explained was not entirely satisfactory to all concerned, but was conceded. This fact and the difference of opinion of Engineers consulted by the Civic Authorities is responsible for increasing the sizes somewhat over what would be required for "separate system" needs pure and simple.

Routes, Grades, Etc.—The sewage of the city proper is intercepted by two branches—the one following approximately the bed of Carling's creek, and the other the bank of the South branch of the river—meeting at corner of King and Ridout Streets. From this point the flow is carried along King Street, across the River Thames (at an elevation of 24 feet above low water), through South London, and across the low lands to the Farm, the South London sewage being intercepted by a pipe laid along the Wharncliffe Road. As a profile is given showing the grades, depths, etc., I will here briefly state that the least grade is 1 in 1,000, and the greatest 1 in 500. These are arranged to give a cleaning velocity when sewers are flowing half full.

Contracts.—The work has all been done by contract, and, in order that it might be pushed forward as rapidly as possible, it was divided into sections ranging in value from $600 to $40,000. The letters on plan and profile refer to these, but, in some cases, several of them were thrown together in one contract. The drawings made for each consisted generally of plan and profiles, with details of manholes, overflows, etc. All contracts were made in lump sum, and extra work was paid for by schedule of rates arranged before calling for tenders.

Setting Out.—In setting out the work, centre stakes (or stakes at definite distances from the centre) were driven every 100 feet apart, and the centre line then marked on the struts by tacks. These were used by the workmen in putting in the timbering, etc. For trimming out the bottom of the brick sewers a plumb line was used at each "bottom" (ranging from 12 to 25 feet in length usually). In laying out the tile sewers the plumb line was not used, but every pipe was sighted for line and level by a rod held vertically.

This part of the work was attended to by the Inspector. The grades were obtained as follows:—Stakes were driven, level with the ground, every 100 feet, at safe distance from edge of trench, and the depths calculated below these, and entered in the Inspector's book. Planed sight boards were then fixed into position over the trench at these points, and whenever a grade was desired at any point this was found by using a sighting rod. Three sights were always kept in position for purpose of detecting errors of calculation or levelling, or settlement of the stakes. In the deepest sewers the sighting rods were usually made in two, and in some cases three lengths, arranged to slide through an iron ring provided with a thumbscrew to fasten them into the right place. The advantage of this in a cut 20 feet or deeper is apparent.

Timbering.—The trenches required usually continuous timbering. This was done by the ordinary methods, using horizontal walings and vertical sheeting. The walings were usually of 2-inch stuff, but some contractors preferred them of 3-inch. Sheeting ranged from 1 to 2-inch, according to the nature of the ground, and the contractor's idea of economy and propriety. In good standing soils, the lighter materials (when properly put in place) were strong enough, but in many of the deeper trenches, where strong pressures were the rule, the heavier materials were none too good, and the extra sense of security, experienced by the workmen, more than compensated for any extra expense incurred by their use. Where possible, one waling in the centre has been made to answer for each set of sheeting, but in bad ground, walings were placed at top and bottom of each. Sometimes the single and double waling methods were used in the same trench. On one small but deep section, the sheeting was laced by means of vertical walings well strutted, thus tying the various sets of sheeting together, and making it more difficult for individual sets to sink.

Caving Banks.—In sewer work the proper putting in of shoring is always an important one. On many sections of the London work the banks sank a great deal. This has not always been evenly distributed, as occasionally one side would go down as much as three feet more than the other. The causes of the irregular sinking were not always apparent, but could be generally traced to undue pressure on the sinking side, or to the direction of the flow of the ground water. Frequently water entering the trench from one side would wash in the fine material, and that side would settle, while the other, being dry, would remain firm.

Other reasons were the running of machines, dump-cars, etc., close to one side. In one instance the contractor piled all the earth from a 20-foot trench on one side, and the ground being saturated with water and being of a mixed nature, a tremendous pressure was brought to bear on the struts, which were bowed from 4 to 6 inches, and the foreman of the work asserted that they were in some cases pushed right through the walings. About 50 feet of this work eventually caved in, and a new method of dealing with the excavated earth was adopted. This settling of trenches made constant watching and attention necessary, the men inserting new raking struts, and tightening up those already in. The work of drawing the shoring in backfilling the deep sand trenches has been frequently dangerous, and much timber was consequently buried. On one section, while taking out sheeting from a 35-foot sand cut, about 25 feet of it caved in, and buried a man below, whose life was saved only by the struts and timbers closing over his head. Usually sufficient warning is given by the creaking of the shoring, but this is not always so.

Brick Sewers.—The manner of laying brick sewers will first be described. The trenches, if in clay or other firm soil, are first trimmed out to the shape of the invert, a template is then fixed in position, true to line and grade at from 12 to 25 feet from the previously finished work, and stretching a line tight along the bottom course, the bricklayers lay the bricks, working from each end towards the centre. The string is then moved to the next course, and the work proceeds as before. The first few courses are laid dry, and the sidewalks then completed to the springing line, the joints being made in no case less than one-quarter inch, and usually made as thin as possible on the face. The invert joints are then filled with cement grout. When bricks have frogs, these are laid up, and all bricks are pressed firmly into place. The springing course is all headers, and is the only one in the sewer. The centres used are four feet long, made with hinged legs. On the arches the key courses are also grouted. Where two-ring work is used, a half-inch collar joint is laid between the rings. This collar joint gives a good bed for the upper courses, and should not be omitted, or laxity allowed, where water-tightness is desired. Even then water will find its way through at times, and the writer has one section in mind where the sewer was laid in 15 feet of clay, underlying 20 feet of sand, with plenty of water. After the work had been completed some time, the water was found in places oozing in small drops right through the bricks themselves.

As soon as the earth has been rammed over the arch to a depth of two feet, the custom here has been to draw the centres. This allows the work to proceed more rapidly, and in small sewers with good backing no evil results follow from the practice. The bricks used are made in the city, and are of a white or greenish-white variety, the hardest samples being more tinged with green. Their porosity is perhaps their most objectionable feature, as they will absorb from 12 to 18 per cent. of water.

Bricks made from the same clay were used in the construction of the old sewers here, some of which have been down 50 years and appear to be sound.

All mortar used was mixed in proportion of three of sand to one of Portland cement—the latter being all of Canadian manufacture, very finely ground and giving good tensile tests.

Concrete.—Concrete used for backing or foundation was generally made of 1-3-3, but on the sections now in progress, where a single ring sewer is quite surrounded by concrete, the same is being made 1-2-4.

Cradles.—Cradles were used wherever shaky or quicksand bottoms were met with, and were usually made of inch planks, nailed to 1 x 4-inch ribs, 18 inches apart, cut to the proper shape. The ribs were usually fastened on the under side of the planks. The cradles, which were made in the lengths of 4 feet 6 inches, were worked into the bottom by the workmen standing or jumping on them. In using cradle foundations the difficulty has not been one of keeping them up (as seems to be the popular idea), but of holding them down, and it was usually necessary here to strut them down until the brickwork was somewhat advanced.

The cradles on one section, however, were made as described above, with the exceptions of having the ribs on the inside and being filled with 4 inches of concrete, which had set at least 24 hours before being lowered in the trench. The reasons for this construction will be explained a little further on.

Treatment of Water.—On many sections of the work, a considerable amount of water was met, but has usually not been more than could be handled by hand pumps of the ordinary diaphragm pattern. Frequently two of these were required. In some cases where the bottom was clay underlying sand, a pump had to be kept working over the completed portion while the backfilling was being done, to prevent same being washed into the sewer. A description of the method used on sections L. and M. (which are now being built), will suffice to show how the water when met with in or near the bottom of the trench is kept from the work. This sewer is being laid along streets adjacent to and occasionally crossing the line of Carling's Creek, and throughout the entire length of two miles, its invert will be from 5 to 8 feet below the creek level. The cutting is mostly sand, and so far as completed (a distance of three-quarters of a mile), there has been enough water to keep a centrifugal pump (with a three-inch discharge) working steadily.

The construction consists of a single ring of brickwork surrounded by concrete of varying thickness. To get this concrete in to the best advantage, the bottom portion (4 inches) is mixed and moulded into the wooden cradles on the bank, and is allowed to set hard before being lowered into the trench. The weight of these is about seven hundred pounds, and they are made in four foot lengths. To enable them to be easily caulked, small strips of canvas filled with grass are nailed to one end of each, and when the cradles are being laid they are pressed tightly together. This forms a very good joint, and is only required temporarily to allow the inside ring of bricks to be laid.

The pump is set about 50 feet ahead of the completed brickwork, and when in operation draws water from both directions, that portion which is near the sewer being conveyed through 2½-inch land tile, laid on each side of the cradles.

This method has proved very successful, and effectually prevents the water and quicksand from boiling up through the bottom. Occasionally entrances into the sewer were left to allow the ground water to drain away. These weepholes are afterwards closed up, but not for some weeks after the work is laid. The pump has to be protected by a wire netting (on bottom and all sides) to prevent chips, etc., getting in and stopping the action.

Tile Sewers.—Glazed tile sewers were laid up to 18 inches diameter. These were jointed with neat cement—gasket being first used to pack the joints. With all 18-inch sewers and with some 15-inch, concrete was used to pack the haunches.

The sections show the manner of doing this. Standard pipes were used, except on one deep section, where a thickness of one-tenth the diameter was demanded. Considerable delay and difficulty were the result.

Manholes.—Manholes were built at from 300 to 450 feet apart, depending upon lengths of blocks, the principle being to have one at each sewer junction. The greater part of these (the manholes) are rectangular in form, being 2 feet by 3 feet 6 inches inside at the bottom, and drawn in to 2 feet by 2 feet at the top to suit frames, 1 foot 9 inches by 1 foot 9 inches inside dimensions. Each frame and cover weigh (together) about 520 pounds, and ventilation is provided by 81 holes 1-inch square each. Iron steps of three-eighths inch by one and one-half inches iron, bent and set in the shafts every fifth course of the brickwork, provide a means of entering the sewer. The walls are of two rings of brickwork down to 16 feet depth, and below this an additional ring is built. On the deepest sewers, however, the manholes were made circular at the bottom, and were drawn in gradually to suit the square tops.

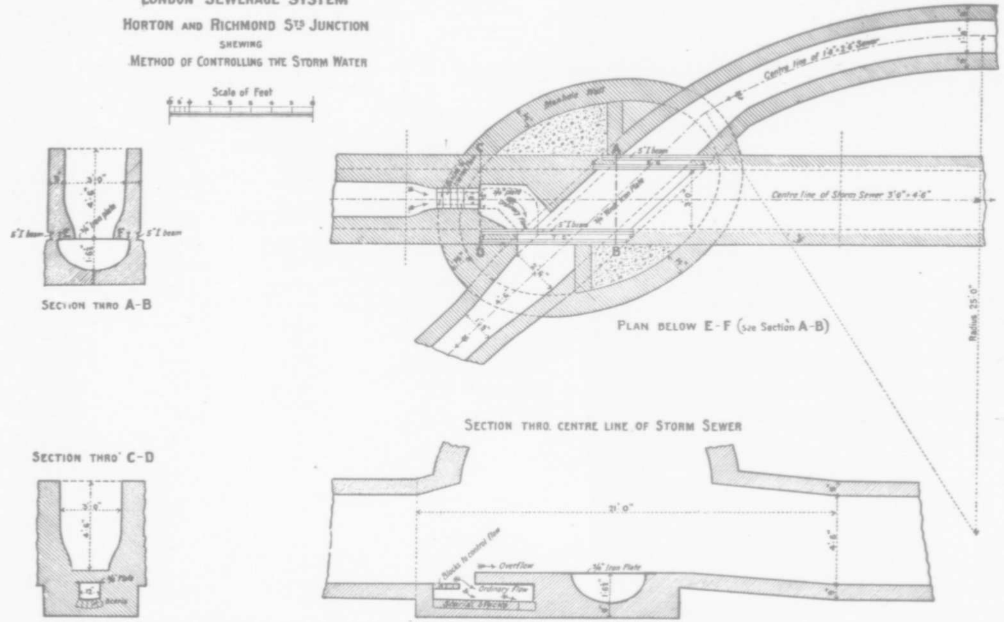
P. D. Connections.—Six-inch private drain connections were left at distances apart varying from 25 to 40 feet, according to the property sub-division, and where necessary enough tile was laid to bring connection to within 11 feet of the road surface. On the deepest sections, viz., J. and parts of K. and P., no private drain connections were left, as it was thought more suitable to lay a shallow sewer later on.

Sewer Junctions and Connections.—Tile sewers are laid straight from manhole to manhole, the bottoms of the latter, where direction changes, being curved suitably. Change of direction in brick sewers has been made by curves of radius of from 30 to 100 feet, with a manhole placed at each end of the curve. Where the north and south sewers join at King and Ridout Streets, a bellmouth junction was built, having a stone tongue 8 feet long, and a brick arch thrown over both sewers of greatest radius 3 feet. Where the main sewer is at same depth below the grade of a future branch, a drop connection is made by means of a vertical pipe outside the manhole wall (see fig. 4, plate IV.). Occasionally two branch connections have been made joining with one vertical pipe, and in each case the connection is open through wall for inspection and for use if any stoppage should come in the drop. Plate V. shows the connection of old Richmond Street south sewer with new sewer, and similar connections (on a smaller scale) have been used throughout where old sewers carrying storm water and sewage were connected. As will be seen from the detail, the ordinary flow is carried through an opening in the bottom of the storm sewer, and this is so regulated that any required excess during rain-storms will still flow in the old channel. There are in all some sixteen connections arranged in this way.

Overflows.—Overflows and relief-outlets have been left at various points. These are simply openings built in the sides of the sewer, and closed by wooden doors whose tops are set at the required height of overflow. If necessary, the doors can be lifted, and the whole flow diverted temporarily.

TRANSACTIONS CAN. SOC. C. E.
VOL. XIII. PLATE V.

LONDON SEWERAGE SYSTEM
HORTON AND RICHMOND STS JUNCTION
SHEWING
METHOD OF CONTROLLING THE STORM WATER



SECTION THRO A-B

PLAN BELOW E-F (see Section A-B)

SECTION THRO' C-D

SECTION THRO. CENTRE LINE OF STORM SEWER

Flushing Arrangements.—Flushing gates (closing against the current) were placed on certain sewers at intervals of 1,000 to 1,500 feet. They are held shut by a bar of iron with a forked end jammed against an inclined rod, and when sufficient amount of water has accumulated behind the gate the bar is pulled or knocked out—the door swings back or is lifted (if for tile), and the flush is immediate and substantial. Both kinds have been found satisfactory. Fig. 1, plate IV., shows flush-gate for egg-shaped sewer. Fig. 2, plate IV., shows that for an 18-inch tile sewer.

Along the north sewer, inlets have been made to utilize the creek water for flushing purposes. Each inlet consists of a large and small chamber, the former being 4 feet by 6 feet by 14 feet long, having an outlet to the sewer two feet from the bottom, and being separated from the small chamber by a 14-inch wall at the other end. This latter is really two chambers covered with gratings set in the bed of the creek. One of these small chambers connects with the large one by a grating, and is intended for an ordinary flow (which can be controlled in a similar manner to that by which storm water is). Should a large flush be required, it can be had by opening a gate-valve connecting the other half of the small chamber with the large one. This large chamber has a sand catching capacity of about 3 cubic yards, and will be required to be cleaned out occasionally.

River Crossing.—To carry the sewer across the river at King Street a bridge was built, and this was made to serve highway purposes as well. The bridge has a central span of 162 feet, and viaduct approaches of 468 feet, making a total floor length of 630 feet. A steel rivetted pipe 36 inches in diameter was carried under the floor throughout the length. This pipe was made of ¼-inch metal, painted with two coats of graphite over one coat of red lead, and its construction (and that of the floor beams supporting it) is clearly shown in the photograph accompanying. Inside the pipe no rivet heads show below the horizontal diameter.

The piers, and pedestals for the viaduct columns were all constructed of 1-2-6 concrete, with 3-inch facing of 2 to 1 mortar, and covered with six inches of concrete composed of one of cement, one of sand and three of crushed screenings. This concrete became extremely hard, and proved harder cutting than limestone three months after completion.

A good hard clay foundation was found for the east river pier at about 6 feet depth, while for the other river pier the clay was ten feet lower, and oak piles spaced 2 feet 6 inches centres each way were driven and covered with a timber platform to receive the concrete. In the construction of the superstructure, attention is drawn to the floor beams, which are shown well in the photograph. They are spaced 18 feet apart throughout the whole length of bridge and viaduct.

LONDON SEWERAGE SYSTEM. KING STREET VIADUCT. SHOWING CONSTRUCTION OF STEEL PIPE AND FLOOR-BEAMS.

TRANSACTIONS CAN. SOC. C.E.
VOL. XIII. PLATE IV.

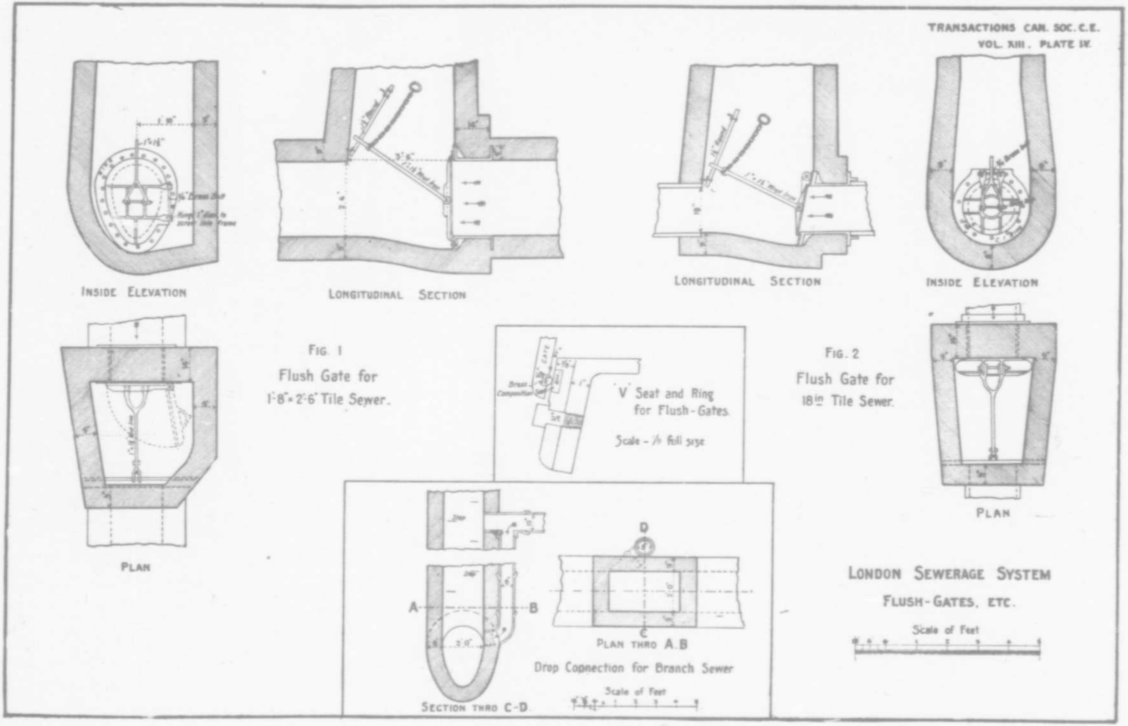


FIG. 1
Flush Gate for
1'-8" × 2'-6" Tile Sewer.

FIG. 2
Flush Gate for
18in Tile Sewer.

"V" Seat and Ring
for Flush-Gates.

Scale - ½ full size

Drop Connection for Branch Sewer

LONDON SEWERAGE SYSTEM
FLUSH-GATES, ETC.

The steel pipes were brought on the ground in 32 feet lengths (4-8 foot plates), and as much as 200 feet of them were laid in position in one day. To facilitate jointing, the butt-strips on the pipes were made in two parts—on one length this strip being shop-rivetted to the lower, and on the next length to the upper half, thus saving some trouble in fitting. The curves were made to a 74 foot radius, the centre of each cross seam lying on the arc of the circle. The work went easily together, and in only a few cases was it necessary to alter the positions of the saddles on the beams. About five joints were rivetted and caulked in a day.

Backfilling Methods.—Various methods were adopted for excavating and replacing the earth. On one sewer of 20 feet cut staging was first tried alone, and afterwards cars were added to carry the material back along a line of rails laid by the trench, and dump into the same. These cars were moved back by men pushing them.

On two sections a machine (built by the contractor) was used for lifting and backfilling. A line of trestle work was made to straddle the trench for about 200 feet, and the whole arranged to move forward on a track as required. In the upper part of the trestles two longitudinal beams were fastened close to each other to form a tramway for a small carriage to run on. As each bucket was filled in the trench, it was lifted by the cable to the carriage, and hauled back along the line by a wire rope passing round a wheel at the rear end of the trestle, and over the framework to the engine stationed about 50 feet in advance of the other end of the same. After dumping, the bucket was returned to be refilled. The buckets were made oblong, about 3 feet by 1 foot 6 inches by 2 feet. The machine worked successfully.

Horse derricks (as they are called) were used on several deep sections. These consisted each of a tripod (made to stand over the trench) having a pulley at the top and a wheel at the bottom of one of the legs, through which a one or one and a quarter inch rope passed. One end of the rope was fastened to a ring with three chains—two of which had a ring at the other end and the third one a hook. In operating, the chains were fastened to the loaded wheel-barrow in the trench by slipping the rings over the handles and the hook through the wheel, and hauling the load up by a horse at the other end of the rope. This method was used on section "J," where the depth averaged 29 feet for a length of 2,900 feet, and gave fair satisfaction.

One contractor operated a system of hoisting buckets by an engine with four drums, then shoving them back by hand and dumping.

On the north sections L., M., N., O., the material was (and is being) excavated and filled into water-tight steel buckets (holding about 10 cubic feet each), which were then hoisted by means of a derrick set on a car, and run back and dumped—the hoisting engine supplying also the motive power to run the truck back and forward. This machine has proved to be a very convenient one.

To give some idea of the cost of moving earth a table has been prepared and placed at the end of the paper giving the probable cost to contractors by various methods. The cost of excavation includes all timbering work, backfilling, wear on apparatus, etc., and in case of tile sewers the labour of laying tile. It would obviously be unfair to make the figures given in the table a basis for close comparison of cost of work by various methods as so many other and unknown quantities enter into the problem, such as the difference in foremen—their ability to handle men, etc.—quantity of lumber left in, etc. Some figures are here given showing approximate cost of taking out clay on deep section by the use of horse derricks described before.

First six feet was thrown out by hand (add this to the depth given for total depth of sewer).

Depth.	No. of Derricks.	Horses.	Men.	Approx. cost per cubic yd.	Materials.
17′2″	4	2⅔	14	58c.	Dry hard clay.
17′6″	3	2	10½	58c.	do
19′6″	5	3⅓	17½	82.7c.	Clay with water.
21′0″	4	2⅔	14	86.2c.	Hard clay with water coming down sides.
23′6″	8	5⅓	28	56c.	Upper half free working sand, lower half hard dry clay.
29′6″	4	2⅔	14	39.2c.	Dry hard clay.

Main Protections.—Water mains, where intersected, were protected from sagging by timbers brought up from the arch, or occasionally by building brick piers under them. Tile sewers crossing above the work were usually supported by building two parallel brick walls to the haunches of the pipe and packing between with concrete.

Inverted Syphon.—To reach the sewage farm a long stretch of low lands had to be crossed. These low lands have at some former period been the bed of the river which, coming through what is now the west part of London West, must have swept for about a mile straight south of the present channel, and then bending sharply to the west returned to its present position within a few hundred yards of its point of deviation. Some of the old channels are still below the river level, consequently standing full of water, and are known as the East and West Coves, and at the point where the sewer is built, there is some 500 feet of higher land separating them. The West cove is connected with the river. This low land being from 2 to 16 feet below the grade line of the sewer, it was decided (after considerable opposition from the ratepayers) to lay an inverted syphon, and in order to make the most of the ordinary dry weather flow, the size was reduced to 20 inches in diameter, the intention being to lay an additional 24-inch pipe when required, and thus bring the total capacity eventually to that of a 30-inch pipe, which it was originally intended to lay at once. The object is of course to have as great a present velocity as possible. Cast iron pipes were used specified to weigh at least 1,620 lbs. per 12-ft. length. They were laid in the same manner as water pipes. The descending leg of the syphon is a brick well 10 feet in diameter and 13 feet deep below grade, connecting with the pipe by a 20-inch gate valve. From this well a 16-inch pipe leads to a relief sewer running to the river—a separate connection being made also with this relief from the upper grade. These are for purposes of overflow for storm-water, and for diverting flow when necessary to examine the syphon.

Over this syphon well a house will be built to cover valve gear, etc., and to allow the sediment and coarse screening to be removed easily. The ascending leg is not now being built, but it is intended to make it a 20-inch pipe.

From its foot a 20-inch pipe is laid to the river, and at present the whole flow will be discharged there.

The syphon crosses the East cove by a 20-inch steel pipe 300 feet long laid on cedar cribs 6 feet by 8 feet (50 feet apart) sunk to hard bottom and filled with stone. The steel pipes are fastened to these by iron straps passing oven the top and bottom to ¾-inch rods in the timbers.*

Across the West cove for a length of about 300 feet, oak piles were driven in pairs well braced and capped with timber cut to the shape of the sewer, while for the water-way a culvert was formed by two concrete walls made wide enough for a road way as well. Manholes were left at intervals of about 600 feet, there being a special casting in each, closed with a cover bolted down. The length of the syphon is 3,200 feet, and the maximum head will be about 22 feet. The syphon pipe is laid on a 1-500 grade.

Note.—Plate III. gives illustrations of some typical sections of sewers as laid.

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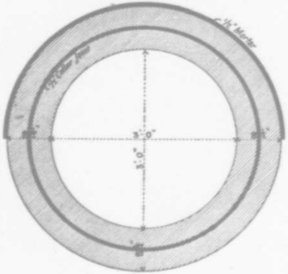
*N.B.—This pipe will not be laid until spring of '99.

TRANSACTIONS CAN. SOC. C.E
VOL XIII PLATE III

LONDON SEWERAGE SYSTEM

SECTION TYPES

Fig. 1 - 36 in Circular



Scale of Feet

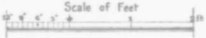


Fig. 2

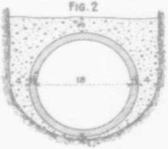
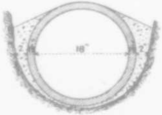


Fig. 3



18 in Tile in Concrete

Fig. 4 - 2'-0"×3'-0" Egg Shape

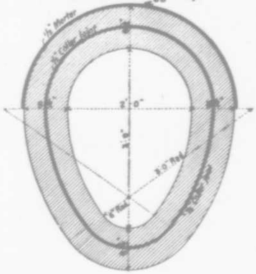


Fig. 5 - Concrete on Arch.

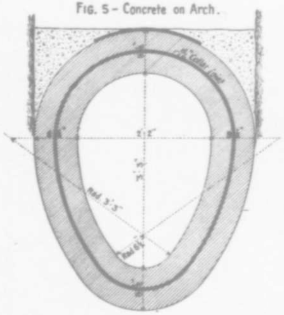


Fig. 6 - Concrete Backing and Cradles.

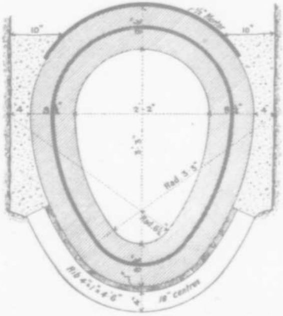


Fig. 7 - Single Ring of Brick with Concrete all round.

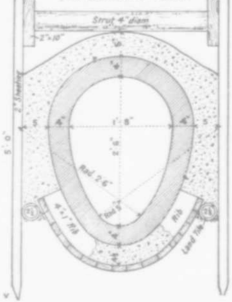


Fig. 8 - 18 in Tile in Concrete

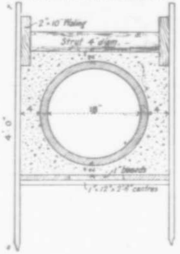
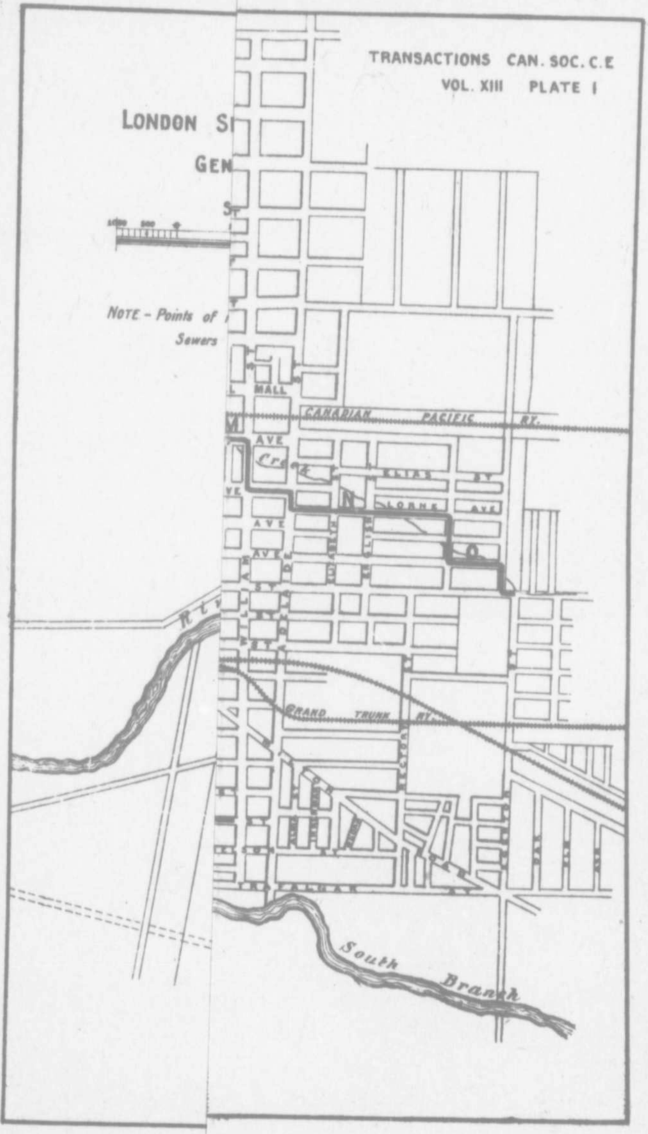


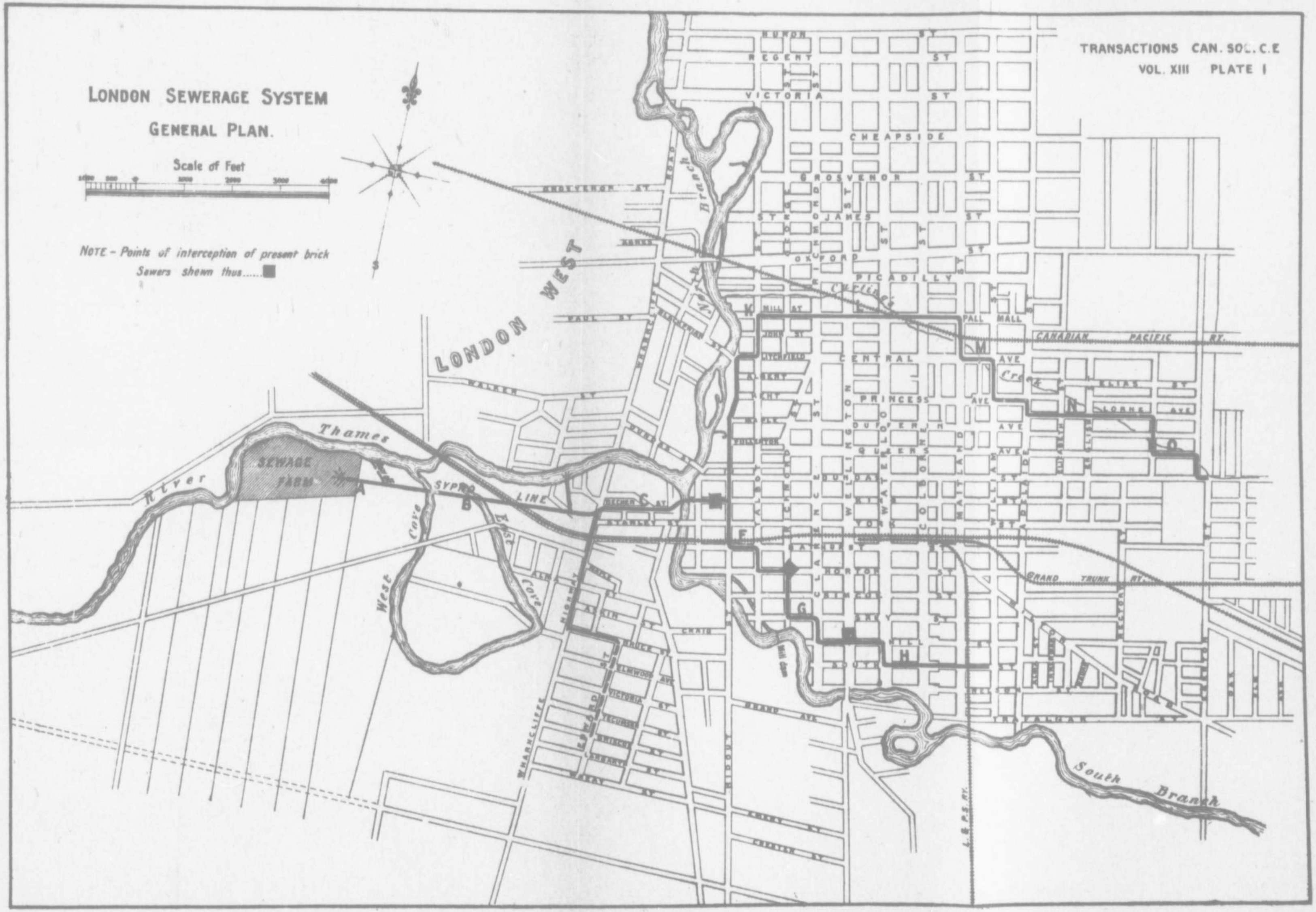
TABLE ACCOMPANYING PAPER ON LONDON SEWERS.

Section Designation.	Outside width Sewer.	Description.	Length of Sewer.	Depth.		Method of Handling the earth.	Approx. cost per cub. yd.	Nature of Soil.
				Average.	Maximum.			
1	4′.6″	Brick.	2400 ft.	17′.9″	22′.9″	Stages in trench Dump-cars to backfill.	58c.	Mostly dry, hard clay.
2	4′.6″ 3′.6″	" "	500 " 3450 "	16′.5″ 18′.0″	22′.0″ 22′.0″	Chiefly done by backfilling machine.*	57c.	Clay bottom, under clay and sand (dry).
3	3′.8″	"	2916 "	29′.5″	37′.2″	Horse derricks.	86c. to 98c.	First half dry, hard clay—balance good clay bottom with as much as 20 ft. sand above and plenty of water.
4	3′.8″	"	2414 "	22′.3″	38′.6″	1st half by machine for hoisting, 2nd half staged.	88c.	All sand—a great deal of water—cradles ⅓ distance.
5	3′.6″	18″ tile (in Concrete).	2275 "	21′.0″	30′.0″	Backfilling machine.*	65c.	Clay bottom, under sand with plenty of water.
6	1′.6″ 1′.2″	15″ tile 12″ tile	970 " 2077 "	18′.1″ 13′.3″	18′.4′ 17′.6″	Staging small part horse derricks.	55c.	Very hard, dry clay.
7	2′.1″	18″ tile (Concrete.)	418 "	11′.0″	14′.8″	Staged.	65c.	Gravel bottom—very wet.

* This is the machine with the carriage, travelling bucket, etc.


TRANSACTIONS CAN. SOC. C.E
VOL. XIII PLATE I
LONDON S
GEN
S
1000 500 0
NOTE - Points of
Sewers
HALL
CANADIAN PACIFIC RY.
AVE
Creek
ELIAS ST
LORNE AVE
AVE
AVE
ST
WILLIAM
ADELAIDE
ST
GRAND TRUNK RY.
RECTORY
TRAFALGAR ST
River
South Branch
M
N
O

TRANSACTIONS CAN. SOC. C.E
VOL. XIII PLATE I

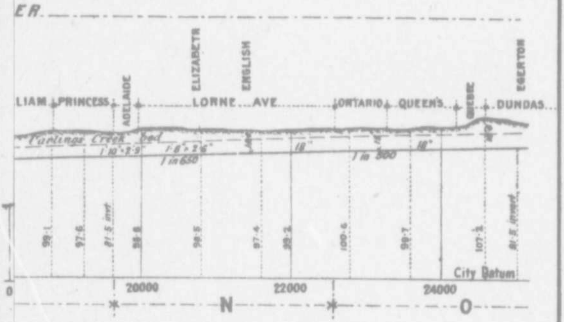


LONDON SEWERAGE SYSTEM
GENERAL PLAN.

Scale of Feet

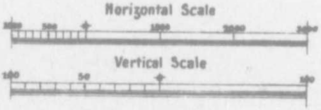
NOTE – Points of interception of present brick Sewers shewn thus...... ■

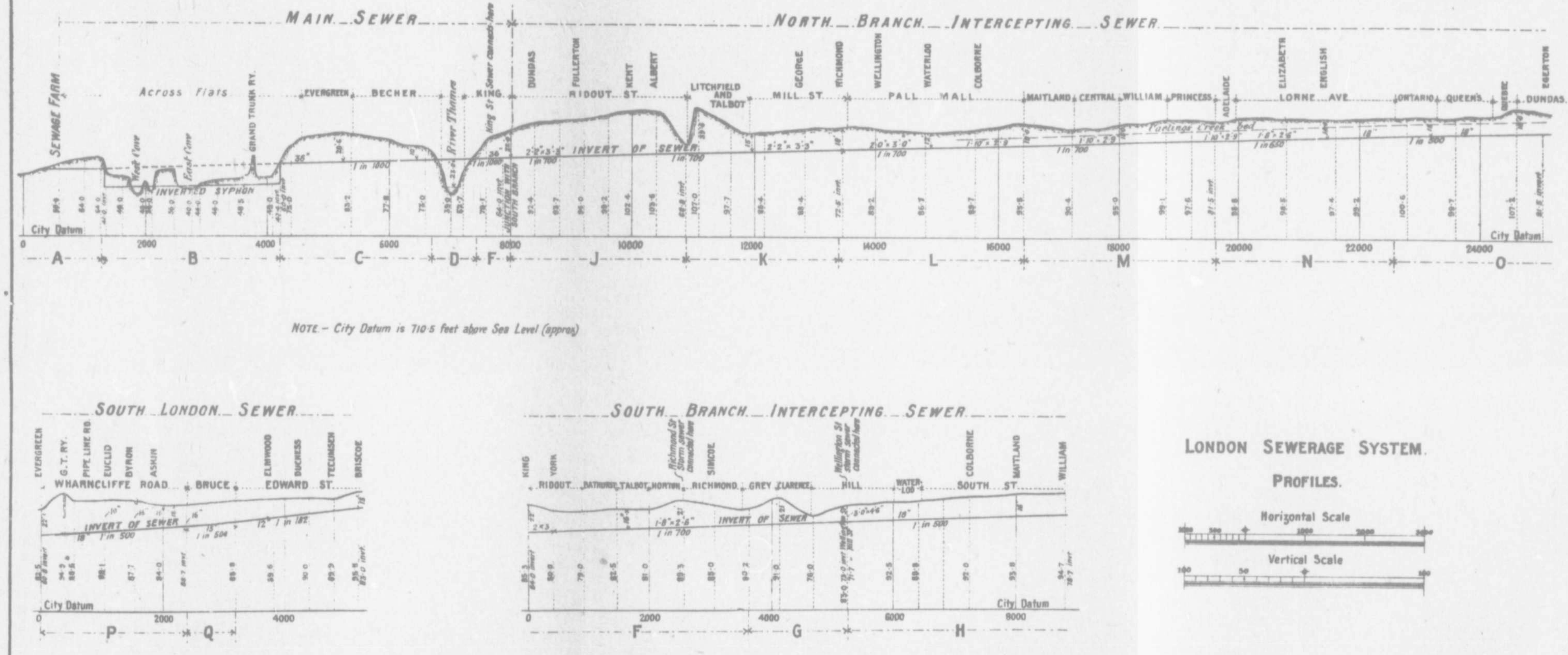
TRANSACTIONS CAN. SOC. C.E.
VOL. XIII. PLATE II.



LONDON SEWERAGE SYSTEM.

PROFILES.





NOTE.—City Datum is 710·5 feet above Sea Level (approx.)

LONDON SEWERAGE SYSTEM.

PROFILES.

Thursday, 13th April.

Henry Irwin, Member of Council, in the Chair.

Discussions on Mr. Anderson's paper on "The Compressive Strength of Concrete," and Mr. Stuart's paper on "Pavements in Vancouver, B.C.," occupied the evening.

Thursday, 27th April.

Paper No. 144.

HOLDING POWER OF WOOD SCREWS.

By W. M. Macphail, B.A.Sc., Stud. Can. Soc. C.E., and T. T. Irving, B.A.Sc., Stud. Can. Soc. C.E.

Engineering records, as far as the authors can ascertain, contain only two accounts of experiments having any reference to this subject. In 1874-77 the U. S. military engineers made experiments on drift bolts, and incidentally compared them with wood screws (*Eng. News*, Feb., 1891), and in 1897 Prof. Martens, of Germany, experimented on the variation of the strength of wood screws in order to find out the most efficient shape of thread and depth of cutting. No effort in either case was made to establish any relation between the strength developed and the size of screw when driven in different sized holes in different woods, both parallel to and across the grain of the wood. This it is the object of these tests to determine in some small degree.

Screws.—317 tests were made. The screws tested were ⅜", ½", ⅝" and ¾", and may be taken as representative types of each size ordinarily used in practice.

Woods.—The woods on which the experiments were made were Red Pine and White Oak, representative respectively of the soft and hard woods. Both were carefully selected, well seasoned, free from knots and shakes, and of as homogeneous a structure as could be obtained. In order to obtain results that could be legitimately compared, the pieces used were in each case cut out of one large stick and were about 6" x 6" by 8' long. They were so dressed that the grain of the wood was parallel and at right angles to the faces.

Boring.—The boring was accomplished by means of a feed drill driven by an electric motor. The holes were bored first on one face parallel to the grain, the screws driven in and immediately drawn. Then intermediate to these holes on one of the contiguous faces the same screws were driven, that is at right angles to the grain of the wood. The holes were spaced $3\frac{1}{2}''$ centres for the small $\frac{3}{8}''$ screws, and as much as $7''$ centres for the $\frac{3}{4}''$ screws and staggered $2''$ in all cases. In case the drawing of one screw would develop cracks along the wood, this arrangement of the holes would eliminate any danger of injury to the next screw drawn, as it gave a distance of $7''$ in the one case and $14''$ in the other along the line of least resistance between the consecutive screws. This gave ample space between, as only in a few cases did any indication of splitting occur. When driven across the grain the layers of wood at the surface were lifted up slightly, but only after the maximum load had been reached, and consequently did not affect the final result and the conclusions deduced therefrom.

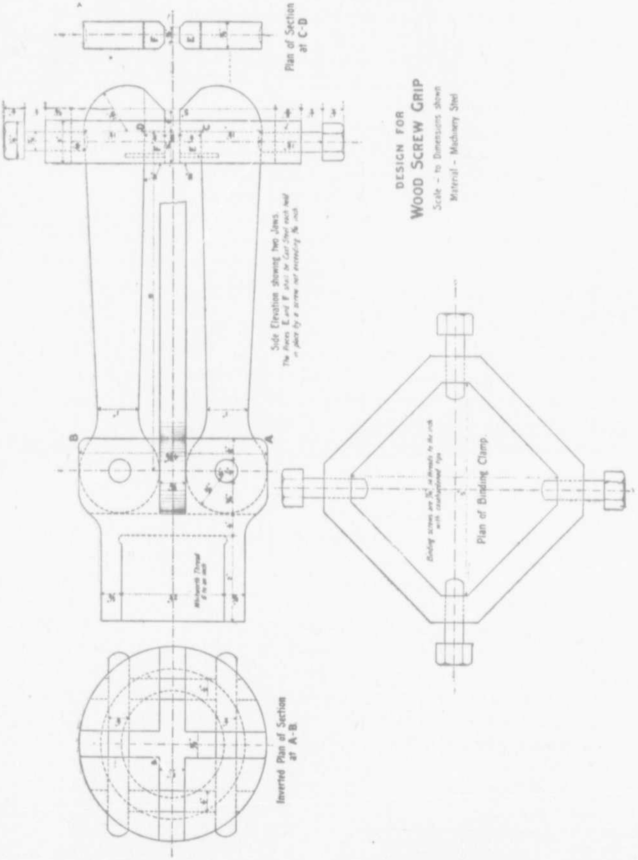
The size of holes into which the screws were driven was as given in the following table:—

Size of Screw in inches.	Min. Diam. in inches.	Size of Hole in inches.	No. Threads per in.
$\frac{3}{8}$	$\frac{13}{48}$	$\frac{1}{4}$ and $\frac{5}{16}$	8
$\frac{1}{2}$	$\frac{25}{64}$	$\frac{3}{8}$ and $\frac{7}{16}$	6
$\frac{5}{8}$	$\frac{31}{64}$	$\frac{1}{2}$ and $\frac{9}{16}$	6
$\frac{3}{4}$	$\frac{35}{64}$	$\frac{9}{16}$ and $\frac{5}{8}$	4

The smallest holes were of the same diameter as the minimum diameter of the screw, and the others were 1-16″ larger or 1-16 smaller than the stem of the screw. These were the only sizes of holes used. It yet remains to determine what is the best size of hole to use to give the greatest strength with the least amount of work done in driving the screw.

DRIVING.—At first a few of the screws were driven by hand, but it was difficult to apply just enough pressure to prevent the fibres of the wood from lifting caused by the resistance to entrance of the screw. This method therefore was abandoned, and all the rest were machine driven, applying just sufficient pressure to maintain on entrance a uniform feed as determined by the pitch of the thread of the screw. For the smaller sizes, viz.: $\frac{3}{8}''$ and $\frac{1}{2}''$ screws, the same feed drill was used for driving as for boring the holes, a special clutch having been designed and constructed to receive and hold the heads; but the larger sizes, $\frac{5}{8}''$ and $\frac{3}{4}''$, offered too great a resistance to entrance to be driven in this way. A torsion machine was therefore fitted up with higher speed pulleys, and though somewhat slower served the purpose very well.

Drawing the Screws.—The Emery Hydraulic Testing machine was used to draw the screws. It was found necessary to design a



special grip for the purpose. The design was based on the strength required to withstand a tensile stress equal to that necessary to break the largest size of screw tested, viz.: ¾", and the bending moments set up in the jaws due to this strain, and also to be easily adjustable to the different sizes tested.

Allowing 50,000 lbs. as the tensile strength of wrought iron, there would be required in the jaws a strength sufficient to withstand a strain of 22,000 lbs. absolute, the minimum diameter of the ¾" screw being 9-16".

The jaws were designed to have a factor of safety of 5', and consisted of a hollow cylindrical head of machinery steel cut internally with Whitworth thread (6 to the inch) and 3' deep, with a solid base slotted at right angles to receive the heads of the four jaws. The jaws were tight fitting, and hung on ½" turned pins, 10" in length and ⅜ sq. in. smallest sectional area, and had case hardened blocks, fastened by a screw, to resist abrasion. The clamp that held the jaws firmly in the head of the screw was of the same material, machine steel. They, with 4 set screws, with case hardened tips resting in cup-shaped depressions in the jaws, as near as may be in the plane of the point of application of the force exerted on the screw head. This was to eliminate as far as possible the effect of bending in the jaws that would otherwise be great.

In applying the force necessary to draw the screw, care was taken to observe a uniform rate of loading so that each screw would be drawn in as nearly as possible the same length of time. This was done by attaching to the valve of the machine a pointer so that the fluid was allowed to flow uniformly in all cases. But, owing to the want of perfect uniformity in the structure of the wood, it was impossible to so regulate the feed that each screw would be drawn in the same time. To determine what effect, if any, this difference of time had upon the maximum load, experiments were made, the results of which are given in Table II.

Table I.—Summary and Remarks.

1. When driven across the grain the *strength developed varied as the depth driven, i.e.*, depth of thread in wood. In no case was the screws driven deeper than the length of thread. Otherwise the friction between the stem of the screw and the wood would affect the maximum load, and the effect of a drift bolt would be added to the effect of the thread of the screw.

Thus taking 960 as the unit theoretical load:—

Ratio	=	1	2	3
Theoretical load	=	960	1920	2880
Actual load	=	960	1970	2940
Difference	=	0	50	60
Per cent. of difference	=	0%	2.5%	2%

The first two results given—600 and 740—are the results of hand-driven screws where insufficient pressure had been applied to prevent the wood from lifting, thus reducing the strength from a theoretical maximum of 930 lbs. to an actual load of 740 lbs., a difference of 190 lbs., or a loss of 24%.

Thus taking 930 as the unit theoretical load:

Ratio	=	1	2	3
Theoretical load	=	930	1860	2790
Actual load	=	740	1870	2744
Difference	=	190	10	46
Per cent. of difference	=	24% loss	.6% gain	1.7% loss

This serves to show the extreme importance of the exercise of care in driving the screws, especially where the depth is not great.

Table II.—In the first division of the table the rate of loading varied between 21 seconds and 130 seconds, and the greatest deviations from the mean load were:

— 350 and + 200.

and the least were: — 20 and + 10.

In the second division of the Table with a practically uniform rate of loading varying between 15 seconds and 18 seconds the greatest deviations from the mean load were:

— 246 and + 354.

and the least were: — 16 and + 54.

Throughout the tests the rate of loading did not vary more than from 10 to 25 seconds, and the above shows that a variation of as great as 109 seconds did not appreciably affect the maximum loads. So that within the limits possible, which are small, the time does not at all affect the results given.

Table III.—1. In Pine, screws in the *smaller hole* gave from 2% to 14% greater maximum strength than the same screws in the *larger* sized hole.

2. In Oak, screws in the *larger hole* gave from 4% to 15% greater maximum strength than the same screws in the *smaller* sized holes.

3. In Pine, screws driven *parallel* to the grain developed 3% to 28% greater strength than those drivon *across* the grain.

4. In Oak, screws driven *across* the grain developed 3% to 16% greater strength than when driven *parallel* to the grain.

5. *The strength developed varies as the circumferences of the screws and hence as the diameters,* the length of thread being the same. Thus taking 2688 as the unit theoretical load:

Size of screw..	=	$\frac{3}{8}''$	$\frac{1}{2}''$	$\frac{5}{8}''$	$\frac{3}{4}''$
Ratio of diameters..	=	3	4	5	6
Loads..	=	2688	3890	4520	5430
Theoretical loads	=	2688	3584	4480	5376
Error..		00	306	40	54
Per cent. of error..		0%	8%	.9	.9%

This ratio is a simple one, and agrees well with the results of our tests. The strength developed appears to be independent of the number of threads per inch. The finer the pitch of the thread of the screw the more bearing area will it have, but there is then the danger of injuring the fibres of the wood to such an extent as to vitiate the benefits of the larger bearing area.

6. All but two of the $\frac{3}{8}''$ screws driven in oak failed in tension at an average load of 55,000 lbs. per sq. in.

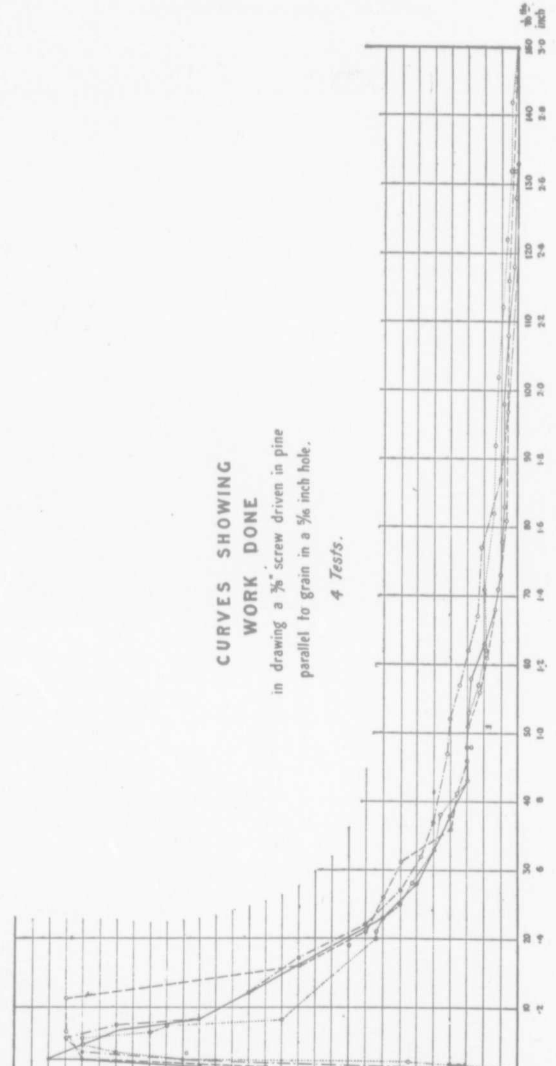
Table IV. gives in compact form the absolute maximum loads borne by each size of screw: (*a*) driven in oak, (*b*) driven in pine, both parallel and across the grain.

The last column gives the absolute load per inch of thread.

Curves.—A sheet of curves is also given showing the work done on a $\frac{3}{8}''$ screw driven 3″ parallel to the grain in Red Pine. The area of the average curve computed by the method of average ordinates gives:

Work done.. .. .. = 1400 ft. lbs.

When driven across the grain the work done would be much greater, because the maximum load was, in almost all cases, maintained for quite an appreciable distance of travel of the screw, although, as was the case with Pine, the maximum load was not as great as when driven parallel to the grain. This is doubtless due to the greater elasticity and lesser rigidity of the fibres transversely than when edgewise to the action of the load. The curve would then at the maximum load show an almost horizontal line somewhat similar to that shown in dotted *black*, only more marked, and would, moreover, fall away less abruptly than those shown on the sheet, thus enclosing a much greater area and hence a greater amount of work done.



CURVES SHOWING
WORK DONE
in drawing a ⅜" screw driven in pine
parallel to grain in a 5/16 inch hole.

4 Tests.

COMPARISON OF STRENGTH DEVELOPED BY A 3/8" SCREW DRIVEN TO DIFFERENT DEPTHS, VIZ., 1", 2" and 3".

Mean of *x* Tests.	Size of Hole.	Depth Driven.	Kind of Wood.	Direction of Grain.	Maximum Load.	Remarks.
5	1/4"	1"	Red Pine	Parallel	600	
5	5/16"	1"	do	do	740	
6	5/16"	1"	do	Across	940	
6	1/4"	1"	do	do	960	
5	5/16"	2"	do	Parallel	1870	
5	1/4"	2"	do	do	2010	
8	1/4"	2"	do	Across	1970	
8	5/16"	2"	do	do	1760	
8	1/4"	3"	do	Parallel	2870	
8	5/16"	3"	do	do	2744	
8	1/4"	3"	do	Across	2940	
8	5/16"	3"	do	do	2845	

TABLE II—COMPARISON OF STRENGTH DEVELOPED WITH RATE OF LOADING.

Size of Screw.	Size of Hole.	Time to Max. Load.	Depth Driven.	Mean of 12 Tests.	Maximum Load.	Deviation from Mean.	Remarks.
1/2"	7/16	0' 21"	3"	3850	3810	− 40	
		28"			3860	+ 10	
		28"			3500	− 350	
		31"			3700	− 150	
		40"			4000	+ 150	
		55"			3900	+ 50	
		1' 05"			4050	+ 200	
		1' 14"			3980	+ 130	
		1' 17"			3760	− 90	
		1' 37"			3960	+ 110	
		2' 00"			3830	− 20	
		2' 10"			3900	+ 50	
5/8	9/16	15"	3"	4546	4600	+ 54	
		17"			4600	+ 54	
		15"			4530	− 16	
		17"			4600	+ 54	
		15"			4490	− 56	
		16"			4900	+ 354	
		14"			4300	− 246	
		18"			4820	+ 274	
		15"			4420	− 126	
		17"			4200	− 346	

TABLE III.—GENERAL COMPARISON OF STRENGTH DEVELOPED BY SCREWS 3/8", 1/2", 5/8" AND 3/4" DIAMETER IN DIFFERENT SIZED HOLES DRIVEN 3".

Mean of x tests.	Size of Hole.	Kind of Wood.	Direction of Grain.	Size of Screw.	Max. Load.	
4	1/4"	Red Pine	parallel	3/8"	2820	
13	3/8"	do	do	1/2"	4500	
12	1/2"	do	do	5/8"	5150	
6	5/8"	do	do	3/4"	5520	
5	1/4"	do	across	3/8"	2865	
12	3/8"	do	do	1/2"	3890	
7	1/2"	do	do	5/8"	3720	
8	5/8"	do	do	3/4"	5330	
5	5/16'	do	parallel	3/8"	2688	
12	7/16"	do	do	1/2"	3890	
12	9/16"	do	do	5/8"	4520	
4	9/16"	do	do	3/4"	5430	
6	5/16'	do	across	3/8"	2678	
12	7/16"	do	do	1/2"	3530	
12	9/16"	do	do	5/8"	3580	
4	9/16"	do	do	3/4"	4700	
4	1/4"	Wh.Oak	diagonal	3/8"	4800	Screw failed.
4	3/8"	do	do	1/2"	7180	do do
4	1/2"	do	do	5/8"	9035	
4	9/16"	do	parallel	3/4"	7715	
6	9/16"	do	across	5/8"	7700	
4	9/16"	do	do	3/4"	8150	
5	1/2"	do	do	5/8"	6520	
3	5/8"	do	do	3/4"	8800	
4	9/16"	do	parallel	3/4"	7715	
4	5/8"	do	do	3/4"	7425	
4	9/16"	do	do	5/8"	7350	
4	1/2"	do	do	5/8"	6300	

TABLE IV.—ABSOLUTE MAXIMUM STRENGTH DEVELOPED.

Size of Hole.	Mean of x tests.	Size of Screw.	Minimum Diameter.	Max. Diameter.	No. of Threads per inch.	Length of thread = depth driven.	Kind of Wood.	Direction of Grain.	Max. Load in pounds.	Strength per inch of Thread.	REMARKS.
$\frac{1}{4}''$	4	$\frac{3}{8}$	....	....	......	3″	Wh. Oak.	parallel	4800	....	Screws all failed
$\frac{5}{16}''$	4	$\frac{3}{8}$	....	....	......	do	do	do	4750	....	
$\frac{5}{16}''$	1	$\frac{3}{8}$	....	....	......	do	do	do	4960	1653	Scr'w drew
$\frac{3}{8}''$	4	$\frac{1}{2}$	....	....	......	do	do	do	7180	....	All failed
$\frac{7}{16}''$	4	$\frac{1}{2}$	....	....	......	do	do	do	7263	....	
$\frac{7}{16}''$	1	$\frac{1}{2}$	....	....	......	do	do	do	7460	2480	Scr'w drew
$\frac{1}{2}''$	4	$\frac{5}{8}$	....	....	......	$4\frac{1}{2}''$	do	parallel	9320	2070	
$\frac{9}{16}''$	4	$\frac{5}{8}$	....	....	......	do	do	do	9845	2180	
$\frac{1}{2}''$	4	$\frac{5}{8}$	...	....	......	do	do	across	9505	2110	
$\frac{9}{16}''$	4	$\frac{5}{8}$	....	....	......	do	do	do	9815	....	
$\frac{9}{16}''$	4	$\frac{3}{4}$	....	....	......	4″	do	parallel	9870	2460	
$\frac{5}{8}''$	4	$\frac{3}{4}$	....	....	......	do	do	do	9720	2430	
$\frac{9}{16}''$	4	$\frac{3}{4}$	....	....	......	do	do	across	9820	2455	
$\frac{5}{8}''$	4	$\frac{3}{4}$	....	....	......	do	do	do	10736	2684	
$\frac{1}{4}''$	10	$\frac{3}{8}$	....	....	......	3″	Red Pine.	parallel	2820	940	Hand driven
$\frac{5}{16}''$	9	$\frac{3}{8}$	....	....	......	do	do	do	2688	896	
$\frac{1}{4}''$	8	$\frac{3}{8}$	....	....	.....	do	do	across	2865	955	do
$\frac{5}{16}''$	4	$\frac{3}{8}$	....	....	......	do	do	do	2678	893	
$\frac{3}{8}''$	12	$\frac{1}{2}$	....	....	......	......	do	parallel	4500	1500	Hand driven
$\frac{7}{16}''$	12	$\frac{1}{2}$	....	....	......	......	do	do	3850	1283	
$\frac{3}{8}''$	18	$\frac{1}{2}$	....	....	......	......	do	across	3890	1296	
$\frac{7}{16}''$	12	$\frac{1}{2}$	....	....	......	......	do	do	3530	1176	
$\frac{1}{2}''$	4	$\frac{5}{8}$	....	....	......	$4\frac{1}{2}''$	do	parallel	7387	1640	
$\frac{9}{16}''$	4	$\frac{5}{8}$	....	....	......	do	do	do	6710	1490	
$\frac{1}{2}''$	4	$\frac{5}{8}$	....	....	......	do	do	across	7037	1564	
$\frac{9}{16}''$	4	$\frac{5}{8}$	....	....	......	do	do	do	6222	1382	
$\frac{9}{16}''$	4		....	....	......	4″	....	parallel	7250	1810	
$\frac{5}{8}''$	4		....	....	......	do	....	do	7360	1840	
$\frac{9}{16}''$	4		....	....	......	do	....	across	6237	1559	
$\frac{5}{8}''$	4		....	....	......	do	....	do	7117	1779	

Thursday, 25th May.

Paper No. 145.

THE INLAND WATERWAYS OF NORTH-WESTERN CANADA.

By Geo. H. Webster, M. Can. Soc. C.E.

At the Annual Meeting of the Winnipeg Board of Trade held in February, 1897, a resolution was unanimously adopted in which it was claimed,—" That in the opinion of this Board the question of Immigration is the most important one that engages the attention of the people of this Province, and of the Government of the Province and Dominion" . . . . . "and that the most important factor in the settlement of the country is the securing of low rates of transportation for the products of this country to the markets of the world. That, in the opinion of this Board, an immediate announcement of reduction in the rates on grain from a central point in Manitoba, say Portage la Prairie, to Lake Superior points, from 17c per 100 lbs. to a maximum of 12½c per 100 lbs., and proportionately from other points in Manitoba and the North-West Territories, would do more to encourage the farmers and promote immigration to the country than the annual expenditure of such a sum as this reduction would give, if expended in any other manner."

Prior, as well as subsequent, to the date of this resolution, various schemes have been promoted to reduce the cost of transporting our products to the seaboard. A railway line to Hudson's Bay, and a competing line to Lake Superior, have particularly received attention, while a water route to Hudson's Bay also has its advocates. All of these schemes have met with opposition from one cause or another. The Hudson's Bay Railway route entails a haul of about 700 miles north, necessarily involving high rates of freight, which it has been hoped might be counterbalanced by a low rate of ocean freight to Liverpool, the latter being dependent on the successful navigation of the Straits for a sufficient period of time. The possibility of this is at present, in many minds, a question of doubt, no matter what its advocates may claim; but it seems to the writer after reading the whole of Mr. Fisher's comprehensive report on the subject that he has collected a vast amount of information, which must convince the most skeptical that the straits present difficulties in the way of navigation that will always operate to destroy its value as a great trade route. No commerce of any magnitude or importance can be successfully established over a route that is absolutely blockaded for upwards of seven months of each year. While Hudson's Straits are blocked with ice there is absolutely no means of communication between the Bay ports and the markets of the world; and this is a most important point to bear in mind when comparing this route with one to the south or east in connection with the Great Lakes. When navigation is closed on the latter we still have the railways connecting us with the great centres of domestic trade, and with ocean ports that are open all the year round. Let Manitoba drop this polar chimera; it never was anything but a political and speculative dream, and never can be anything else.

The Hudson's Bay route entails a deflection of export traffic to the north, in a direction far removed from the current of domestic trade and from its centres, and the writer is not aware of any instance in which trade routes that depart from the lines of domestic traffic have been successfully established. A well-known authority, Lyman E. Cooley, C.E., of Chicago, asserts:—"If you consult the history of canals and railways you will find the line of domestic transportation determines the line of foreign shipment." The Mississippi River, with its navigable tributaries and railway connections, penetrating an immense producing district, affords proof of the hopelessness of endeavoring to divert export traffic from the line of domestic trade. The great grain producing States of Illinois, Indiana, Iowa, Kansas and Nebraska are much closer to the river ports than they are to the Atlantic, but the proportion of their export traffic which finds its way to the ocean via New Orleans is infinitesimal compared with that which reaches the Atlantic and St. Lawrence River ports.

Capt. Eads, the distinguished engineer and projector of the Mississippi Jetties, once held the view that the advantages of the Mississippi route would compel the trade of the States named to seek its outlet by this channel. Thirty years ago, in addressing the River and Harbour Convention at St. Louis, he spoke as follows:—

" The improvement of the Mississippi River involves the contemplation of one of the sublimest physical wonders of a beneficent Creator. The boundless reservoirs which supply its channels through such long periods of the year, and make it so valuable to man, and which, if opened simultaneously, would overwhelm the valley and mar its usefulness, are, with that thoughtful care which orders all things wisely, unlocked in beautiful succession, month after month, by the touch of Spring, as she leaves her home in the tropics to bless the colder regions of the north.

"This great stream, with its head shrouded in Arctic snows, and embracing half a continent in the hundred thousand miles of its curious network, and coursing its majestic way to the Southern Gulf, through lands so fertile that human ingenuity is overtaxed to harvest their productiveness, has been given by its Immortal Architect into the jealous keeping of this Republic. . . . This great valley lies between those parallels of latitude that are known to be most conducive to health and to the development of the mental and physical energies of man. In its capacity to produce the cereals, grasses, cotton, sugar, tobacco, hemp, vegetables and fruits of every kind; in the richness and variety of mineral wealth, the grandeur and value of its forests, its inexhaustible quarries; in a word,—in all the natural resources which conspire to increase the wealth and power of a people, the bounty of Providence has been most wonderfully manifested.

"The stream which, in every direction, penetrates this favoured region, and is the grandest natural feature of North America, holds in its embrace the destinies of the American people.

"It is the great arterial system of this Republic. . . . . Through its copious channels, for all time to come, are destined to circulate the sustenance and abundance of its people.

"The commerce of this great empire will, in time, certainly exceed that of any other in Christendom; and the mouth of the great river constitutes the only natural gateway through which the immense products of that region will henceforth find their way to the various nations of the earth."

The Jetties were completed in 1876, and a channel 22 feet in depth obtained at a cost of 5¼ millions. And what was the result of this effort to divert export trade from the line of domestic transport? It is shown in the following report of the movement of cereals for the year 1896, twenty years after the completion of this great work:

Shipments of Grain, Flour and Meal (in bushels at 4½ bushels to the barrel) for all the principal Atlantic and Gulf Ports for the year 1896:—

	Wheat and Flour.	Corn.	Oats and Barley.	Rye, Pease and Meal.	
Atlantic Ports	94,800,591	83,174,471	37,872,514	4,964,032	220,811,608
Montreal........................	14,429,307	6,795,104	2,965,571	2,503,544	26,693,526
New Orleans (Mississippi River)	5,056,530	25,292,502	262,143	17,700	30,628,875
Galveston (Railways)..........	3,693,371	6,222,282	....	....	9,915,653
	117,979,799	121,484,359	41,100 228	7,485,276	288,049,662

These are facts the significance of which cannot be overlooked in determining upon the proper route for a trade outlet such as we require. It cannot be claimed that the United States Atlantic ports draw this trade from their Gulf ports entirely on account of the shorter ocean voyage to Liverpool, for, if this was a very potent factor, why is Montreal so far behind in export shipments? It is miles nearer Liverpool than New York, and has the St. Lawrence and Welland canals, with a depth of 9 to 14 feet, to help it, as compared with the Erie Canal of only 6½ feet effective depth. Is it not because the largest centres of domestic consumption, trade and commerce are found in the Atlantic States of the Union, and not in Eastern Canada or the Gulf States? There can hardly be any doubt that this is the controlling factor in determining this problem.

It seems quite clear, therefore, that "the line of export trade is determined by the line of domestic trade," and we must bear this in mind in considering the question of an outlet for our products.

As Eastern Canada grows into a manufacturing centre it will become to us what the Eastern States have become to the Western, the centre of domestic consumption, and our trade outlet and inlet should be located where it will enable us to reach that manufacturing centre in the cheapest manner possible.

The Canadian Pacific Railway will always be able to dictate terms to any railway to Hudson's Bay, and has nothing to fear from competition in that direction. Its main line and branches penetrate the richest and most productive portion of Manitoba and the North-West Territories, and its haul from a common point of deflection, say Portage la Prairie to Hudson's Bay and Lake Superior, is but little over half the distance to the Bay. At Lake Superior it finds a water route to the consuming centres of Canada and the United States, and to the ports of Montreal and New York. It has connections on Lake Superior with one of the largest mercantile fleets in the world, and lower rates of freight to Buffalo and Port Colborne, than are charged for a corresponding distance even on the ocean.

These facts should convince us that our requirements would be best served by securing cheaper freight rates to Lake Superior points, where connection by water with ocean ports and all the requirements for prompt handling of a large domestic and export traffic are already established.

Any other route than this will always receive the active opposition of Eastern Canada, and we may as well take it for granted that the spirit which prompted our people there to undertake and carry to completion the gigantic task of building the Canadian Pacific Railway will be exerted in the strongest possible manner to prevent the loss of trade to them which the railway was intended to promote. It will be wise, therefore, for us to endeavor to gain their sympathy and assistance in accomplishing our object to secure lower freight rates.

The only schemes having Lake Superior as an outlet that have received any degree of attention are a railway to Duluth, and the

Manitoba South-Eastern Railway and connections to Fort William, now under construction. The latter is being aided by our Provincial Government, with the avowed object of securing a reduction on wheat to 10 cents per 100 lbs., or 6.2 cents per bushel from Winnipeg to Fort William. This will be a step in the right direction, and will prove a great boon to the Province and North-West Territories if the proposed road gets any of the wheat. But it must be remembered that Winnipeg is the Eastern extremity of the wheat growing districts, that the Canadian Pacific and its connections, and the Northern Pacific, both having outlets on Lake Superior, are the only lines which penetrate those districts and collect traffic; that the only district likely to benefit materially by the construction of this outlet will be that served by the Dauphin Railway, which is under the same management; and that under existing laws there is no power to compel the other lines to transfer freight to a rival line to Lake Superior. Even if the Provincial Government succeeds in securing the construction of this line and the establishment of the 10-cent rate, there can be no guarantee that it will prove effective in fully accomplishing its object until western connections for the new systems have been obtained.

In regard to the line to Duluth, objections have been raised to grant Provincial aid to a railway to this port, on the grounds that it would divert Canadian trade into American channels, and build up American cities at the expense of our own; and our Government will be upheld by public opinion in deciding to concentrate their efforts in promoting the construction of the lines to Fort William in preference to Duluth. The construction of the Red River Valley Railway did not divert any traffic collected by the Canadian Pacific Railway to the south, and had it not been for the construction of the two branch lines to Portage and Brandon, the traffic over the main line from Winnipeg to Emerson would not pay operating expenses. The net earnings for main line and branches for the year ending June 30, 1897, were less than $12,000.00. In the preceding year they were less than $3,000.00. The experience of this competing line does not afford much encouragement for the investment of capital in a third railway from Winnipeg to Lake Superior, and nothing but public aid of a most unusually liberal character could have induced Messrs. MacKenzie & Mann to undertake its construction. But granted that the desire of the promoters is fulfilled, and that 10c per 100 lbs. on grain becomes the railway rate from Winnipeg to Lake Superior points,—granted also that rates from points west of Winnipeg are not increased by way of compensation for this reduction, there still remains the fact that the traffic must all be handled by rail. And there is a limit below which railways in this country cannot haul in its present conditions, and the present volume of traffic, without absolute loss.

But given a largely increased trade, especially in westbound traffic, then lower rates on our products can be profitably given. This west-bound traffic can only be secured by a large increase in our population to serve as consumers for the manufactures and merchandise which must come from or through Eastern Canada. It results, then, that, even with a ten-cent rate on grain from Winnipeg to the Lakes, heavy rates on transportation generally will still confront us until the country is filled up with a large population, while the growth of population is itself retarded by the continuance of high rates.

Is there no other way of reaching a solution of the difficulty, one that will lead to a general lowering of freight rates between points far west of Winnipeg and the Lakes? The writer ventures to say that there is, and that this solution is to be found in the development of navigation on the numerous rivers and lakes between Lake Superior and the far West; in other words, the writer believes that a magnificent system of waterways is capable of being opened, at a reasonable cost, that will reach from the Lakes to the farthest bounds of the rich prairies of Manitoba and the Territories. We have been singularly favoured in possibilities in this respect. Probably no such extensive territory in the world apart from the St. Lawrence and Mississippi valleys is possessed of such advantages for furnishing cheap transportation facilities as our vast prairie stretches.

A most important feature at the same time in connection with these rivers and lakes is that they are all located on the line of our domestic and export traffic routes.

Between Fort William and the Red River, a distance of 453 miles by the old Dawson Route, we have actually 305 miles of navigable waters. The remainder of the distance is made up of 40 miles of land between Fort William and Lake Shebandowan; seven miles in several short sections between this lake and Fort Frances; and 101 miles from Lake of the Woods to Winnipeg. This route is practically all within Canadian Territory; a portion passing through the Lakes and Rivers on the International Boundary. Its establishment would assist in reclaiming and developing a portion of this Province east of the Red River, as well as an extensive part of the Province of Ontario rich in minerals, timber and agricultural lands. It would carry our products to a Canadian port, and build up a second Duluth and Superior at Fort William and Port Arthur.

On the first section of 40 miles between Fort William and Lake Shebandowan we encounter the only serious obstacle to connecting Lake Superior with a stretch of navigable waters, or waters capable of being rendered navigable, reaching almost to the foothills of the Rocky Mountains. The bare possibility of establishing continuous navigation from our most westerly prairies to the Lakes suggests such stupendous advantages that it is surely advisable to consider earnestly whether this serious obstacle may not be overcome.

The total rise in this section of 40 miles is 863 feet, and to ascertain whether a feasible route by water can be established over it will require very careful examination by competent engineers. It was examined by Dawson, and he reports as follows (1869):—

"As may be supposed, the streams running down from such a height in so short a distance have a very rapid course, and as a consequence could only be rendered navigable at an expenditure which, whatever the future may require, is quite out of the question for the present."

This opinion was written when the Government of the day was first endeavouring to open up the cheapest possible line of communication between Eastern Canada and the West, and when our public men had no conception of the development that has since taken place. The question of an outlet for our surplus products was not then at issue.

It will perhaps be found on making surveys that the greater portion of this rise can be overcome by the use of pneumatic lift locks such as have been proposed for the ship canal around Niagara Falls, and are now under construction on the enlargement of the Erie Canal at Lockport, N.Y. Or a feasible route for a ship railway might be found over which barges with their cargoes can be transferred between Fort William and Lake Shebandowan.

The distance from Lake Shebandowan to the north-west angle of Lake of the Woods is 312 miles, all deep navigable water except about seven (7) miles in ten sections; three of which are each two miles in length, and the remainder from 10 to 12 chains each. The total lockage is about 463 feet, made up of 29 feet up from Shebandowan to Kashaboiwe, and 434 down to Lake of the Woods, an average of only 1.48 feet per mile. The Rideau Canal has 457 feet of lockage in 126 miles, an average of 3.63 feet per mile, so that, in proportion to the distance, the section under consideration requires but little over one-third the lockage of the Rideau Canal.

The Erie Canal from Lockport to Albany, a distance of 321 miles, has a total lockage of 655 feet, or 2.04 feet per mile, while on this route from Buffalo to Albany, 352 miles, there is about 270 miles of canal and 82 of canalized river, as compared with 7 miles of canal and 305 miles of wide and deep lakes and rivers on the Dawson route, giving the latter a tremendous advantage in capacity and in the speed at which boats may travel.

The Welland Canal, between Lakes Erie and Ontario, has 327 feet of lockage in 27 miles, or over 12 feet per mile. The St. Lawrence canals from the head of Galops Rapids to Montreal have a total lockage of 220 feet in 110 miles, an average of two feet per mile.

From these figures it will be seen that this, the longest section of the suggested route, has a decided advantage in lockage and capacity over any of the important canals mentioned.

The accompanying profile, constructed from information derived from "Dawson's Reports," and "Upham's Altitudes," shows approximately the elevation of the different lakes, etc., on this route. Some of these levels were altered by the improvements made in 1872, especially near the summit, and might be still further improved by raising the waters of Lac des Milles Lacs and Shebandowan so as to lengthen the navigable reaches and avoid construction of locks in that portion of the route.

Of the character of this section of country and its suitability for navigation, Dawson, in his report of 1868, writes:—

"Westward of the Height of Land on the streams tributary to Rainy Lake there is a section of country remarkable from the fact that a very considerable portion of its area is occupied by lakes. Those on the various routes which have been followed are set down on the annexed map, but these give only a faint idea of their number. Every river and rivulet has its lakes. Go in whatever direction he will, the explorer, on passing over a mountain range, is sure to stumble on a lake. . . So numerous are they that it would be difficult to say whether the country would be better described as one vast lake with ridges of land running through it, or a land intersected by water. . . . Such a region is but ill-adapted for railways, but nature has made up for the deficiency by providing such means for canals as rarely exist. Between the hills and the mountain ranges there are long reaches of tranquil water, which could be connected together by means of lock and dam, with but little excavation. . . . A very marked characteristic of the region is that the streams are not subject to sudden or considerable floods, and this is a feature which the engineer who has to provide for waterworks of whatever description will look upon with unmixed satisfaction. . . . The lakes are everywhere studded with wooded islands, and so sheltered that the smallest canoes are seldom windbound."

And in his report of 1869:—" Between the Height of Land and Rainy Lake the lakes are so numerous and so large that it would be difficult to say whether land or water predominates. The lakes, however, afford the means of making a very good water communication at a moderate outlay.

" From Fort Frances to the north-west angle of Lake of the Woods the navigation is uninterrupted, save by two little rapids (Manitou and Long Sault), easily overcome."

It is quite evident, therefore, that on the section between Lake Shebandowan and the north-west angle a navigable route can be opened at a very moderate expense by following the old Dawson Route.

Recent discoveries, however, of large gold-bearing districts along the Seine river, and immense deposits of high grade magnetic iron ore on the Antikokan river, render it advisable to seek an outlet in this direction from Rainy Lake to Lac des Milles Lacs. This latter route was also examined by Dawson, but abandoned for the one bearing his name for certain reasons which may not be applicable now. In his 1869 report, he says:—

"Two routes have been followed from Lac des Milles Lacs, one by its discharge, the River Seine, and the other by the old Canoe Route. . . . Either route can be made practical in the manner I have recommended for the Seine, at a moderate outlay, but, after duly weighing their respective advantages, the old Canoe Route will be, both as to economy of work in rendering it available, and facility of managing and navigating it afterwards, the best."

The amount of local traffic, however, which would now be tributary to the Seine River route, and the assistance its improvement would give in developing this rich district, point to the necessity of further examination, with a view to its possible adoption in place of the Dawson route, for the business it would develop compared with the other would perhaps warrant a larger expenditure to open it up. In distance, too, the Seine River route has a slight advantage over the Dawson. Between two common points, Fort Frances and Brule Portage, the distance by the Dawson route is 133 miles, and by Seine river 125 miles. In this 125 miles there are four miles longer sailing through the deep water of Rainy Lake than by the other route, all of which helps to shorten the time of the through trip. The Seine river route is entirely through Canadian territory, while a portion of the other passes through the rivers and lakes on the boundary, and in adopting the latter we would open up American territory at our expense. For these reasons, therefore, the Seine river route should be carefully examined, and adopted if at all feasible.

In addition to its other advantages, a large revenue would no doubt be obtained from the mines because of the power which can be developed at the various falls and transmitted by electricity for use in them, and in tramways connecting them with the canal.

At Fort Frances the Dominion Government has already constructed a basin for a canal and lock to overcome the 23 feet fall in the Rainy River at Couchiching Falls. This basin is 800 feet in length, and the lock 200 ft. by 36 ft., with 7 ft. of water on the mitre sill. This work was commenced in 1875, and stopped in 1879, when it was reported to be ready for the lock gates. Nothing appears to have been done to it from that time until the present, but it is understood that the Government is now about to complete it, and also the work of removing boulders and obstructions at the Manitou and Long Sault Rapids on Rainy River.

The next section to consider is that between Lake of the Woods and the Red River. There are four routes by which this connection could be made: (1) the Winnipeg River; (2) the Rousseau; (3) the north-west angle to Winnipeg via Seine River Valley; and (4) that via Reed River, Whitemouth Lake and River and the Seine Valley.

In choosing the best location for this section of the route it will be necessary to take into consideration the navigable connections west of the Red River. It should be located, not necessarily on the cheapest line for construction, but on the most direct, for saving of time in passing through the canal to Lake of the Woods is of greater importance and represents a greater saving in transport charges than the interest on additional capital expended in first cost of construction. It is very probable, however, that in this case the shortest route will be found to be the cheapest to construct, and without doubt the cheapest to maintain and operate. For these reasons the two last-named routes (3) and (4) only will be considered. They form the most direct route to the mouth of the Assiniboine river, which may be considered the trunk line of communiaction from the west, because upon it can be converged water routes traversing for hundreds of miles the most productive and thickly populated portion of Manitoba and the North-West Territories.

Route No. 3, from the north-west angle of the Lake of the Woods, is about 101 miles in length, and the fall to the Red River is 337 feet. The first 24 miles from the north-west angle passes through a low, swampy country, which is comparatively level, so that it may be found possible to excavate a channel without locks connecting with the Whitemouth river. This river would then be followed for six miles to the line between Ranges 12 and 13 east of the Principal Meridian. Thence the route would follow a direct line by lock and canal 27 miles to the Seine River, concluding with 44 miles through the Seine River Valley to its junction with the Red River at Winnipeg.

Route No. 4, via Reed River, will have Buffalo Bay as its harbour on Lake of the Woods. Entering the Reed River the course of that stream is followed for several miles, thence to Whitemouth Lake, and passing through it and Whitemouth River to the point where Route No. 3 strikes that stream; from that point to Winnipeg it will follow Route No. 3. This route will be some eight miles longer than No. 3, but it may prove much cheaper to build, following as it does the courses of rivers and lakes to a greater extent. The sailing distance across Lake of the Woods is, however, about 14 miles shorter to Reed River than to North-West Angle; thus giving a saving in distance from the mouth of Rainy River to Winnipeg of 6 miles in favour of the Reed River route, No. 4.

The construction of a canal across this portion of Manitoba will drain a large section of the Province, which is now almost impassable, owing to the numerous swamps which cover its surface. It has a considerable growth of timber suitable for fuel, lumber and railway ties, which would find a ready market in Winnipeg, where it could be delivered very cheaply on barges, but which is now inaccessible to it, owing to the high cost of transportation.

Dr. Dawson, of the Geological Survey, describes part of the district as follows:—"That part of the country east of the 6th Range of Townships is more or less swampy, with occasional tracts of dry land; these swamps and muskegs are as a rule very shallow, and might be easily drained. The water shed dividing this section of country from Lake of the Woods is within a few miles of that Lake, and is only 12 feet above it. There is a fall from the water shed to the western limit of this section of 220 feet, but a very small proportion in its present state is fit for tillage, though if drained at least one-half will be found to have a rich and productive soil, in many places equally as good as that west of Red River. The chief present value of the region, however, seems to be as a reserve for fuel and timber for construction for the more fertile land bordering the Red River."

This is the final link to connect Red River with Lake Superior, and an examination of the profile will show the amount of lockage to be overcome, and the general character of the route. It has been shown from the testimony of competent men that it is an entirely feasible route, and that it has an abundant supply of water at all summit points for the operation of locks sufficient to carry a very large traffic; that it will give easy access to immense mining and timber districts; that it will be a reasonably cheap route for construction, as in the total distance of 453 miles, 305 miles are now navigable streams or lakes, and only 148 miles, one-third of which follows natural water courses, requires canalization. It will furnish numerous water powers to grind wheat in transit, and it is reasonable to assume that at such points flourishing communities will be established, as has been the case at similar places on the Erie, Welland and St. Lawrence Canals.

The open season for navigation over this route is given in the Public Works Report for 1882, as extending from May 15th to October 20th; but in the same report, page 651, an account is given of the transportation, late in the Fall of 1871, of Wolseley's Expedition, a fact which is still fresh in the minds of many Manitobans:—

"The force assembled in Collingwood on October 20, and reached Lake Shebandowan on the 26th, the first detachment of boats leaving there at midday on the 27th. The season was very far advanced, some of the boats and steam launches had been laid up for the winter, and thin ice had formed on some of the smaller lakes. But by great exertions the force was hurried through, and arrived within 10 miles of the North-West Angle on the 12th of November.

Here the ice had formed so solidly that it was impossible to get the boats through it, and the men had to march to the shore over the ice."

Now, if such an undertaking could be accomplished at this late season, when there were no boats moving to keep a channel open, can it be doubted that a fleet of boats, continually moving over the route, propelled by steam, would without difficulty keep it open until the 15th of November at least, which is within a few days of the closing of navigation on the St. Lawrence east of Montreal. The Erie Canal is by such means frequently kept open a week or ten days after neighbouring waters are frozen up. The Sault Ste. Marie Canal is usually open from May 3 to December 3, so there would be only 18 days' difference in the open season between it and this proposed water route; but it is eighteen days of very valuable time, and if there is the same rush on the water route during this period as there is on the Canadian Pacific Railway to get the grain forward before close of navigation on the Lakes, the open season on it may, in most seasons, be still further prolonged.

Feeders from the West.

Having described the possible routes for a continuous waterway between Winnipeg and Fort William to serve as an outlet from the prairie country to the Lakes, attention will now be directed to the wonderful system of rivers and lakes that traverse all parts of the Western country, and an endeavour will be made to show how they can be united to form a vast system of waterways, reaching out for hundreds of miles north, south and west, penetrating the most productive and thickly populated portions of the Province and Territories. Such a system of waterways would furnish feeders to the outlet described, just as the network of railways west of Winnipeg now serves as feeders for the railway outlets to the east and south. But they would be vastly more valuable than a line of railway, as their capacity for the transportation of grain and heavy bulk cargoes would be several times over what any single line of railway could carry, while profitable freight rates over them should bear about the same proportion to railway rates as they do in other countries.

The Red River.

This river is now practically navigable from a point considerably south of the International Boundary to Winnipeg, but it would no doubt require improvement at some points to make it suitable for general use. It should attract considerable traffic from the northern part of the state of Minnesota, as well as from southern Manitoba, and it should have a considerable influence over traffic rates from the Mennonite settlements, one of the largest grain-producing districts in the Province.

By the extension of the railway lines of Southern Manitoba to the river banks and the establishment of elevators for transferring cargoes to barges, the rail haul would be reduced to a minimum, quick return of cars to congested points would be possible, and the result would be beneficial alike to producers and railway companies. The latter particularly should benefit by such an arrangement, as the present equipment of cars and engines would be more regularly employed in hauling paying loads, while the unprofitable business of hauling long trains of empty cars from Fort William or Duluth as far as Red River points in Manitoba would be avoided. Grain trains unloading at river ports would very soon get return loads of lumber and bulky freight for interior points, for it is tolerably certain that on completion of the canal between the Red River and Lake of the Woods, the principal lumber industry of the Province would be established on the river, and St. Boniface would be to Manitoba what Tonawanda is to the State of New York, the great centre for the storing and distributing of the products of the forest.

The Red River north of Winnipeg can hardly be classed as a feeder to the outlet to Lake Superior, but no description of our western waterways would be complete without a reference to it and Lake Winnipeg.

During high water it is now navigated by small steamers to Selkirk, where connection is made with the larger steamers sailing on Lake Winnipeg. The only obstruction on the river which prevents large steamers and barges sailing up to Winnipeg is the St. Andrew's Rapids, and to overcome these a somewhat expensive dam and lock are necessary, but the benefits its construction would confer on the chief city of the Province and a large section of Eastern Manitoba would fully warrant the necessary outlay. It would give an immense impetus to the speedy development of the great natural resources of Lake Winnipeg. In connection with the western system of waterways about to be described, it might bring the iron ores of Lake Winnipeg and the coke of the Crow's Nest Pass mines within profitable reach of each other,and promote the establishment of iron industries in the Province.

Lake Winnipeg is 280 miles long by an average of 35 wide. Its principal resources are lumber, cordwood, fisheries, which are worked very largely, sandstone and limestone. Iron ore is found on Black Island. Several gold discoveries have also been found recently near Hole River.

The Assiniboine River.

This great river flows directly through the central portion of the Province; it passes the town of Portage la Prairie and City of Brandon; a country rich in agricultural possibilities is tributary to it; and with its tributaries, the Souris and Qu'Appelle, the most thickly populated and fertile portions of the Province are reached. The two latter streams at their lowest discharge have sufficient water to supply all the locks that would be necessary to make them navigable. Their average fall per mile is low, and but few dams and locks would be required on them compared with many streams which have been improved elsewhere. The Assiniboine is the most important of these three streams, and, in the early days of settlement in the Province, it was navigated by large steamers for two or three months in the spring and early summer. It played an important part in transportation as far as Fort Ellice until the advent of the railway, and will do so again when it forms part of a continuous waterway to Lake Superior. It has a large and constant flow, and its low fall of about a foot and a half per mile makes it an easy and cheap stream to convert into a navigable one throughout its entire length to the mouth of the Qu'Appelle at Fort Ellice. There is no doubt that these three streams can be converted into great arteries of trade and commerce at much lower expense than it would cost to construct and equip a single track railway, and, as already stated, their carrying capacity would be considerably greater, as it only requires two barges similar to those in use on the old Erie Canal to carry as much grain as a train of twenty-four (24) cars holding 666 bushels each.

The principal objection which can be raised to the use of these rivers as navigable channels is the excessive distance the present rivers traverse in their course. They are all very crooked, and wander from side to side of their valleys, covering probably from two to three times the distance of a straight line between any two points; but the very same causes of this peculiarity in these streams can be utilized in making them straighter, that is, the solubility of the soil in the valleys, which is extremely susceptible to the action of water, and is generally speaking free from boulders or hard pan. An ice-jam in spring will sometimes divert the stream from its old bed to an entirely new one, a feature which will render it necessary to exercise care in the selection of sites for dams and locks, and to take precautions to confine the river during its highest flood to its proper channel.

By far the greater number of the larger bends in the river can be got rid of by excavating a deep narrow ditch across the neck of land at their base so as to allow the flood waters in spring to pass through it. It is an axiom that water hates angles, and it might be added in this case sharp curves; and one season's flood is usually sufficient to excavate a channel along the line of the ditch through which the whole flow of the river will pass. This method has already been successfully employed at several points on the Assiniboine between Winnipeg and Portage la Prairie, and the writer adopted it to straighten a large bend in that river where it is crossed by the

Manitoba & North-Western Railway at Millwood. This plan of straightening the river reduces its length, and consequently increases the current; this, however, would be overcome by the construction of dams where necessary to convert the river into slack water stretches. It is estimated that the length of the Assiniboine River between Winnipeg and Fort Ellice can be reduced from 400 miles to about 300 miles.

The Qu'Appelle River.

From its junction with the Assiniboine to the mouth of Big Cut Arm Creek, the Qu'Appelle River has a width of 70 to 90 feet, and is from 8 to 12 feet deep, with a current of about 1½ miles per hour. From Big Cut Arm to Round Lake its width varies from 70 to 100 feet, and its depth from 2 to 4½ feet, the bed being soft mud, and free from boulders except at the rapids near Round Lake, where it is filled for about 100 yards with large and small granite boulders.

Commencing at Round Lake and going west is a succession of lakes, all wide, and varying in depth from 20 to 60 feet, and all connected with water courses, which can easily be made navigable by lock and canal. The total distance from the mouth of the Qu'Appelle to Eye-brow Lake, the most westerly one on the river, is about 254 miles, and the rise is 421 feet, an average of 1.65 feet per mile. About 8 miles west of Eye-brow Lake the height of land is reached at an elevation of 19 feet above that lake. This ridge is all that separates the Qu'Appelle river navigation from the South Saskatchewan, which turns abruptly to the north opposite the lake. The distance from the height of land to the Saskatchewan is about 10 miles, and the descent is about 85 feet.

Between the crossing of the Regina & Long Lake Railway and the Saskatchewan, about 98 miles, there may be some difficulty in maintaining a system of locks and canals, owing to the absence of a sufficient supply of water. A careful survey and study of local conditions may, however, produce some means of solving the difficulty. There is always one way of doing so, if less expensive plans fail, and that is by connecting these two rivers; and the importance of doing so might easily be sufficient reason for adopting it. It will be comparatively easy to open a channel right through the dividing ridge, as its greatest depth, and that for a short distance only, would not exceed 90 feet. The waters of the South Saskatchewan would then flow through the Qu'Appelle Valley, as it is believed they did in past ages, and continuous navigation would thereby be established between Lake Superior and the foot-hills of the Rocky Mountains.

The South Saskatchewan.

The question of the navigability of this great river appears at one time to have been in doubt, but Prof. John Macoun, in his book, "Manitoba and the Great North-West," writes:—

"While exploring the great Buffalo Plains in 1879 I was particular to make enquiries regarding the navigation of the South Saskatchewan, and in my report to the Government for that year made allusion to it in the following words:—'We pitched our camp on the hill-top, about a mile and a half from the river. . . . Below us lay the mighty Saskatchewan, rolling its turbid flood between banks 250 feet high, seeming altogether out of place in this arid region. The river at one crossing was 770 yards wide, and the main channel, over which our horses had to swim, was not less than 500 yards. Shoals and sand bars were numerous, but nothing to indicate that the river at this point was unsuited for navigation.'" Prof. Macoun continues:—"Why the south branch should be thought unfit for navigation I cannot understand. Mr. Hind, who passed down this river in August, 1858, never speaks of its depth as being less than seven and a half feet, and the current is never more than three miles per hour, except when close to the north branch. . . . When on the plains I never heard of this river being fordable below the mouth of the Red Deer River. . . . When at the Blackfoot crossing of Bow River, a branch of the South Saskatchewan, 27th August, 1879, I found that it was with the utmost difficulty horses could cross without swimming. No person ever mentions a rapid being anywhere in the river below this, so that I have come to the conclusion that there is nothing to prevent all the supplies wanted for the South-West being sent up the South Saskatchewan.

"Coal is abundant in the river banks at the Blackfoot Crossing, and further eastward, so that there will be no difficulty as to fuel for steamers. Should the attempt be made to navigate the river it will be found to have better water for a longer period than the North Saskatchewan, as its head waters drain a greater extent of the mountains.

"Further on in the same report I say:—'In my Journal I showed why I believed the South Saskatchewan was navigable, and I now reiterate the statement after a careful review of all said for and against it. When its navigation is an accomplished fact all supplies for the Police and Indians can be taken to within less than thirty miles of Fort Walsh and Cyprus Hills, and those for Fort McLeod landed at the Forks of the Bow and Belly rivers within two short days of the Fort. Here (at the Fort) is abundance of coal (Galt coal mines) so that there will be an ample supply of fuel for all purposes. . . . If the coal deposits can be developed by this means, all the prairie land seen by me will become in the course of years thickly settled with a prosperous population, as there is no physical defect in the country but the want of wood.'"

Assuming then, that, after connecting the Qu'Appelle and the South Saskatchewan rivers, no further obstructions to navigation exist so far as Medicine Hat, 280 miles distant, that point may at first be chosen as the terminus of navigation for convenience of the railway connections. The distance by rail from the Anthracite Coal mines is 257 miles, from Lethbridge 113, and from the Crow's Nest mines 218 miles. The coal shipments to the east can be concentrated at Medicine Hat, and by means of steamers and barges can be delivered at points in Eastern Assiniboia and Manitoba at a cost which will never pay the railways to haul for, but which will be remunerative to vessel men and economical to consumers.

The Souris River.

Not much about this river is known to the writer beyond the fact that it flows through a very fertile and thickly populated part of the Province, and by its means a short railway connection with Estevan and the Souris coal fields may be established. As to the possibility of rendering it navigable for barges, there does not appear to be any doubt. Professor Hind describes it briefly as follows:—"The Souris or Mouse river joins the Assiniboine 140 miles from Fort Garry, by the windings of the river. . . . At its mouth the Souris is 121 feet broad and three feet six inches deep in the channel, and a current of half a mile per hour. . . . Near Snake Hill, 61 miles from the outlet, it is 100 feet wide and four feet deep in the channel. Near the Hudson's Bay Co. house (near Hartney) found extensive deposits of bog iron ore, capped by shell marl covered with drifted sand. The river is 25 feet broad and very shallow, flowing 20 to 25 feet below the general level of the prairie."

Prof. Macoun adds to this:—"From the foregoing it is obvious that in general the river is quite deep enough for river steamers, and should the rapids, which are said to exist some distance above its mouth, be found passable, another 100 miles will be added to the river navigation."

Prof. Macoun's idea was evidently confined to the probability of its being navigable without improvement, and it is reasonable to assume that by means of locks and dams navigation may be extended as far as Melita, if not further. From Melita to the Estevan coal mines the railway haul is only 98 miles, so that in addition to regulating the rates on grain from this portion of the Province, its improvement would result in a great reduction in cost of delivering coal in the Province as far east as Winnipeg.

Northern System of Waterways.

Eighteen miles north of the Assiniboine at Portage la Prairie lies Lake Manitoba, 120 miles long and about 24 miles in extreme width.

Among the natural resources of this lake may be mentioned its fisheries, limestone of excellent quality, and, in almost inexhaustible quantity, spruce lumber and cordwood. Gypsum of exceptionally good quality is found in immense quantities about nine miles east of the lake north of Fairford. Lake Manitoba is 14 feet above the Assiniboine river at the mouth of Long Lake, and, by following the course of this last-mentioned lake and its creek to the west, connection from the Assiniboine can be made with Portage Creek, a wide sluggish stream on about the same level as Lake Manitoba. A channel dredged through the bar at the head of Portage Creek will give access to the lake. One lock may be necessary to maintain the level of water in Lake Manitoba.

At Meadow Portage the head of Water Hen river is found the next obstruction. This narrow neck of land separates Lakes Manitoba and Winnipegosis, the latter being about 19 feet above the former; two locks and a channel two miles in length is all that is required to connect these large bodies of water.

Lake Winnipegosis.

This lake is about 100 miles long and 12 to 15 miles wide. Prof. Macoun describes it as follows:—

"The general appearance of this lake is much finer than that of Manitoba, as there is little or no marsh, except at the southern end . . . . Numerous islands are a marked feature, and sandy beaches are much more common than on the other lake. . . . As we proceeded up the lake the country constantly improved. The shore marshes became less and less, and finally disappeared; in their place beaches of white limestone glittered in the sun, and fine forests came down to the beach. The timber increased in size, and at Pine River spruce of large size were abundant. On the various islands were very large elms, and mountain ash over ten inches in diameter were frequently seen.

"Duck Bay is noted for its brine springs, which are said to be of considerable extent. These are situated between two rivers which issue from Duck Mountain, and are only five miles off; about six miles south of the salt springs in the direction of Mossy River are springs said to be as good as those where the salt is made. Large salt springs occur at a point about seven miles from Water Hen River on the east side of Lake Winnipegosis.

"As we went north the richness and the luxuriance of vegetation increased; the banks became higher, and the forest trees of larger size. Many exposures of rock were noticed around Dawson's Bay. . . . .

"The northern end of Lake Winnipegosis is filled with lovely islands, which are margined with fine drooping elms of a large size. The sail across Dawson's Bay on a lovely day in July reveals more natural beauties than I ever before beheld on our inland waters. Green islands with white sand or gravel beaches, covered with drooping elms or other fine trees; the mainlands rising gradually up from the water, covered with an unbroken forest of tall poplar, intermixing with the gloomy spruce, deep bays backed with the distant forest, and high over all the steep escarpment of the Porcupine mountains form a picture as seen from the Lake which has few equals in any part of the world."

In addition to salt, timber and limestone, this lake numbers amongst its natural resources fisheries of very large proportions second to none in the Province.

Immediately south of Lake Winnipegosis lies Lake Dauphin, with which it is connected with Mossy River. This river is over 100 feet wide, but shallow in depth. The banks are from two to fifteen feet high, which would indicate that no difficulty would be experienced in making it navigable by means of lock and dam. Dauphin Lake is only eleven feet higher than Winnipegosis; it is 30 miles long and 12 wide. It is very shallow, and it would be necessary to dredge channels to reach the shore.

Immediately west of Lakes Dauphin and Winnipegosis lie the famous Dauphin and Swan River districts, and the opening of an inland waterway to their borders would prove of great value to them.

The North Saskatchewan.

Four or five miles north of Lake Winnipegosis lies Cedar Lake, an enlargement of the great Saskatchewan. The water level in each is practically the same, only varying a few feet during flood seasons. The barrier between them is practically a swamp, and the greatest elevation at the lowest crossing is about 43 feet. All that is necessary then to connect our system with Edmonton, 800 miles to the west, is a channel 4 or 5 miles long, with a guard lock to control the waters of the Saskatchewan in time of flood, and to prevent its flowing into Lake Winnipegosis.

In 1882 five large stern wheel steamers were in service on the North Saskatchewan between Grand Rapids and Edmonton. It was navigated with considerable difficulty at some points, owing to the presence of boulders in the channels, as well as several rapids, but it was estimated by competent authorities at that time that for a sum of $50,000.00 most of these obstructions could be removed, and a safe channel be provided. About $30,000.00 was spent on the work by the Federal Government under the supervision of the Hudson's Bay Co. in 1884, so that it cannot require more than twenty or thirty thousand dollars additional to complete the work and make this great river safe for navigation.

The average fall of the river is about 1½ feet per mile; the difference in elevation of Cedar Lake and Edmonton being 1,200 feet.

The country traversed by this river is as yet sparsely settled, owing to its inaccessibility from existing railway lines, which touch it at two points only, Edmonton and Prince Albert. But at both these points large settlements exist, and they are being rapidly filled up. In its suitability to sustain a large population this immense district is second to none in the whole North-West. It is well watered by numerous streams, and has an abundance of timber within easy reach, while its soil is rich and fertile. Lignite coal of superior quality in almost inexhaustible quantities is found near Edmonton, which, by means of this river, could be marketed along its whole length at remunerative rates.

To summarize, it has been shown that, for the purpose of feeders to the canal from Winnipeg East, there now exist west of Winnipeg the following rivers and lakes, which are capable of being improved and connected together as navigable routes for steamers and barges:

	Miles.
Feeders:—	
Red River	100
Assiniboine River	300
Qu'Appelle River	278
South Saskatchewan to Medicine Hat	280
Souris River	100
Long Lake and Portage Creek	27
Lake Manitoba	130
Lake Winnipegosis	120
Lake Dauphin and Mossy River	45
Great Saskatchewan and North Saskatchewan	800
Connections:—	
Red River north of Winnipeg	45
Lake Winnipeg	280
Total	2,505

These Lakes and Rivers are situated in the most fertile and thickly populated parts of Manitoba and the North-West Territories; they branch out in all directions, like a well-planned system of branch railways.

They touch nearly all the important traffic producing and consuming points now reached by railways, in addition to immense districts still open for settlement, and the announcement that the works necessary to utilize these great inland waterways were about to be commenced, works that are comparatively small in themselves but immense in their results, would mark the beginning of a degree of development in our fertile prairie country surpassing any expectations which have been hitherto entertained.

Dimensions of Locks in Proposed System.

This subject will be considered from the standpoint that nothing but a first-class up-to-date system shall be established. No old-fashioned small-dimensioned make-shift canals can compete with the modern railway of to-day. The lessons learned by the failure of the old barge canals to successfully compete with railways must be kept in mind when determining upon the dimensions of canal prism and locks for a water route of such immense importance to the future of our prairie country.

The old style of canal for barges carrying 100 to 200 tons has had its day, and while it accomplished wonderful things in securing cheap transportation it has been unable to hold its own against the aggressive spirit manifested by the management of the modern railway. Small boats, slow speed and horse flesh are no match for the powerful locomotive and cars of 30 and 40-ton capacity of to-day.

The modern canal, then, must have ample dimensions, and barges must be towed by powerful steamers. The Erie Canal, originally completed in 1836, had only a depth of 4 feet, admitting barges of 75 tons capacity; it cost $7,200,000.00. The first enlargement was commenced before the original canal was fully completed. It was enlarged to 7 feet in depth, admitting barges of 240 tons capacity, and cost $44,500,000.00. This was completed in 1862. A second enlargement is now under way, increasing the depth of water to 9 feet, and admitting barges of 400 tons capacity, the estimated cost of which is about $23,000,000.00. The total expenditure for construction on this canal, when the present plans are completed, will be close on 75 millions. The former cost of 52 millions was more than repaid to the State of New York in tolls and reduced freight charges, and since 1883 the canal has been free of tolls. It is claimed that during the past 30 years over 200 millions of dollars have been saved in transportation charges on grain alone shipped through this canal. The lesson to be learned from the experience of the Erie Canal, and a similar one from the history of our own Welland and St. Lawrence river canals, then, is to build our proposed canal of sufficient dimensions to admit barges carrying not less than 400 tons, to avoid the necessity of enlargement for many years to come, and the resulting increased cost which such work entails.

A depth of 9 feet of water will be required for boats of this capacity, and this is probably the maximum depth that can be obtained upon the rivers west of Winnipeg, and, while a greater depth can be obtained throughout the portion of the system east of Winnipeg, it may be considered advisable to maintain a uniform depth throughout the whole of the proposed system west of Lake Superior, and 9 feet will therefore be taken as the ruling depth of water.

It is customary on the Erie Canal for one steamer to haul three barges. The locks should therefore be built to pass two boats in tandem; and the boats would each be about 115x17½x8 feet. This general plan should be followed throughout the whole system, so that steamers on the rivers west of Winnipeg can pick up their tows at various loading points, and continue their journey through to Fort William without interruption.

Time consumed in Passage.

For this purpose Winnipeg will be considered the concentrating point for barges going east or west, as it now is for the cars on the railway systems, and the estimated time for a steamer and three consorts to sail to Fort William and return will be used as a basis to estimate what it should cost to transport a bushel of wheat or ton of merchandise between Winnipeg and Fort William by water. To arrive at these figures the present practise and expenses on the Erie Canal as used by Major Symons (see 1897 report on the proposed ship canal between the great Lakes and Hudson River) for estimating charges on the enlarged canal will be made use of, as they fairly represent conditions which will be found similar in general respects on the Winnipeg-Lake Superior route.

The distance from Buffalo to New York is 504 miles, and from Winnipeg to Fort William 453 miles. The former consists of 350 miles of contracted canal, and 154 miles of deeper and wider water in Hudson River. The latter consists of only 148 miles of contracted canal, and 305 miles of deep rivers and lakes; but the advantage which this gives to the Winnipeg-Lake Superior route in sailing time over the Erie will be partly counterbalanced by the increased lockage on the former. It will be fair, then, to assume that the time required by a four-boat fleet to make the round trip between Winnipeg and Fort William will at least not exceed that required between Buffalo and New York. Major Symons estimates that on the enlarged Erie Canal a fleet will make 9 to 11 round trips per season, but on account of the shorter season here one trip will be deducted, making the average, say, 9 trips, depending on the business management and despatch at terminals.

Estimated Expenses of Four-Boat Fleet (Symons' Report).

"Fleet 1 steamer and 3 consorts—1st class.—Steamer carries 300 tons, or 10,000 bushels; each consort 400 tons, or 13,333 bushels each. Fleet loaded, 1,500 tons, or 50,000 bushels by 9 equals 13,500 tons, or 450,000 bushels.

"Return freight, 1-3 loads miscellaneous, 4,500 tons, charges at Buffalo 1.3c per bushel of wheat. Estimated transfer charges at Buffalo 25c per ton on return freight."

(As similar transfer charges must be provided for at Fort William and Winnipeg, these figures will be used, but it should be possible to reduce the Buffalo charges to ¾c per bushel, and give a good margin of profit for transferring from barges to lake steamers, or 1c per bushel for transfer and 3 or 4 days' storage in elevators.)

" Steamer value..	$10,000 00		
Three consorts..	10,500 00		
		$20,500 00	
" *Season's Expenses:*			
Wages and subsistence of crews..			$ 3,174 00
Fuel, oil and waste..			1,962 50
Ordinary repairs..			225 00
Insurance on fleet..			255 00
Insurance on wheat..			1,012 50
Interest on investment at 6 per cent..			1,230 00
Depreciation, etc., at 6 per cent..			1,230 00
Miscellaneous..			150 00
			$9,239 00
" *Transfer Charges:*			
On 450,000 bushels wheat at 1.3c			5,850 00
On 4,500 tons of up freight at 25c..			1,125 00
			$16,214 00

" Assuming return freight reduced to wheat, there would be 450,000 plus 150,000 equals 600,000 bushels of wheat carried, and the cost of transportation, including transfer charges, would be 2.70c per bushel, or 90c per ton."

As all the items making up the expense of $16,214.00 per season are very similar to those which obtain here, with the exception of coal for steamers, it should be possible to establish a rate not exceeding 3c to 3¼c for carrying a bushel of wheat by water from Winnipeg to Fort William, and load it on lake steamers.

The present rate by rail is 15½c per 100 lbs., or 9¼c per bushel. The difference of 6c per bushel on 30 million bushels of wheat, which we will soon be exporting, represents an increased return of $1,800,000.00 per annum to the farmers of the North-West on this item alone—or capitalized at 4 per cent., a sum of $45,000,000.00, which is probably in excess of what it would cost to build the whole system of waterways that has been described.

On coal the freight by rail is now $3.00 per ton Fort William to Winnipeg. By water it should not exceed $1.00.

On lumber the freight by rail from Rat Portage to Winnipeg is $3.00 per 1,000 feet B. M. By water it should not exceed 60 cents per ton, or 40 cents per 1,000 feet B.M.

From the coal mines of the West and the forests of British Columbia, upon which we already draw largely, and would be glad to draw still more largely, for our supplies of fuel and lumber, similar results in reduction of freight rates may be expected. By means of the Ohio and Mississippi rivers coal is carried from Pittsburgh to New Orleans, 1,970 miles, at an average cost of 71 cents per ton. Why should we not get our coal from Lethbridge, Crow's Nest Pass and anthracite by rail to Medicine Hat, transfer it to coal boats similar to those used on the rivers mentioned, and which are sold for the lumber they contain at New Orleans, and secure the same rate for towing on the Saskatchewan, Qu'Appelle and Assiniboine rivers to Winnipeg, much less than half that distance?

Further comparisons might easily be made, but enough has been shown to illustrate the immense benefits which may reasonably be expected upon the opening up of this wonderful system of waterways, which is our national heritage; and the influence which it would bear upon the building up and development of our great Western country it would be impossible to over-estimate.

Canal Dues.

No allowance for canal dues has been made in the foregoing estimate for transporting wheat, coal and lumber.

This is a question which is open to discussion, and it is not intended to enter into it very fully here. But when we consider what a vast amount of money has been granted to aid the construction of private railways in the North-West, and is still being granted for extensions of our splendid railway systems, is it unreasonable to suggest that an equally liberal policy might be adopted in connection with the waterways. Over 44 per cent. of the paid-up capital of Canadian railways has been granted to them by the Federal and Provincial Governments and Municipalities.

The United States gives practically no public aid towards the construction of railways now, but spends millions annually in improvement of its inland waterways, which are free to all.

France, with over 8,000 miles of canals and improved rivers, abolished all tolls in 1880.

The State of New York abolished all tolls on the Erie Canal in 1883.

Having created the railways, we must now create something more effective than statutes to control them, and there is nothing that will do this more thoroughly than free waterways.

Having described a possible system of connected navigable waterways between Lake Superior and the far west, consisting of a main outlet east of the Red River, and a system of feeders throughout the west, branching out into all the important producing districts, the scheme, as outlined, will now be considered from the following standpoints:—

The Economic Results of the Extension of Waterways, and its Influence on Railways and Freight Rates.

These points have been very ably dealt with in a Monograph on Inland Waterways by Emory R. Johnson, published by the American Academy of Political and Social Science in 1893, and the writer cannot do better than conclude this paper with some extracts from this source.

"The influence of canals, improved rivers and lakes, as regulators of railroad tariffs, is a subject of interest alike to those countries whose railways are under private ownership and management and to those which themselves own the means of transportation. The control of rates on private railroads has presented to legislators a problem they have as yet been able only partially to solve. After sixty years of effort on the part of the English Parliament, first to prevent combination, then to secure reasonable rates, England has the highest railway charges of any country. The establishment of maximum rates by law is no guarantee of moderate charges. In this country the attempt to control rates by rail led to the vigorous attack of the Western States against the railroads by means of the 'Granger legislation.' This policy was soon abandoned, and the State railroad commissioners were given wider powers and increased functions. The State commissions having no power to lay down rules concerning charges on inter-state commerce, the national commission was established in 1886, with power to supervise interstate traffic, and to compel revisions of rates when charges are unreasonable, or when they are unfair to particular shippers. All this is evidence that some control over the administration of private railway companies and some regulation of their tariffs are considered necessary. The results of the commissions' efforts, whatever may be said of their value, and they are indeed important, have in no sense solved the question of rate charges.

"Only the threshold of the problem has been reached, and the investigations of the commission have only enforced the need and importance of inland waterways to set limits to railroad charges, and to exercise a constant pressure in the direction of cheaper rates and more efficient service.

"There is a vital difference between the railway and the public waterway. The lakes and large navigable rivers of every country are public highways accessible to all. Any shipper who will may navigate them with his own boats, and at present usually without payment. Canals owned by the State are likewise highways, either free or toll, and those owned by corporations or individuals are usually, at least in theory, ways on which individual shippers may compete. With the railway it is different; the conditions necessary to its successful management have, at least up to the present, prevented its being a highway open to the common use of individual shippers. As is well known, the railway was at first supposed to be of the same character as the turnpike. The first laws, both in England and in the American States, were framed with that idea in mind. It was not long before the error was discovered, and in 1839 the fact of the inability of individual shippers to compete on a railroad by running their own cars and trains was definitely recognized by Parliament.

"Another truth, and one of greater significance, began to manifest itself early in the history of railroads, viz., the fact that combination and monopoly, and not competition, is the natural law governing the relations of railways to each other. This law was not so easily comprehended as was the fact of the difference between the railway and the turnpike; indeed, there are still many to-day who fail to comprehend the monopolistic character of railroad business. It may be said, as a general statement, that the chief aim of legislation for the control of railway charges has been to maintain competition in a business which is by nature monopolistic.

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"A few persons early discovered the real nature of the railway. As early as 1836, Mr. Morrison, a man whose voice on later occasions was often heard on railroad questions, made a speech in Parliament that can be read with profit even to-day. 'Suppose,' he said, 'that in spite of all the difficulties opposed to the formation of a new company, one is formed, obtains an act, and actually comes into competition with the present line, would not the obvious interests of both parties, unless prevented by such precaution as I have proposed (periodical revision of rates by the Government), inevitably bring about some understanding between them by which the high charges would be further confirmed, and all chances of competition removed to a greater distance.'

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"The tendency towards combination is equally strong in the case of railroads and competing private waterways, and unless prevented from so doing, they will unite to secure higher rates. In England this was observed by Parliament to be the case as early as 1840, and the subsequent struggle of the two agents of commerce furnished ample evidence of the strength of the tendency. The English railroads usually bought the canals, because they wanted to control rates, and seldom because they wished to use the waterway for moving freight. The chief purpose of English legislation, since 1872, has been to stop the destruction of the canals by the railroads, and, by keeping the waterways independent, to preserve them as regulators of freight tariffs.

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" The best regulator of railroad rates is the independent waterway. Competition between railroads and water routes is quite different in kind to that of railroads with each other; it is bound to produce cheaper rates, and can do this without detriment to the railroads.

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"There is abundant evidence showing the power of water transportation to lower freight rates. The past and present opposition which the railroads have shown the waterways in order that rates might be controlled indicates clearly enough that the railroads are conscious of the potency of water competition. The railroads see in the waterway an agency which can move certain kinds of freight at lower rates than they can be transported on land; and without analyzing the results of this to see what the secondary effects on the freight business by rail of the cheaper transportation charges for these certain kinds of goods, the railroad strives to quash the waterway out of existence. The success of the railroad companies of England, of Pennsylvania and of Ohio in this regard has been noted.

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" The cheapest freight rates by rail to be found in the world are those for grain between Chicago and New York, and why ? Because the cheapest inland water transportation rates in the world are those between the same points. All the railroads of the United States have been steadily lowering freight charges during the past twenty years, and largely, of course, because improvements in track and equipment have made this possible. These roads, however, that have made the most improvements and the greatest reductions in rates are the great trunk lines leading into New York from the West, those that compete with the great Lakes, the Erie Canal and the Hudson River. The average freight earnings per ton mile of all the railroads of the United States for the year ending June 30, 1890, were .941 cents. The ton mile earnings on the New York Central and Hudson River Railroad were .730 cents, and on the Pennsylvania Railroad, .661 cents; on the Lake Shore and Michigan Southern, .653 cents, and on the Michigan Central, .726 cents; whereas the average earnings per ton mile on the Chicago, Milwaukee and St.

Paul, and the Chicago and North-Western, roads coming but slightly into competition with the Great Lakes and other waterways, were 1.06 and 1.03 cents respectively. The following table, showing the wheat rates per bushel from Chicago to New York for the years 1870, 1880 and 1889, by water, by water and rail combined, and by rail, indicates very plainly how freight rates have fallen, and how this movement has been led by the waterways:—

	By lake and canal.	By lake and rail.	By all rail.
1870..	17.10 cents.	22.0 cents.	33.3 cents.
1880..	12.27 "	15.7 "	19.9 "
1889..	6.89 "	8.7 "	15.0 "

"The important influence of the Erie Canal on freight rates has often been emphasized; only a few facts need be given here. They are for the year 1891:—

"The Erie Canal was opened in May, at which time the pool rates on grain from Buffalo to New York were *seven and four-fifth cents* per bushel. The grain rates on the canal for the various months of the season were, May, 2.51 cents; June, 2.53 cents; July, 2.68 cents; August, 3.94 cents; September, 4.19 cents; October, 4.44 cents, and November, 4.13 cents. The railroad pool rates, though nominally unchanged, were not maintained. Mr. Edward Hannan, Superintendent of Public Works, New York, says:—'My information on that subject, which has been received from private sources, is that contracts were made by the various railroads to carry grain in the months of June, July and August, for four cents a bushel; September four and one-half; and October five cents.'

"On petition of the Merchants' Exchange, of Buffalo, the Superintendent of Public Works kept the canals of New York State open five days longer than the allotted time. This shows very plainly that shippers regard the canal as a freight regulator. When the canals closed for the winter, the railroad charges again rose to the pool rates.

"Of course, the Great Lakes and the Erie Canal, though very important, constitute only one of the waterways that compete with the railroads of the United States. On the Mississippi River and its numerous long branches there is an immense traffic, setting limits not only to the charges on freight by rail carried up and down the valley, but also to a large extent on that carried out of the valley. The grain rates in 1888, from St. Louis to New York, changed from ten cents a bushel in September to twenty-nine cents during December and January, when the Mississippi River was closed to traffic.

"These great natural waterways exercise the most important influence of any of the inland navigable routes of the United States on the charges which railroads make; but the smaller streams are not without their effect. Whenever the improvement of a stream has given shippers a choice of means of transportation, the freight rates on the articles having such option have been cheapened.

"One of the questions which the Senate (Cullom) Committee on Interstate Commerce sent out in 1885, when making the investigation which preceded the framing of the bill establishing the Interstate Commerce commission, was:—'In making provision for securing cheap transportation, is it or is it not important that the Government should develop and maintain a system of water routes?' The answers to the question, and the testimony before the Committee, embodied the views of ninety men, most of whom were eminent in railroading and the transportation business; and seventy-three out of ninety agreed in regarding 'a national system of internal water communication as the most certain and effective method of regulating railroad rates, and of insuring to the people the advantages of cheap transportation.'

"The total volume of freight by rail within the United States and every other country is, of course, much larger than that by water. The reasons why this is now so, and will continue to be so, were noted in discussing the traffic in the Rhine Valley. The waterways, however, can regulate rates by carrying only a fraction as much as the competing railroad; and it by no means proves the inability of the waterway to fix rates to show that the volume of freight passing over the railroads is several times that on the competing routes of navigation. The rate charged by the waterways sets a limit—not so low, it is true, as the tariff on the waterway—beyond which the railroad cannot go without surrendering its traffic to the waterway. The traffic will bear only a much more limited rate by rail when transportation by water is possible.

"A well-informed engineer, John L. Van Ornum, Chief Topographer of the International Boundary Survey, which has just been made between the United States and Mexico, says:—'It is the universal experience in America that water communication tends to keep down railway rates. Instances are not rare where railways have carried freight for the same rate that competing boats have done until the boats have been sent away or sold on account of lack of business, and then at once the railways have raised their tariffs. In all the number of instances I know of, when water navigation has been resumed, the competing railways have been obliged to lower their rates. Herein lies the great value of our waterways, not so much in actual tonnage carried, as in their far-reaching indirect effect in forcing down railway rates.'

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"No one, it is to be hoped, will interpret the foregoing discussion to imply that the small, ill-equipped, antiquated canals constructed three-quarters of a century ago, to meet the requirements of the commerce of that time, can exert any important control over railroad traffic. The waterways which have such power are those that more or less fully meet the requirement of the commerce of to-day.

"Furthermore, in order for inland waterways to control the charges on private railways, they must be independent of the ownership or control of the railroads. From the experience of the English canals, it is not to be expected that the freight rates by rail in that country are much influenced by the waterways. There is, in fact, but little competition, and the result of this is a very high rate of charges. The average ton-mile rate on the railways of the United Kingdom for heavy traffic is nearly double the average freight earnings of the railways of the United States. This difference is to be accounted for partly by the existence in the United States of great masses of raw products, which are carried long distances; but more by the fact that a large part of these products may be carried either by water or by rail.

"The conclusion to which the Cullom Committee came as the result of its investigation in 1885 on the effect of water competition upon railroad charges is in perfect harmony with the position taken in this discussion. The report to the Senate was that 'The evidence before the Committee accords with the experience of all nations in recognising the water routes as the most efficient cheapeners and regulators of railway charges. Their influence is not confined within the limits of the territory immediately accessible to water communication, but extends further, and controls railroad rates at such remote and interior points as have competing lines reaching means of transport by water. Competition between railroads sooner or later leads to combination or consolidation, but neither can prevail to secure unreasonable rates in the face of direct competition with free natural or artificial water routes. The conclusion of the committee is, therefore, that natural or artificial channels of communication by water, when favourably located, adequately improved, and properly maintained, afford the cheapest method of long distance transportation now known, and that they must continue to exercise in the future, as they have invariably exercised in the past, an absolutely controlling and beneficially regulating influence upon the charges made upon any and all means of transit.'

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"*Influence of Inland Waterways on Railway Revenues.*

"The relationship between waterways and railroads as freight carriers is but half expounded by showing that inland navigation is the most important regulator of the railroad charges for the transportation of several important categories of freight; it still remains to investigate the effect which this lowering of charges has on the net receipts of the railway companies. If net profits of the railroads are seriously cut into by the competition of waterways, the results can hardly avoid being injurious to the best development of the means of transportation and communication. Although it is doubtless true that in special cases the railroads, by means of monopolistic powers, secure an unduly high rate of gains, this can hardly be said of the railroad business in general. It would be unfortunate, both for the public and for the railroads, were the Government or any other agency to inaugurate a policy that would lessen the returns on capital invested in railroads. It is to the interest of the public that railroad capital should return good profits, in order that railway companies may continue to pay their employees well for their work, that the companies may be able to improve the service rendered the public, and to extend their system of roads to every nook and corner of the country. The State can have no object in restricting the freest development of the railroad. The interests of passengers and shippers ought to be guarded by careful legislation, but to disregard the interests of the railways in so doing is to commit as grave an error as to neglect the welfare of those who ship goods or travel by rail.

" Water competition is not ruinous, but helpful to the railroads. If waterways be extended, and their regulative power over rail rates be increased, they will prove no hindrance to the development of the railroads. This statement may seem somewhat paradoxical, but is, in fact, not at all so. The two means of communication are very different agents of commerce; they compete with each other for the carriage of several kinds of traffic, and with sufficient force to influence strongly the charges by rail; but the waterway does more than compete; it both aids and complements the railroads. This fact cannot be too strongly emphasized. It must be kept in mind throughout the consideration of the relation of waterways and railways. The two means of transportation do not perform the same work, but services that are largely distinct and complementary to each other.

"Not all the freight transported by water would be moved by rail if the waterway did not exist. Canals, rivers and lakes create a large share of their traffic. The cost of transportation determines to a large extent the amount of goods shipped. Cheaper rates give to existing categories of freight a larger and wider market, and introduce into commerce new articles, such, for instance, as sand, stone, straw, fertilizers and wood, which were formerly unable to bear the costs of transportation. Again, the waterway creates traffic for the railroads as well as for itself. It makes raw materials cheaper, increases the number of those that are available for use.

and thus adds to the products of agriculture and manufacture seeking transportation. The effects of increasing and cheapening raw materials are complex; cheaper wholesale and retail prices, and higher wages are possible, and these in turn prepare the way for a larger and more varied consumption of goods. This means important additions to the shipments, especially of manufactured goods, the kind of freight which from its nature falls mainly to the railroads.

"The statistics of the traffic of the railways and waterways at Frankfort-on-the-Main, before and after the canalization of the Main from Mayence to Frankfort, show in a striking way that an increase in water traffic may be accompanied by an equal or greater rise in the traffic of competing railroads. The improvement of the Main from Mayence to Frankfort was completed at the close of 1886. The following table gives the tonnage by rail and by water for the three years before and for the three years succeeding the canalization of the Main.

	Traffic on waterways and railways. Tons.	On the water ways. Tons.	Increase over previous year.	On the railways.	Increase over previous year.
1884...............	1,014,518.7	150,513.7	....	864,005	....
1885...............	1,047,845.0	150,805.0	281.3	897,040	33,035
1886	1,088,046.8	155,956,8	5,151.8	932,000	35,050
Average of the 3 years..........	1,050,136.8	152,425.2	....	897,712	....
1887............ ...	1,373,690.8	360,062.8	204,106.0	1,013,628	81,538
1888.........	1,748,733.1	516,798.1	156,735.3	1,231,935	218,307
1889*.............	1,911,758.4	577,610.4	60,812.3	1,334,148	102,213

"The table shows that the total increase of the tonnage of 1888 on that of the average for the years 1884-85-86 was 698,596 tons; by this increase the waterways gained 364,373 tons, and the railways 334.223 tons. The gain of 1889 on that of the average for the years 1884-85-86 was 861,621.6 tons; and in this instance the railways show greater gains than do the waterways. The waterways and railways increased their tonnage 425,185.2 and 436,436.4 tons respectively. The great gains in the tonnage of the railroad since the canalization of the Main as compared with the gains before is seen if the yearly increase be noted.

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*"(The relative decline in the increase of the tonnage both of waterways and railroads in 1889 was due to a strike. The increase of the railroads in 1890 was again large.)

"Was this increase in traffic due to other causes than the canalization of the Main, and could it have taken place without the waterway? If so, the entire increase in freight might have been secured by the railroads. According to Consul Puls, of the Chamber of Commerce of Frankfort, the products of the interior, such as wood, loam and building materials, secured a greater market through the canalization of the river. The industrial activity of Frankfort increased because of cheaper raw materials, especially coal. The amount of traffic from Frankfort to the sea was greatly enlarged, by rail and by water, and the railroads profited both by a growth in their freight and by an equalization in volumes carried up and down from the sea to Frankfort. This equalization was an advantage to the railroads, because it enabled them to run fewer empty wagons, and thus to reduce the expenses of operation.

"An important consideration, and one that has not received due attention, is that much of the freight taken from the railroad for water transportation involves little or no real net loss to railway companies. Railroads, especially the American, are doing an immense amount of business which brings them little or no direct profit. Operating expenses constitute a large share—sixty-seven per cent.—of earnings, and this is because a great deal of bulky freight is carried at a rate so low that the costs of operation often include ninety per cent of earnings. Indeed, it is asserted that coal, coke, stone and iron ore are sometimes carried at a loss by the railroads in order that by so doing they may keep down the prices of crude products, and thus sustain industry and enlarge the volume of higher grades of traffic. The operating expenses on the German railroads constitute only fifty-five per cent. of the gross earnings. Were the American railways to give over a good share of their bulky freight to the waterways it would not materially reduce their net profits. Grain is another article of transportation on which the railroads make only small profits. Grain rates are much lower in America than in Germany, but local freight tariffs are much higher. American railroads are making the local freights pay for the trouble of handling grain at low profit.

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"The increase and extension of waterways aid the railroads through the increased travel which results from building up manufactures, developing trade, and promoting the growth of large cities. Take, for instance, the influence of that greatest of all inland waterways, the Great Lakes, on the growth of the passenger traffic in the States bordering the lakes. It has been, in large part, the improvement of the harbors and channels of the Great Lakes that has caused the phenomenal growth of Duluth, Milwaukee, Chicago, Detroit, Toledo, Cleveland, Buffalo, etc. The railroads have not only aided the growth of these cities, but have in turn been greatly benefited through the development which has come to them by means of the improvements of the water route. Indeed the most important railroad systems of the United States are those which share in the commerce of the region round about the Great Lakes.

"This fact reveals the true relation of the two agents of commerce. They are complements of each other. When the waterway and railroad are perpendicular, they feed one another; when they run parallel, competition results in reciprocal development of each—at least, will so result when the waterway corresponds, as to dimensions and equipment, to the commercial needs of the present, and provides for the transportation of goods through comparatively long distances. The Rhine Valley, as well as our own Lake region, furnishes an illustration of this truth. The statistics of the traffic during the last forty years on the Rhine River and on the railroads of the Rhine Valley show that the growth of the transportation on each has been about equally rapid. 'Neither of the two means of communication has prevented the development of the other.'

"Though the railroads and waterways ought to be competitive means of transportation, they ought not to antagonize each other. Only the benefits which the railroad receives from the waterway have been cited; but the aid is reciprocal. The well-located and well-constructed waterway need not fear co-ordination with the railway; indeed, the attainment of the highest degree of usefulness is otherwise impossible. The railroad must be present to aid in distributing the finished products manufactured from the articles transported by water, or there will be but small freight by water. Not only these manufactured goods but such articles of consumption as pass directly from the waterway to the consumers must be distributed by the railway, for water routes are few in number, and reach, directly, but a very limited number of consumers. The general relation of waterways and railroads, as collectors and distributors respectively, is shown by the shipments into and out of Paris by water and by rail in 1890. The waterways brought to Paris 4,037,719 tons, and the railroads 5,826,548 tons, the percentage carried by each being 41 per cent. and 59 per cent. respectively; but of the freight from Paris, which, of course, consisted mostly of manufactured articles, the waterways carried only 953,834 tons, while the railroads transported 2,335,252 tons, the percentages being 29 per cent. and 71 per cent. respectively. This took place, however, with very poor connections at the ports between the waterways and the railroads, so poor, indeed, as to greatly limit trans-shipment. The close connection of the waterway with the railroad, so that shipment from one to the other may be easily accomplished, is hardly less essential to the waterway's best use than the improvement of the way itself.

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"The division of freight between the two means of transportation is not, of course, into two distinct classes—one class going by water and one by rail—for each agent carries many kinds of articles that the other does. Still, the waterway reduces the ratio which the bulkier goods would otherwise bear to the more profitable classes of rail freight, and this is to the advantage of the net returns on the capital invested in railroads.

"The State (referring now to State ownership of Railways and Canals), furthermore, by extending inland waterways, would save not alone in amount of necessary investment in railroads, but also in expenses of operation relatively to gross receipts. As was seen, the costs of operation are a very large share of the gross receipts from the freight that would mostly go to the waterway, and the waterway would enable the railway to develop a kind of traffic where net receipts above costs of operation are larger. Thus it comes about that both burdens of expense which the railroads must meet, interest on investment and costs of operating, are rendered lighter when the waterways co-operate with the railroads in the transportation of freight. The development of inland navigation has also been shown to increase rather than to lessen the volume of traffic by rail. Waterways, therefore, enable the State to reduce tariffs on its railroads and still receive as large a net return on their business as would be possible without the traffic by water.

"Because of the fact that the inland waterways and the State railways of Prussia are under the control of different officials there has been a good deal of rivalry between the two means of communication. The managers of the railroads have been anxious to show a surplus, and have opposed the extension of inland waterways. Of late this opposition seems to have weakened. Prussia has entered upon the construction of canals, and the connection of the two means of transportation has been made closer, without detriment either to the traffic or net receipts of the railroads. The Prussian Minister of Public Works, Thielen, said in 1891:—'The subsequent development of the railway service must go on simultaneously with the improvement of the navigable ways. The navigable way is the sister, equal by birth, of the railway.'

"The commercial position of the waterway, and its influence on the tariffs and revenues of the railroad are well stated by the following resolution of the Fourth International Congress on Inland Navigation:—'The existence and development together of railways and waterways is desirable, first, because these two means of transport are the complements of each other, and ought to contribute each according to its special merits to the public good; second, because, viewed broadly, the industrial and commercial development which will result from the improvement of the means of communication must in the end profit both railways and waterways.'"

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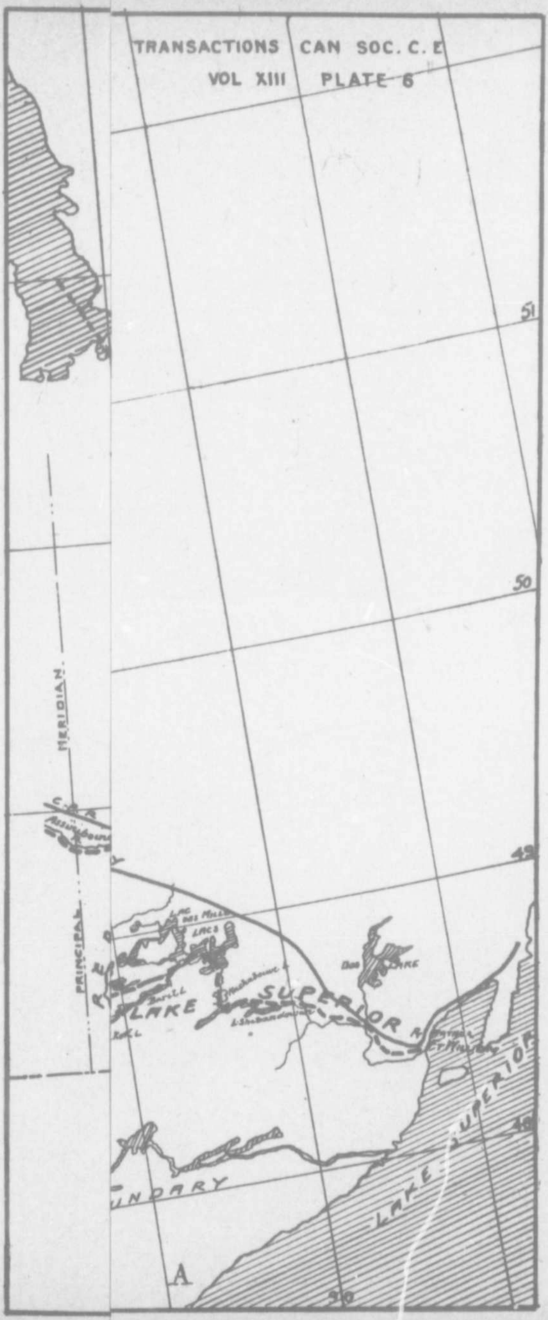
The following works have been referred to in the preparation of this paper:—

Altitudes, Lake Superior to Rocky Mountains, by Upham.
Dawson Route Reports, 1868 and 1869, by S. J. Dawson.
International Deep Water Way Report, 1895.
Report on Ship Canal, Great Lakes to the Sea, 1897, Major Symons.
Rivers and Canals, Vernon-Harcourt.
Manitoba and the Great North-West, John Macoun.
Annual Reports, Department of Railways and Canals.
Blue Book of American Shipping, 1898.
Report Buffalo Merchants' Exchange, 1897.
Description of Manitoba, pub. by the Dept. of the Interior.
Report Can. Members of Deep Waterway Commission, 1897.
Report, Jas. Fisher, Esq., M.P.P., on Hudson's Bay, 1899.
Freight Rates on U. S. Railways, Canals, Great Lakes and Rivers, 1898.
General Report Public Works Dept., Canada, 1867 to 1882.
Corthell on enlarged waterways—Trans. Can. Soc. C. E., 1891.
Report, Winnipeg Grain Exchange, 1899.
Inland Waterways, Emory R. Johnson.
Bureau of Mines Reports, Ontario.
Geological Survey Reports, 1886, and Lake of the Woods and Rainy Lake.
Expedition to Hudson's Bay in SS. "Diana," 1897, Commander Wakeham.



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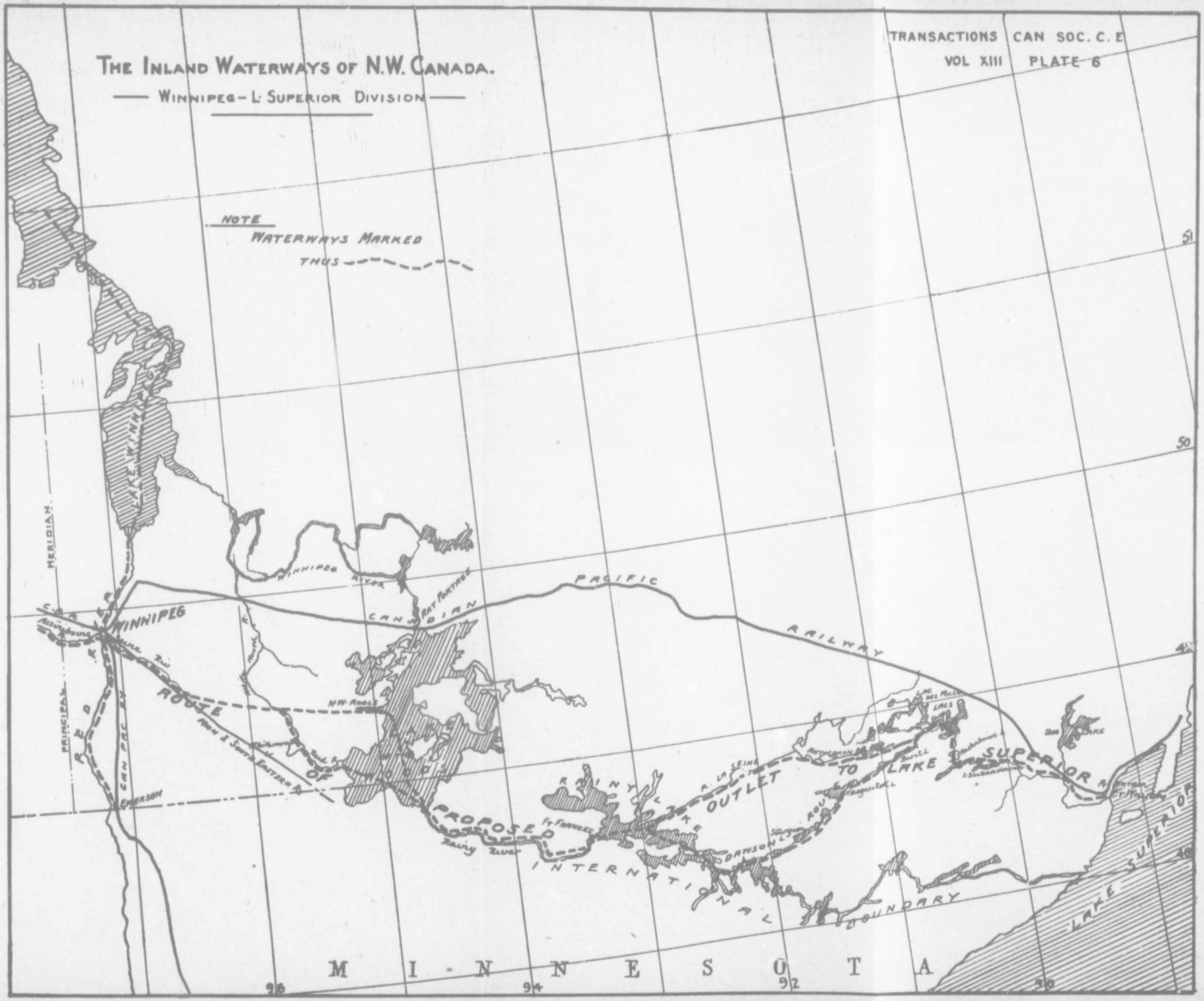

THE INLAND WATERWAYS OF N.W. CANADA.

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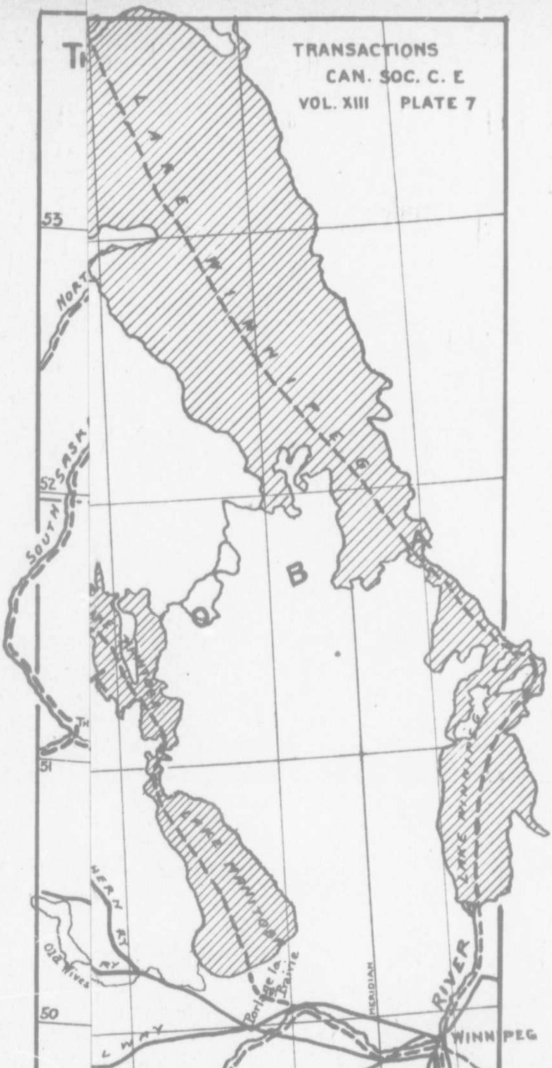

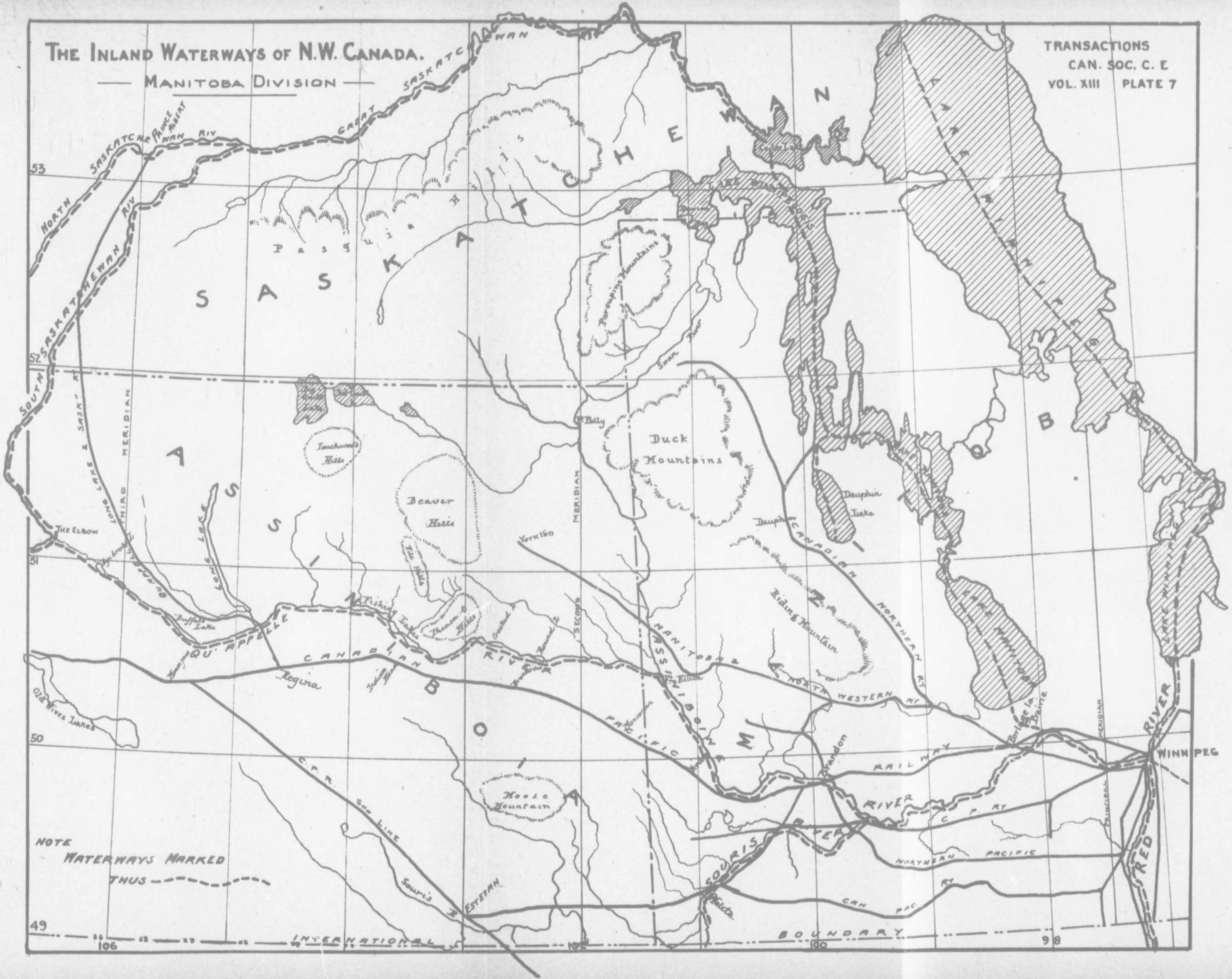

THE INLAND WATERWAYS OF N.W. CANADA.

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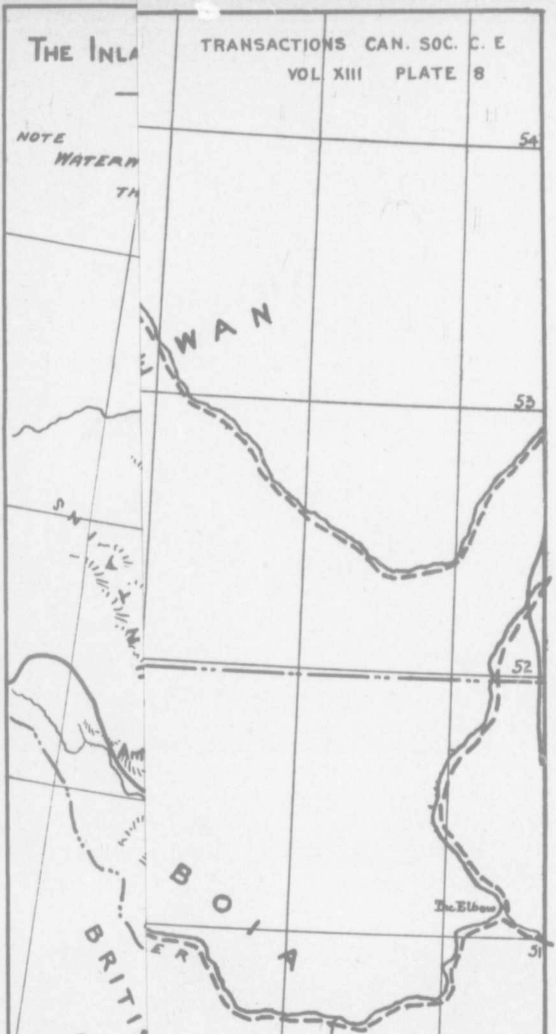

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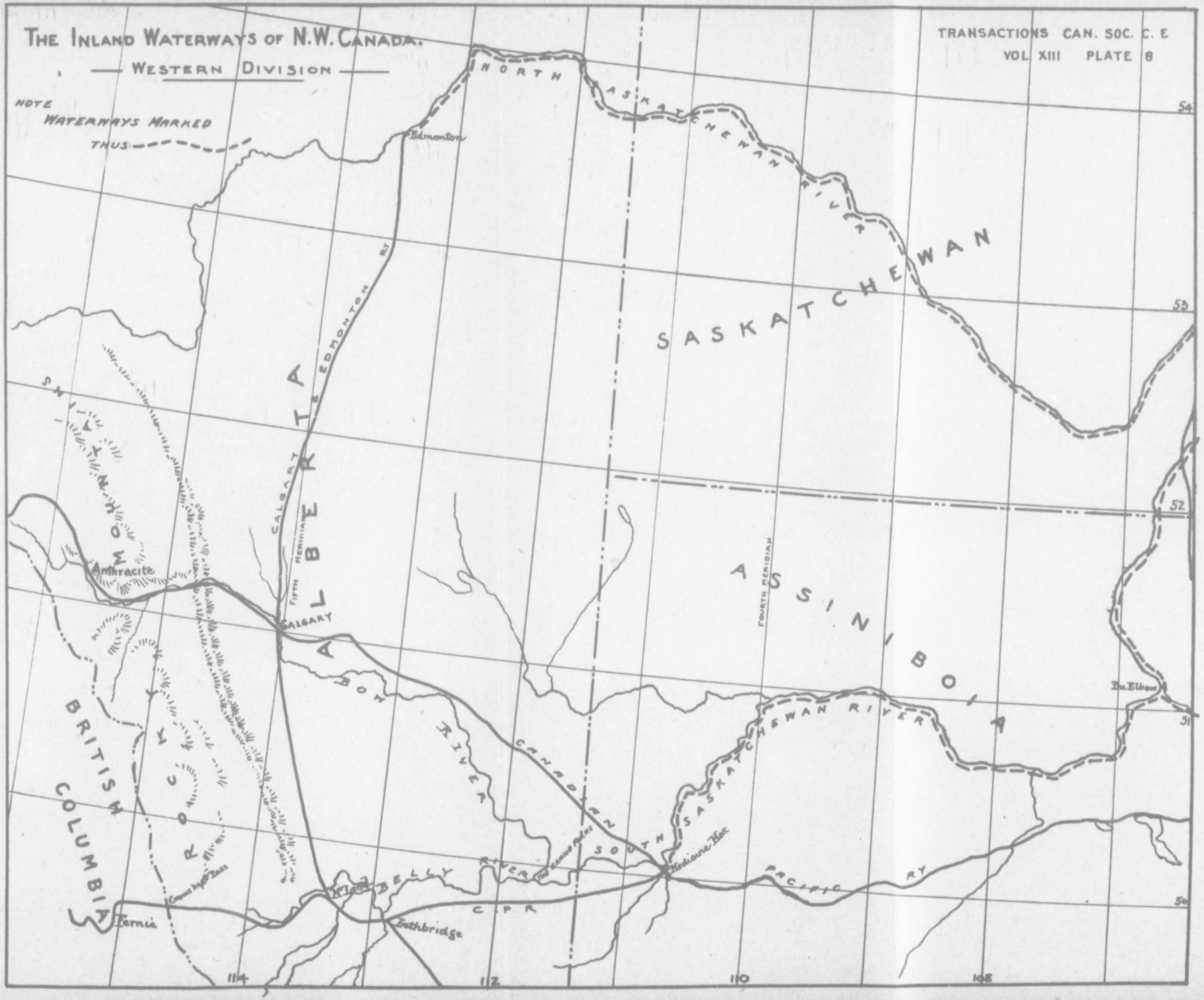

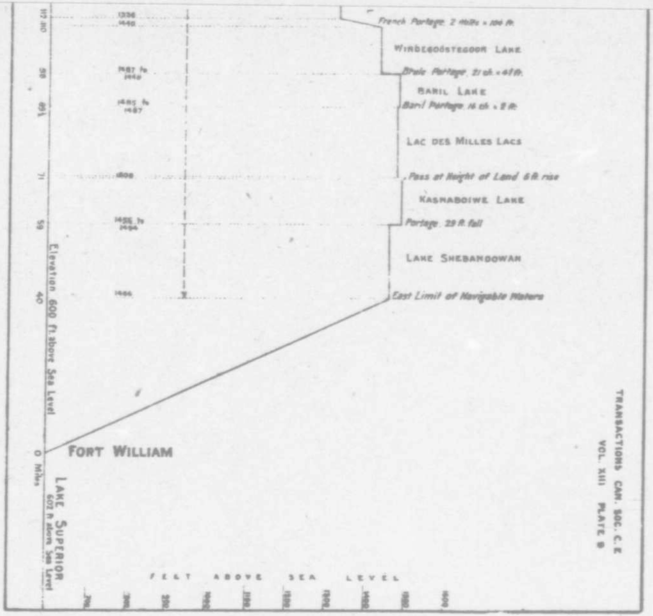
French Portage. 2 miles × 104 ft.
Winbegoostegoon Lake
Brule Portage. 21 ch. × 41 ft.
Baril Lake
Baril Portage. 14 ch. × 2 ft.
Lac des Milles Lacs
Pass at Height of Land 6 ft. rise
Kashaboiwe Lake
Portage. 29 ft. fall
Lake Shebandowan
East Limit of Navigable Waters
Fort William
Lake Superior
602 ft. above Sea Level
Elevation 600 ft. above Sea Level
0 Miles
40
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117
1336
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FEET ABOVE SEA LEVEL
700
800
900
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1200
1300
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1600

TRANSACTIONS CAN. SOC. C. E.
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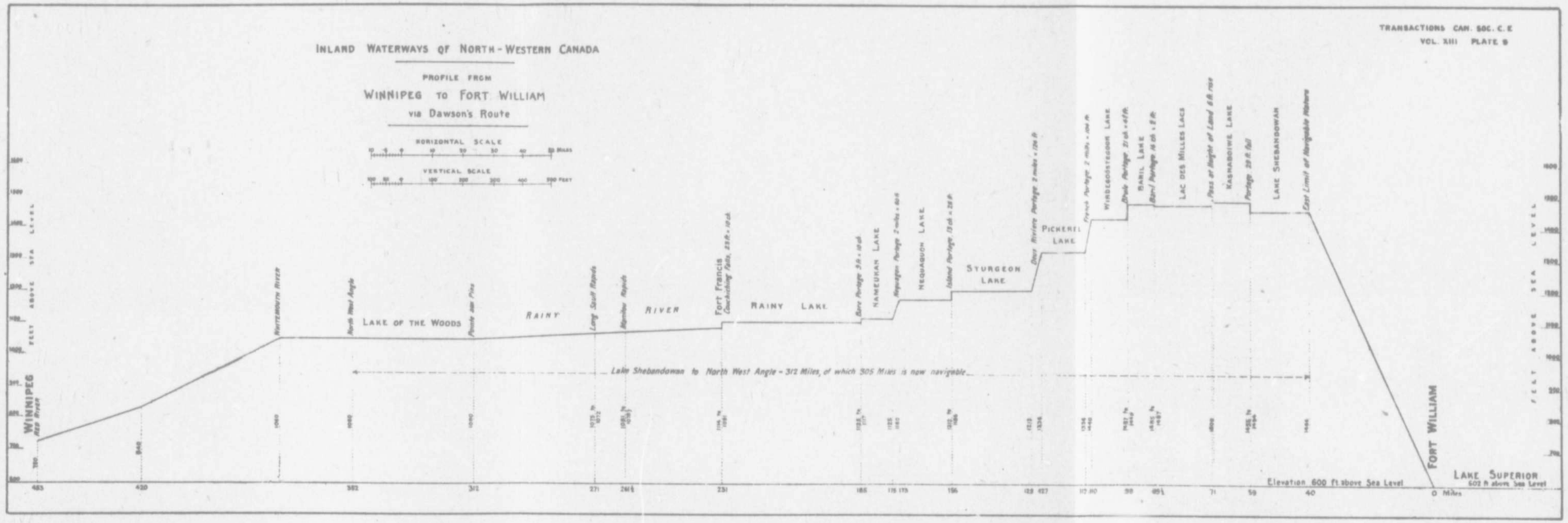
INLAND WATERWAYS OF NORTH-WESTERN CANADA

PROFILE FROM

WINNIPEG TO FORT WILLIAM

via Dawson's Route



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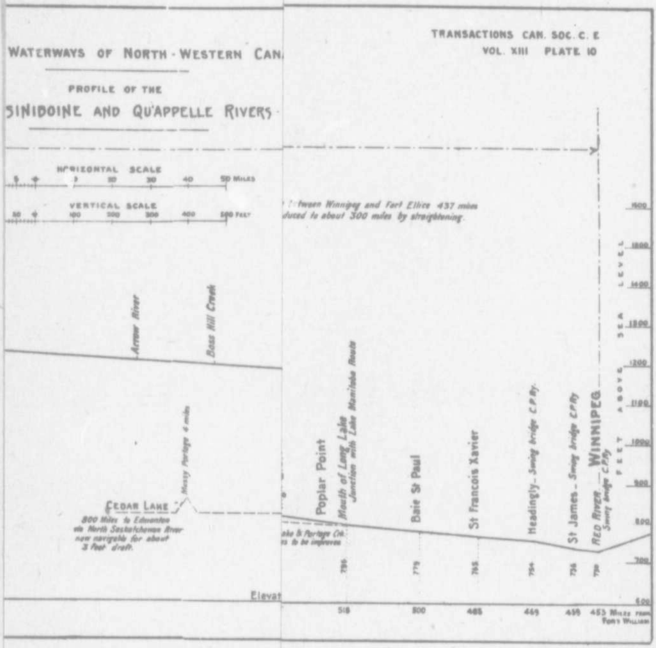
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VOL. XIII PLATE 10

WATERWAYS OF NORTH-WESTERN CAN

PROFILE OF THE
SINIBOINE AND QU'APPELLE RIVERS

TRANSACTIONS CAN. SOC. C. E.
VOL. XIII PLATE 10

INLAND WATERWAYS OF NORTH-WESTERN CANADA

PROFILE OF THE

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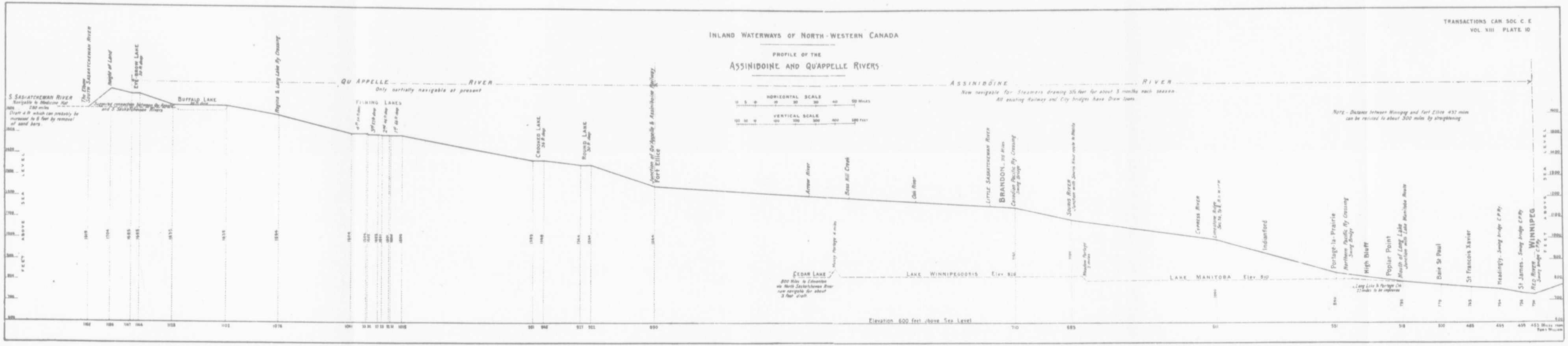

DISCUSSION.

Mr. W. T. Thompson.

Mr. W. T. Thompson said he had read with interest Mr. Webster's paper, but could not accept his conclusions regarding "The Hudson's Bay Route," and in opposition to the views expressed by Mr. Webster, based on Mr. Fisher's report, he would quote the favourable opinions of several experienced scientific gentlemen on the subject.

General Sir J. H. Lefroy, President of the Geographical Section of the British Association, who spent two years in the Territories taking magnetical observations, stated in his address to the Association in 1880.—"Hudson's Bay itself cannot fail at no distant date to challenge more attention. York Factory, which is nearer Liverpool than New York, has been happily called by Prof. Hy. Hind the Archangel of the West. The mouth of the Churchill, however, although somewhat farther north, offers far superior natural advantages, and may more fitly challenge the title. It will undoubtedly be the future shipping port for the agricultural products of the vast North-west Territory."

In an interview in London, on March 4th, 1898, Rear-Admiral Markham, the well-known explorer of Hudson's Strait and Bay, is reported to have expressed his surprise at the account received at Ottawa of the experiences of the exploring steamer "Diana" while along the Labrador Coast, and in Hudson's Bay and Strait.

"This account," he said, "was at variance with all previous experience. In his opinion the Hudson's Bay Route is open certainly four months, and possibly six months a year. He declares that it would be an immense boon to commerce, cheapen the transport of cattle and wheat to Great Britain, be invaluable from an Imperial standpoint in saving time in the transport of men and stores to the naval base at Vancouver, and afford a duplicate British route should the Canadian Pacific Railway be seized by the United States in time of war."

Prof. Hind, in his report on Navigation of Hudson's Bay, 1878, says:—"The Newfoundland, Dundee and the Norwegian sealing steamers, being properly protected, pushed their way through into the apparently illimitable fields of ice in March and April, in pursuit of seals, seeking the ice, for it is there only that they can capture the seals. . . . . It is not unreasonable to suppose that, with ice navigation so thoroughly understood, not only by the captains of sealing vessels, but by steamer whalers, the passage through Hudson's Strait successfully accomplished for 200 years and more by bulky and unweildy sailing vessels, and vessels of war, should now become an easy problem . . . the modern sealing steamer has led the way to the solution of that all-important problem, which has in view the creation of an ocean port and an extensive seaboard for the future commerce of the North-west."

Dr. Robert Bell, Assistant Director of the Geological Survey, who has spent many years exploring the country around Hudson's Bay, in his evidence before the committee of the House of Commons, in April, 1883, stated in reply to the question:—Have you the dates of the opening and closing of navigation of Hudson's Bay?

"In regard to the Bay itself, there is no date for the opening or closing of navigation, because the Bay is open all the year round, like the ocean in corresponding latitudes. It is strictly correct to say that the Bay is open during the winter, because, although in the shallow water at the head of James' Bay a narrow margin of ice forms, it does not extend outward, and is due to the land-locked nature of the bay and the shallowness of the water. Further north there is a margin of ice along the shallow water, but it never extends so far but a man on the beach can see the fog on the open water on a clear morning. On parts of the eastern coast, I am told, the sea washes against the rocks all the winter, just the same as on the coast of Nova Scotia or Newfoundland.

"The Harbours are not closed by ice till the middle of November, and sometimes not till near Christmas. There is no difficulty in a vessel leaving the coast of the Bay up to the latter part of October or the middle of November. Shore ice would not interfere with navigation for over six months of the year."

Regarding Hudson's Straits, it appears that, under the influence of the tides, any ice which forms in winter is kept almost constantly in motion, so that they do not freeze across. On this subject Capt. Wm. Kennedy, of Manitoba, who resided for eight years on the shores of Ungara Bay, states: "The Strait ice is never fast, and it keeps forming and breaking from shore during the winter months, covering it with moving ice more or less compact."

Arthur Dobbs, in his account of countries adjoining to Hudson's Bay, published in 1744, says:—"It is probable that during the whole winter, from October to March, there is no ice in the Strait to obstruct their passage into or out of the Bay, for a ship which chanced to be closed up with ice in the inlet, by the breaking of the ice got out and came through the Strait at Christmas without finding any ice in the Strait to prevent her passage."

From the foregoing it would seem that Hudson's Straits are not continuously blocked with ice in winter as Mr. Webster believes to be the case, and it is at least possible that if a harbour on Hudson's Bay could be kept open in winter, the voyage might be made at that season.

In this connection it may be noted that the Russian ice-breaking steamer "Ermak," designed for keeping the harbour of Cronstadt open in winter, is reported to have proved successful, having made her way through ice 10 feet thick at a speed of 2½ miles an hour.—On the shores of Hudson's Bay, the narrow margin of winter ice which forms cannot be very thick, for, on the testimony of several whaling captains, it breaks up with every gale of wind.

"Capt. Hackland, who has had sixteen years' experience in the Bay, states that the distance the ice forms from the shore is entirely dependent on the depth of water.—He says at Churchill, where the water is deep, the ice does not form for more than half a mile from the shore, while at York it forms at times as far as three miles, on account of less depth of water, though the mouth of the Nelson River is never really closed."

The foregoing extracts are taken from a pamphlet entitled, "Our Northern Waters," compiled by Mr. Charles N. Bell, secretary of the Winnipeg Board of Trade, and published in 1884.

In an interview accorded a reporter of the "Winnipeg Telegram" by Mr. William Mackenzie, of Mackenzie & Mann, the well-known railway contractors, who control the charter of the Dauphin Line, or Canadian Northern, published in the "Telegram" of June 15th of this year, Mr. Mackenzie said: "The terminus of the Dauphin Line will be some point on Hudson's Bay, probably York Factory or Churchill."

"Is that the first step to the Hudson's Bay navigation service?" enquired the reporter. "Yes, certainly," was the reply. "A great many people have no faith in that route, but not so with us. We have the authority of the men best fitted to know, and are perfectly satisfied with the prospect. The steamship service is quite possible."

Mr. Webster says, "Let Manitoba drop this polar chimera; it never was anything but a political and speculative dream, and never can be anything else." The writer considers the term polar in regard to the Hudson's Bay Route altogether inapplicable, inasmuch as Hudson's Straits, the most northern portion of the route, lie between 60 and 62 degrees of north latitude; they are therefore from about 300 to 450 miles south of the Arctic Circle, and he believes Mr. Webster to be equally far astray in the conclusion he has arrived at; even Mr. Fisher, whom he appears to regard as an authority on the subject, does not go to such extremes, as will be seen from the following quotations from his report:—"It would surely be a most favourable route in many respects, not only for live cattle, but for our dairy products.

"I reaffirm my decided conviction that a Hudson Bay route can never, for the reason I have stated, even if opened, be a factor in competing in the traffic of Manitoba, except possibly the very North-westerly district to which the railway system of the province is now being extended.

"At the same time, I will not deny the possibility of a commercial route being established by way of Hudson's Strait.

"In my judgment, however, the true conception of a Hudson's Bay scheme . . . is one involving a great transcontinental line. . . . . There are considerations which might be served by the construction of such a line."

Referring to the last paragraph, the writer would say that a transcontinental line from say Port Churchill on Hudson's Bay to Port Essington at the mouth of the Skeena River on the Pacific Coast would be only about 1,400 miles in length, or less than half the distance from Montreal to Vancouver, and apart from its advantages from an Imperial standpoint, and in the transport of through freight between Great Britain, China and Japan, it would tap our great northern waterways, open up the fine Peace River country, and aid in the development of important mining districts, so that along it a considerable domestic trade would soon be established.—In regard to the proposed water route between Winnipeg and Fort William, the locking up 863 feet and down the same distance between these points would seem to be rather a serious obstacle; but possibly this may be overcome, and any means by which freight rates can be reduced is certainly well worth consideration.

In an article entitled, "A new food route to Europe via Hudson's Bay," by Col. Scoble, C.E., of Winnipeg, published in the Great West Magazine, of November, 1898, will be found an account of a proposed water route from Winnipeg to Hudson's Bay, in which the total distance is given as 681½ miles to York Factory, of which it is claimed 616½ is navigable, and the cost of canaling and improvements on the remainder in order to provide a navigable channel of 7 feet deep is estimated at £1,000,000 sterling.

The Assiniboine, Red, Saskatchewan and other rivers flowing into Lake Winnipeg would all be feeders to this route, and the lockage would all be down going to Hudson's Bay.

Referring to the proposed diversion of a portion of the waters of the South Saskatchewan down the Qu'Appelle Valley, the writer believes it would be quite practicable to do this; the subject was he thinks, referred to in Hind's report of the Assiniboine and Saskatchewan exploring expedition of 1868. The late Archbishop Tache, in his sketches of the North-West of America, published in 1869, refers to it, and appears to have been afraid that, if the scheme was carried out, the inhabitants in the valleys of the Qu'Appelle and Assiniboine rivers would be flooded out. The amount of water admitted would, of course, be regulated by head gates.

The valley of the Qu'Appelle is continuous with that of the Saskatchewan, and, as shown by Warren Upham, in his report on the glacial Lake Agassiz, was formerly the outlet of a glacial lake in the valley of the South Saskatchewan until, by the recession or gradual melting of the great ice sheet which covered the lower land to the north, the river changed its course at the Elbow; it is probable a sand bar may have formed there, and contributed towards making the diversion.

Referring to the fact that wheat is not shipped to any great extent via New Orleans at the mouth of the Mississippi, is not this due to some extent to the circumstance that the climate there is too hot for the storage of grain, and that in consequence it is liable to heat?—Also the trend of the Mississippi is not in the direction of Liverpool, which is the objective point in the shipment of wheat. Regarding the export of wheat the same season it is harvested, the writer believes but little is exported in any case until the following spring, most of it being either stored at Fort William or in elevators along the railway lines until navigation opens.—The principal occupation of the North-west farmer for several months during the winter is the hauling of grain to market, which can be more conveniently done with sleighs than waggons. During the winter the wheat could be manufactured into flour, utilizing the water power of Nelson River, and both wheat and flour could be forwarded to Hudson's Bay to be stored in elevators ready for shipment on the opening of navigation.

OBITUARY.

Sir Casimir Stanislaus Gzowski, K.C.M.G., Honorary A.D.C. to the Queen, died at his residence, "The Hall," 279 Bathurst Street, Toronto, on the 24th August, 1898, at the age of eighty-five. He was born at St. Petersburg on the 5th March, 1813, and was the son of Stanislaus, Count Gzowski, a Polish nobleman, and officer in the Imperial Guard. Sir Casimir was intended for a military career, and, at the early age of nine years, was placed in the Military College at Kremenetz, where he remained for eight years, and in 1830 obtained a commission in the Imperial Russian Engineers. Three years later, however, owing to the part which, with other officers of the same nationality, he had taken in the Polish insurrection of 1830-31, he was, after having been confined in a military prison for some months, shipped to the United States. With his fellow-exiles he landed in New York in the summer of 1833, without friends or money.

His career in this country was rendered more difficult by the fact that he was, on his arrival in America, entirely ignorant of the English language. With characteristic energy, however, he immediately set to work to overcome this difficulty, and, while engaged in the study of English, obtained his livelihood by teaching German, French and Italian, and by giving lessons in drawing and fencing. In order to perfect himself in that knowledge of the English language which he knew to be essential to his success as an engineer, he articled himself as a student in law to Mr. Parker Hall, of Pittsfield, Massachusetts. At the end of three years he passed all the required legal examinations, and in 1837, having become a citizen of the United States, he was admitted to the bar and practised as an advocate in Pennsylvania until 1841. In this year he abandoned the practice of law, and, moving to Toronto, Canada, obtained through the friendship of Sir Charles Bagot a position in the Department of Public Works. For six years thereafter he was Superintending Engineer of Roads and Harbours in Western Ontario. In 1846 he became a naturalized British subject, and, having left the service of the Government, acted for some time as Superintending Engineer for the Upper Canada Mining Company. From 1850 to 1853 Sir Casimir was Engineer of the Harbour Works at Montreal, and, at the same time, was consulting engineer on the ship canal improvements between Montreal and Quebec. He next turned his attention to railway construction, and became Chief engineer of what is now the main line of the Grand Trunk Railway between Montreal and Island Pond, but was then called the St. Lawrence and Atlantic Railway. Resigning this position, he entered into partnership with Sir Alexander Galt, the Hon. H. Holton and Sir David Macpherson for the construction of the Grand Trunk main line from Toronto to Sarnia. This contract proved to be a profitable one financially, and it was upon it that the basis of Sir Casimir's fortune was laid. On the completion of the work, Sir Alexander Galt and Mr. Holton withdrew from the firm, and the two remaining partners continued operations as railway contractors, and carried out, amongst other large contracts, the construction of the lines between Port Huron and Detroit, and London and St. Mary's. The firm of Gzowski and Macpherson also successfully completed the construction of the International Bridge across the Niagara River near Buffalo in 1873. The cost of this work was $1,500,000. Subsequent to 1873, Mr. Gzowski practised on his own account, and was largely consulted by the Dominion Government with reference to railways and harbours, having, amongst other works, been called upon to report on the enlargement of the Welland Canal and Baie Verte Canal.

"He was also interested in military matters, and took an active part in forming the Rifle Association of Ontario. He acted as President of the Dominion Rifle Association, and was instrumental in sending the first Canadian team to Wimbledon. In 1873 he was appointed Lieutenant-Colonel of the Central Division of Volunteers in Toronto, and six years later was promoted to the rank of Colonel, and was gazetted an honorary A.D.C. to the Queen. In recognition of valuable services rendered to the Dominion of Canada, he was created a Knight Commander of the Order of St. Michael and St. George in 1890. He held office in 1896 as Administrator of the Government of Ontario."

Throughout his busy life Sir Casimir took a deep interest in everything that tended to the uplifting and improving of his fellow-citizens. In this connection it may be incidentally mentioned that he was Chairman of the Niagara Falls Park Commission, and that, as a recognition of his services in this direction, a fine bronze bust of him has been placed in the Queen Victoria Park near Table Rock.

He was one of the founders of the Canadian Society of Civil Engineers, and held the office of President during three successive years, 1889, 1890 and 1891. During his presidential term he endowed the well-known "Gzowski" medal for the best original paper read before the Society. Sir Casimir was deeply interested in the well-being of the Society, and aided it not only by his wise advice and encouragement, but also by liberal contributions towards its funds.

He married, in 1839, Maria, daughter of Dr. Beebe, of Erie, Pennsylvania, an eminent American physician.

WILLIAM KINGSFORD.

A TRIBUTE TO HIS MEMORY.

There can be no doubt that the late Dr. Kingsford was a very remarkable man, and his varied career merits a far more extended record in our pages than can reasonably be permitted within the limits prescribed by "the tyranny of space." He was born in December, 1819, in the parish of St. Lawrence, London, and in that city he was educated. He came to Canada in early manhood with the 1st Dragoon Guards, and, on leaving the regiment in 1841, obtained employment in a professional capacity in the City Surveyor's office, Montreal. For three years subsequently he held the position of Deputy City Surveyor. He was then induced to join the late Murdo McIver in a journalistic enterprise, and became part proprietor and joint editor of the "Montreal Times," which was discontinued after two years. In preference to drawing up details of his after-life, we will cite Dr. Kingsford's own summary of the events of his career, which he dictated, at the Windsor Hotel, to the present writer, who was acting as a representative of the "Montreal Daily Star." In answer to a question, "How long is it, Dr. Kingsford, since you conceived the idea of writing the 'History of Canada,' and what led you to think of it? You are, I believe, a civil engineer by profession." He replied: "I may say that ever since my connection with the press in 1846, when, with my poor friend, Mr. McIver, I was joint editor of the 'Montreal Times,' I have been an eager historical student, and I early felt it was desirable that a full history of Canada should be written. I cannot say that I felt specially adapted for the long task, but, as in the case of many others in the world, my faith in this respect was moulded by circumstances. After the 'Times' newspaper came to an end, I returned to my original profession. I had previously been Deputy Surveyor of Montreal, and I obtained employment in the Public Works of Canada on the Lachine Canal. At that date a cloud hung over the prosperity of Canada. Accordingly, I engaged in some private practice in New York, and was on the Hudson River Railway for two years, until I went to the Panama Railway, where I remained nine months. On my return from Panama, the Hon. John Young was Minister of Public Works, and I was engaged on the Grand Trunk. I located the line to Cornwall, and may claim that I traced the line of the Victoria Bridge across the river, under my friend and Chief, A. McKenzie Ross, and I was in charge of the maintenance of the line from Toronto to Stratford. I then went to Italy, visited the Island of Sardinia, and examined numerous public works during the year. On my return to Canada, I was again employed on the Public Works—made a map of the Rideau navigation

—and was engineer of Harbors from Gaspe to Fort William, Lake Superior. This position I occupied for eight years."

After referring to his dismissal by Sir Hector Langevin, the historian continued as follows: "Employment as an engineer to anyone who is under the ban of the Government is almost an impossibility; and, on this becoming patent to me, I fell back on the resources that my education and extensive reading had furnished me with, and, after due preparation, and much serious study, the different volumes of my history were the result."

After more conversation on this topic, the writer enquired: "May I ask if you are satisfied with the general reception of your work?" The author replied: "It has been most kindly and sympathetically noticed by the leading journals of the Mother Country, such as the 'Times,' the 'Spectator,' the 'Saturday Review,' the 'Athenaeum,' the 'Scotsman,' etc.; while the principal papers of the whole Dominion have, without any exception, passed a favourable judgment on my labours. The work, unfortunately, has brought me no remuneration during the eleven years that I have conscientiously devoted to its composition. It has been completed under great embarrassment and difficulties; and, had it not been for the intervention of three friends, who assisted me generously, I must have succumbed under what more than once appeared to me the labour of Sisyphus. . . . . If it were not for a sense of extreme delicacy as regards their feelings, it would be an act of genuine satisfaction to me to divulge the names of my benefactors; for, without their aid, I assuredly could never have reached the goal of my ambition." After acknowledging his debt of gratitude to Dr. Brymner and M. Decelles, of Ottawa, to the Abbe Verrault and to Mr. Bane, of the Toronto Library, Dr. Kingsford added: "One other friend I can never forget; for he carefully read all my proofs in sheets, while his classical learning and wide knowledge of English literature have often been exercised to preserve me from error."

In this last sentence a sense of gratitude is blended with a modesty which, though undoubtedly sincere, was expressed far too emphatically; for Dr. Kingsford himself had "a wide knowledge of English literature," and he retained throughout a long life his love of classical lore. Shakespeare and Pope may be mentioned among his favourite English authors, while he was thoroughly familiar with the writings of Livy and Tacitus, Horace and Juvenal. Scarcely a day passed without his dipping into some of their pages. In addition to this, Dr. Kingsford was well acquainted with the languages of France, Germany and Italy, and spoke them fluently, though with an undeniably Anglican accent. But the marvel of his life is that, at the age of 66, he should have begun so great a work as his "History of Canada," and by constant assiduity have brought it to completion in his 79th year. Such an achievement is not often equalled, and rarely attempted. The deep study and research which he made into the original sources of Canadian history enabled him to cast fresh light upon many important events of our annals while his fine independence of mind gave peculiar value to his conclusions, that were not seldom antagonistic to those which, in some cases at least, have long been held and repeated on insufficient grounds. When he undertook his patriotic task, he probably knew that he would finally be rewarded only by the consciousness of having served present and future generations of his adopted country, and of having handed down his name to coming times. All honour to the worker who, without thought of personal gain, unselfishly devoted twelve years of his life to a "magnum opus," for which every student of Canada's story must always be deeply indebted to the writer.

The "brave old man," as the "Toronto Mail" rightly called him, realized the fine lines of Milton in "Lycidas":

> Fame is the spur that the clear spirit doth raise
> (That last infirmity of noble mind)
> To scorn delights, and live laborious days;

and, as an illustration of the historian's self-denying course, we may be allowed to quote the following passage from a letter to a friend, who had been intimate with him for a quarter of a century: "For myself, my life is one of labour; but, like all busy men, I have always leisure, more or less, for some outside matters, such as to write to a friend, or for a duty. To the siren Pleasure, I must turn a deaf ear. I rise at five, work till nine, go to the Archives, or the Library of Parliament, work there until half-past twelve, return home, and dine at one; resume work at three, write such letters as I have to attend to, or continue at my M.S., until a quarter to six. After tea I read or write, and go to bed at eight. Such is my life, and so it must continue, until I have ended my work." Aided opportunely by three friends, whom he termed his "benefactors," he triumphed over every difficulty, and sealed his life's work with the surrender of life itself. As so often happens, when the tension was removed, the spirit fled.

Dr. Kingsford remained to the last a "true-born Englishman." In concluding his history he wrote: "There is one point on which I may hopefully dwell, and that is the fact that we remain part of the great British Empire. Throughout the Dominion it is a source of pride that such is our condition. British statesmen have not always acted wisely towards us, but there can be no doubt of the great truth that the Mother Country has unceasingly desired our prosperity and happiness, and has made many sacrifices to maintain them. I believe that pride in this relationship is a dominant feeling in British North America." It would be wrong to quit the subject of this "History" in 10 volumes, without some brief criticism of its merits, and, though the present writer carefully reviewed each volume as it was issued from the press, he prefers, instead of offering his own judgment, to quote the following passage from an influential London journal, the "Athenaeum." It says: "The History of Canada by Dr. Kingsford was completed shortly before his death, and the ninth and tenth volumes now crown the work. The preceding ones have been noticed as they appeared, and we had hoped to review the work as a whole; but the author's death removes the chief inducement, as criticisms or suggestions can no longer profit him. His history is the best of the kind that has yet been written, and its defects in parts are amply counterbalanced by its general excellence. Dr. Kingsford possessed the rare merit of writing with plainness and point, and with freedom from the flashy rhetoric which often passes for good writing on the American continent. His political views are by no means obtruded, while his patriotism is not open to question. . . . . He had to face the difficulty of having to deal with many things from a two-fold standpoint, whether they affected the French and English in Canada, or Canadians and citizens of the United States. Nevertheless, he accomplished a great work in the teeth of many obstacles—the absence of financial aid being one of them."

Dr. Kingsford's last strictly professional work was a report that he made in 1897 to the Minister of Railways on the extension of the Intercolonial to Montreal; but it is almost impossible to give a list of his numerous casual contributions to general literature. He wrote many hundred articles in the "Montreal Times," the Toronto "Leader" and other influential journals. In 1870 he contributed a weekly essay, entitled "The Spectator," to "The Cosmopolitan," a journal of Literature and Public Opinion, edited by Mr. W. T. Urquhart. These essays "de omnibus rebus" were extremely popular, but were never republished. His other contributions in book form to authorship include: "History, Structure, and Statistics of Plank Roads in the United States and Canada" (1852); "Impressions of the West and South" (1858); "The Canadian Canals: Their History and Cost" (1865); "A Canadian Coin: A Monograph" (1874); "Canadian Archæology: An Essay" (1886); "The Early Bibliography of Toronto" (1892); and, finally, "Some Considerations on the Advantages we may hope to Derive from Education," a long Address, delivered before the meeting of the Ontario Teachers, held in the Normal School, Toronto, May, 1896. In special honour of his "History of Canada," the degree of LL.D. was conferred upon him by Queen's College, Kingston, and Dalhousie University, Halifax. After his death Sir W. C. Macdonald endowed a Chair of History to be associated with the name of Dr. Kingsford, and, besides this, settled a life annuity of $500 upon the historian's widow. We are also gratified to learn that more recently Her Majesty has been pleased to confer upon the same lady a pension of £100 sterling per annum from the Imperial Civil List, in consideration of the eminent literary services of her late husband. It may here be appropriately mentioned that, in March, 1848, Dr. Kingsford married Maria Margaret, eldest daughter of the late W. B. Lindsay, then clerk of the Legislative Assembly, Canada. Two children, Rupert Etherege, and Alice, survive their father.* The son, born in 1849, who distinguished himself at Toronto University in 1869 by gaining the medal in Classics and Modern Languages, was called to the bar in 1873, and was appointed Deputy Police Magistrate of Toronto in 1894.

Dr. Kingsford became a member of the Canadian Society of Civil Engineers in 1887, and was one of the original Fellows of the Royal Society of Canada, in which he was once President of the section of English Literature. Little now remains for us to do but to record the lamented historian's death. He died on the 29th of September, 1898, at 310 Chapel Street, Ottawa, after an illness of several weeks, and was buried the next day in Beechwood Cemetery.

We have already transgressed our prescribed limit, and will, in conclusion, quote a few affectionate words from the pen of a journalist who was intimately acquainted with the subject of this imperfect sketch. "In private life Dr. Kingsford had many friends. He was a man of strong attachments, and where he placed his affections he was as true as steel. He was at the same time a man of rare independence of character; and, notwithstanding his old-fashioned courtesy and real kindness of heart, was fearless in condemning what he disapproved. In this respect the history is characteristic of the man. In the ranks of his own profession, at the meetings of the Royal Society, and wherever his tall and imposing figure was familiar, Dr. Kingsford will be missed and regretted. But most of all will he be missed in his own family, to whom our fullest sympathy is due." As Antony said of Brutus:

> The elements
> So mixed in him, that Nature might stand up
> And say to all the world, "This was a man!"

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* We have to record, with deep regret, that since these words were written, Miss Kingsford died at Ottawa on Sunday, October 22, 1899.

The publicatio
in the hope that
" The Transmis
B. Owens could
he has been quite

In justice to
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The publication of this volume has been greatly delayed in the hope that the manuscript of the series of lectures on "The Transmission of Electrical Power," by Professor R. B. Owens could be obtained. Professor Owens regrets that he has been quite unable to find time for its preparation.

In justice to the authors of the two brief papers, which constitute all the remaining material for the volume, further delay has not been considered advisable.

C. H. McLEOD, *Secretary.*