

HALIFAX WATER WORKS.—H. W. JOHNSTON, Assistant City  
Engineer, Halifax, N. S.

Read 12th February. 1906.

The city of Halifax is situated on a peninsula, at the head of Chebucto Bay, formed by the harbour and Bedford Basin on the east and north, and the North West Arm on the west, and joined to the mainland by a strip of land about  $1\frac{1}{2}$  miles wide at the Dutch Village, separating the Arm and Basin. The slopes to the water on all sides are steep, and there is a practically level plateau at the summit extending north and south about two miles and east and west one mile, with a high hill called Shaffroth's or "Hungry Hill" at the north end. The general elevation of this plateau is from 150 to 170 feet above mean low tide, and the elevation of Shaffroth's or "Hungry Hill", the highest point in the city, is 247.50 feet. There is also an elevation at Willow Park, the highest point at present supplied with water, of 225. The business district lies on the eastern slope between Jacob Street and Salter Street, surmounted by the citadel, which is 214 feet above mean low tide. The chief wharves are from Richmond to South Street, a distance of about  $2\frac{1}{4}$  miles. The rest of the city, with the exception of a few streets, is residential, with few houses on the western and northwestern slopes.

The city was founded in 1749 and incorporated in 1841. Previous to 1844 the city was dependent entirely upon wells for its domestic supply, and on them and the salt water of the harbour for fire protection. It was the custom at that time on an alarm of fire being sounded for the citizens to turn out and assisted by the troops line the streets and pass buckets of water from the harbour to supplement the scanty supply from the wells, which was drawn by a hand fire pump owned by the

military authorities. In the year 1844 a company composed of local men was formed, with a capital of £15,000, under the name of the Halifax Water Company, which on the 17th of April obtained a charter from the legislature of Nova Scotia, for the purpose of supplying the inhabitants of the city with water. An amendment to the act of incorporation was passed during the same year, providing that the city council might make such ordinances as might be deemed necessary for raising such monies as might be required to furnish the city with public fountains, hydrants and fire plugs, abundantly supplied with water, by causing a fair and proportionate rate, not less than £400 in each and every year, to be made upon the whole property of the city; and that the said company should in consideration of the said annual payment of £400, erect and build in the city eighteen fountains and hydrants and twenty-five fire plugs. The first meeting of the company was held at the Exchange Coffee House on the 22nd July, 1845, when a board of directors, consisting of James B. Uniacke, Thomas Hosterman, W. A. Black, William Lawson, Jr., William B. Fairbanks, James N. Shannon, and William Stairs, were elected. Mr. Stairs refusing to act, the Hon. Michael Tobin was elected in his stead. Mr. Uniacke was elected president, and continued to act as such until 1855. Mr. Charles W. Fairbanks was employed by the directors to make surveys of the lakes adjoining the town, and on their completion Mr. John B. Jarvis, a well known engineer of New York, was engaged to report on a scheme to supply the city with water.

On the 28th August, 1845, he submitted his report to the Company recommending that the water be brought from Chain Lakes—two lakes about  $2\frac{1}{2}$  miles long, situated about  $1\frac{1}{4}$  miles from the head of the North West Arm—by a line of pipes to a reservoir on Wind Mill Hill (now called Camp Hill), the elevation of this reservoir to be 170 feet above mean low tide. That the Chain Lakes be connected by an open channel or canal with Long Lake (formerly called Beaver Lake) about 1200

feet long, and that the surface of Long Lake be raised from its elevation of 175 feet to 200 feet above tide by a dam at its outlet at McIntosh's run. Mr. Jarvis estimated the population of the town at from 20,000 to 25,000, and that there would be 1500 water takers within five years from the introduction of the supply, and that this number would ultimately reach 2000. This would require, at 200 gals. for each tenant, 400,000 gals per day. The natural flow from the valley of the Chain Lakes was estimated to be capable of supplying the mill owners who had rights in the stream and dams already built, and to furnish the town with 300,000 gals per day for five months in the year, leaving seven months supply to be stored in the reservoirs. This supply he estimated could be obtained from the Chain Lakes storage reservoir. In his report he makes no mention of any data regarding precipitation, and the presumption is that as there were no records for Nova Scotia in existence previous to this record, the New York or Massachusetts records were taken. He recommended that a 12-inch pipe, which was estimated to be capable of discharging 800,000 gallons per day when new, but only 700,000 when incrustated, be laid from the Chain Lakes to the reservoir in the city. The estimated cost of the works, including Long Lake, the reservoir on Wind Mill Hill and the distribution, was about \$120,000. The reservoir was proposed to be 1.58 acres in area and about 15 feet deep, which would hold a supply when drawn down of about 5,000,000 gallons.

Before leaving this report, there is a clause dealing with the principle of municipal ownership of water-works which should be quoted, especially as the question of municipalities owning or controlling all public utilities is to-day a very live issue. After reciting several benefits following the introduction of water-works, he says: "A good supply of pure water has a further public benefit in promoting the cleanliness, health and general comfort of the citizens. These are con-

siderations that should induce a city to supply water under their own authority. If the rates should not be sufficient the general benefits would be ample remuneration for an deficiency that might, under favorable circumstances for the introduction of water, be necessary."

A further report was submitted by Mr. Jarvis on the 10th September, 1845, on the advisability of bringing water direct from Long Lake without connecting with Chain Lakes. He reported that the cost of bringing the water by open cut to within 1500 feet of the lower end of Chain Lakes and then laying pipes, would be practically the same as the original estimate, and he could see no objection to the scheme. However, the directors adhered to the original scheme and constructed a dam at Long Lake, the canal from Long Lake to Chain Lake, and a 12-inch pipe line from Chain Lake to St. Andrew's Cross (the local name for the junction of Robie Street and Quinpool Road), but did not build the reservoir on Wind Mill Hill. Considerable trouble was had in securing the rights to Chain Lakes from the mill owners, but eventually these were secured, although on terms which have been the cause of dispute ever since.

The water was turned on to the city in 1848, the first service pipe being laid to Mr. Liswell's house and bakery on Gottingen Street on the 29th September, 1848. (The 6-inch main originally laid on this street was taken up in 1905.)

A contract with the city was made on October 3rd, 1849, agreeing to supply eighteen fountains or hydrants and twenty-five fire plugs at an annual rental of £400. In July, 1849, the directors of the company authorized a free supply of water to be given the poor from certain hydrants between the hours of six and seven morning and evening.

At this time the engineer reported that there were 2700 houses inhabited and 400 uninhabited between North Street and the gas works.

In 1849 the shareholders instructed the directors not to build the reservoir, and in 1851 the portion of the act requiring this to be done was repealed. In December, 1849, the directors issued a notice to water takers that they should during the ensuing winter keep the water constantly running in a small stream during the night to keep the pipes free from frost—an order that has ever since been only too faithfully carried out, much to the detriment of the works and the financial showing of the system.

In fact, as early as 1854, the directors, in replying to the city's complaint of poor pressure, said that the difficulty in keeping up the supply has been caused by the great waste of water, by the water takers running it off during the severe weather. In this year, finding the supply insufficient, the directors employed Mr. J. Forman to make an examination of the lakes and report on the advisability and expediency of raising Lower Chain Lake, and to what extent, and also the propriety of laying another 12-inch pipe from the head works at Chain Lakes and the advantages to be derived from it. Mr. Forman reported to the directors on the 5th August, 1854, and at a special meeting of the shareholders on the 24th February, 1855, a resolution was passed authorizing the directors to proceed with the laying of a new line of pipes, providing the opinion of a competent engineer who had not been connected with the company be first obtained. An amendment that the directors turn their attention to the immediate waste of water was defeated by a large majority. Acting under this resolution, Mr. Forman was again engaged to report on an increased supply, and in answer to a series of questions put to him, advised that the effect of a 12-inch pipe would double the supply and would cost £6,026. To give full effect to the increased supply the 9-inch, 6-inch and 3-inch distribution pipes should be changed to 12-inch, 9-inch and 6-inch. Also that a 15-inch main would give fully one-half more than the existing supply at a cost of

£8,500, and that there was more water in the lakes than a much larger pipe than one of this capacity could run, and that there would be no danger to existing distribution pipes from increased pressure. He also reported that the cost of bringing the water to the pipe-house direct from Long Lake in a conduit would cost £7,200; but he could see no advantage to be gained. By repairing and raising Long Lake dam 290 million gallons, extra storage would be gained at an outlay of £550. He did not think that a reservoir on Camp Hill would obviate the necessity of a new pipe to the lakes; but it would add to the present supply by storing water at St. Andrew's Cross when the consumption of the town was less than the flow through the mains. This would be the case at some periods and tend to preserve the effective head. In reply to the request whether he could suggest anything to remedy the present evil resulting from frost, he recommended that frequent inspections of water-cocks be made and consumers warned against allowing a more copious flow to run than was necessary.

At the annual meeting on the 2nd July, 1855, Forman's report was adopted, and the directors authorized to lay another line of 12-inch pipe if necessary arrangements could be made with the city council as to increased cost. A resolution also passed that a strict supervision be had over water takers to prevent excessive waste. The city having agreed to pay £200 per annum for an additional ten hydrants, providing some changes were made in the distribution, at a meeting 15th January, 1856, the shareholders decided to lay a 15-inch pipe, which was done in the fall of this year. The company also raised its rates to all private takers fifty per cent. The city first approached the company in this year with a view to buying the works, but the latter's reply was that they were not then in a position to sell. In 1859 a committee of the city council was appointed, after the great fire of the 9th September in that year, to report on the improvement of the fire department and on the best means of obtaining an additional supply of

water for the city. After considering several propositions this committee reported to the council recommending the purchase of the company's works by the city, and also that the Birch Cove Lakes be acquired and connected to a reservoir on Shaffroth's Hill, from whence the water be distributed by three lines of pipes, one supplying the north, one the south and the other the middle district of the city. This scheme was proposed and advocated by Mr. E. J. Longard. Acting upon this report, the council again approached the company, and at a special meeting of the latter it was resolved to sell the works to the city for £52,000, which offer the city accepted, delivery to be made on the first of May, 1860; but as the city neglected to secure the necessary legislation, the agreement fell through. In the following year, however, the sale was made to the city for £56,000. The transfer of the works was made on the 30th June, the formal transfer of the deeds, etc., being made on the 5th August, 1861.

The water company's capital when the works were taken over by the city was £44,000. There were 960 water takers at an average rate of £13 per annum, with special rates to the military, breweries, bakeries and distilleries; and £700 was being paid by the city for rental of fire and street hydrants. There was about 21 miles of pipes laid for the supply of the city. After the transfer, the works were managed on behalf of the city by a board of three paid water commissioners under authority of an act passed 15th April, 1861. The commission was composed of J. A. Bell, chairman, and Messrs. J. L. Barry and E. J. Longard, the latter taking the place of Mr. J. R. Morse, who was elected by the city council but declined to serve. These gentlemen continued to act until the control of the works was vested in a committee of the council (the board of works) on the 30th September, 1872.

Before the purchase of the works a commission on water-supply, with Mr. Henry E. Pugsley as chairman, was appoint-

ed by the city council, and they engaged Mr. James E. Laurie, C. E., of New York, to report on the works and increased sources of supply. Mr. Laurie submitted his report, which is an exceedingly interesting and valuable document, on the 10th May, 1860. The population of the town at that date was 30,000, and there were 892 water tenants on the books of the company. Allowing eight persons to a family, this would give 7,136 people using the water; but as the barracks, navy yard and city counted as single tenants and a large number were using water from free hydrants, he estimated that there were about 20,000 consumers. While the mains were capable of discharging 2,000,000 gallons per day, on account of there being only about two 12-inch distributing mains only about 1,500,000 gallons were being used by these 20,000 consumers, or at the rate of 75 gallons per capita per day. In calculating for an increased supply he based his estimate on a population of 60,000 using at the rate of  $83\frac{1}{3}$  gallons per capita per day or for a total of 5,000,000 gallons per day.

He discussed two plans for increasing the supply, and two for the proposed high service, and also improvements in the distribution system:—

1st. Long Lake.—By raising this lake three feet and replacing the 12-inch main with a 24-inch main a daily supply of 5,000,000 gallons with a storage capacity for 160 days would be obtained at an estimated cost of \$70,070.00.

2nd. Birch Cove Lakes.—These lakes consist of several bodies of water connected by narrow passages, having a surface elevation of 239 feet above mean low tide, and an area of 241 acres, with several other lakes emptying into them. The natural flow was small, a 9-inch x 12-inch penstock carrying the greater part of the water in the dry season to a mill on the stream. Assuming the lakes to be capable of being raised ten feet, which was problematical, as the eastern banks were low and unsuitable for dams, and eight feet of water being drawn off,



the capacity of the reservoir would be 586,000,000 gallons or 117 days full supply for the city. But as the mills on the stream would require the whole natural flow through the summer and autumn, it would be necessary to purchase their rights, or there would be available for the city's use but forty-six days supply. The cost of bringing water from these lakes, including \$40,000 for land and compensation and \$30,000 for reservoir on Shaffroth's Hill, would be \$353,980.

3rd. High service, Ragged Lake.—This lake lies about  $2\frac{1}{4}$  miles westerly from the gate-house at Chain Lake, and contains about 100 acres of water area at an elevation of 325 feet above tide. Lying at the summit level of the country, it has a limited water-shed (less than 300 acres by a later survey) and would not be a suitable source to furnish the quantity required. The estimated cost of obtaining a supply from this source, exclusive of the distribution, was \$55,030.

4th. Pumping by steam power to Shaffroth's Hill.—The most convenient station for pumps would be near St. Andrew's Cross, and the cost, including the annual working expenses capitalized at 6 per cent. would be \$99,000. Another scheme was suggested—to use the stream running from the Chain Lakes to Hosterman's mill to pump into a stand pipe, and thence by gravity to a reservoir on Shaffroth's Hill. The first cost would not be very different from pumping by steam, but the operating expenses would be less. The practicability of the plan depended on the amount of water running from Chain Lakes in a dry time, the amount required to operate the pump being about  $4\frac{1}{2}$  million gallons per day. In summing up, Mr. Laurie recommended that Long Lake dam be raised and a 24-inch main be substituted for the 12-inch from the lakes to St. Andrew's Cross, as the whole of the city, with the exception of the district lying to the north and west of Gerrish and Creighton Streets, could be supplied by gravitation. This district would have to be supplied either by bringing water from a

higher source or by pumping to a reservoir. He also recommended extensive changes in the distribution system.

In 1863 the original 12-inch main was taken up and a 24-inch main laid in its stead. Long Lake dam was not raised until some years later, but the distribution system was remodelled and enlarged on the lines of the report. The commissioners in their annual report for this year discussed the necessity for a high service supply and warmly advocated something being done, as without artificial means being employed sufficient head could not be obtained from Long Lake to supply the higher levels of the city with water by gravity. In reviewing Laurie's report they mentioned a high hill near the foot of Chain Lakes suitable for a reservoir site, which would do away with the necessity of a stand pipe and reservoir on Shaffroth's Hill in case it was decided to adopt the method of pumping from the Chain Lakes. William Gossip, Jr., C. E., was engaged to report on the question of obtaining a high level supply from this source. On the 29th of June of this same year he submitted a lengthy report dealing with this matter and also with the general state of the works, in substance as follows:—That to pump by water-power from the Chain Lakes to a reservoir on the adjacent hill would require the following quantities of water: To work the water-wheel and keep the reservoir full (supposing 600,000 gallons per day to suffice for the high service for some years to come) 5,000,000 gallons per day, to which must be added 2,000,000 gallons for the low service, 600,000 for the high and 100,000 for leakage and waste, or a total amount of 8,600,000 gallons per day from the Long and Chain Lakes reservoirs. The lakes in their then state were estimated to be capable of sustaining a daily draught of 5,000,000 gallons without reducing the level of Long Lake to more than two feet below the waste weir in the driest part of the year, leaving a deficiency of 400,000,000 gallons. By raising Long Lake dam three feet (at a cost of \$1,450) 260,000,000 gallons additional storage could be had, leaving 140,-

000,000 gallons more required, which could only be obtained by tapping some new source. The waters of Spruce Hill Lake could be diverted into Long Lake and supply this amount by a cut about a quarter of a mile long at a cost of \$16,000. The cost of the new works, using water-power for pumping, would be \$61,411 and using steam-power \$44,537, the annual operating charges in the former case being \$800 and in the latter \$3,286.50.

The commissioners, however, were imbued with the idea that the Spruce Hill Lakes, lying about three miles to the westward of Long Lake, were the best available source of supply, and in 1865 obtained the services of Mr. W. B. Smellie to make surveys and report on their capabilities. On the 5th April, 1865, he reported that he had made a survey of the lakes and found the second lake had an area of  $92\frac{1}{2}$  acres, and was 153 feet above Long Lake, and the third lake an area of 70 acres, and about  $2\frac{1}{2}$  feet higher than the second. He recommended a dam across the outlet of the second lake, raising the water  $7\frac{1}{2}$  feet, which would allow, say, 6 feet of water to be drawn from the second lake and  $3\frac{1}{2}$  feet from the third, and would yield 217 millions of gallons, or 180 days' supply of 2,000,000 gallons per day. By raising the lake one foot higher twenty-two days' further supply could be had, and by lowering the pipe three feet below the existing surface an extra quantity equal to twenty days' consumption would be obtained.

In a further report on the 8th July, 1865, the cost of building a canal to let the water of Spruce Hill Lakes down to Long Lake was estimated to be \$33,500, and to conduct the water by a line of pipes to a reservoir near Chain Lakes would be \$87,000. But neither of these schemes commended itself to him, and he recommended conducting the water from the lakes to St. Andrew's Cross by a 15-inch pipe, which would be capable of delivering two and one-half million gallons every twenty-four hours.

The commissioners, after considering the various reports upon the proposed increase in supply, had no hesitation in recommending that Spruce Hill Lake be raised 10 feet, and the water conducted into the city by a line of pipes.

In 1866 the whole scheme was submitted to Mr. Thomas C. Keefer, and on September 25th of that year he submitted his report. He recommended taking the supply from Spruce Hill Lake by gravity, and estimated that these lakes would ordinarily furnish a supply of 2,000,000 gallons, and in a dry year not less than 1,000,000 gallons per diem, or sufficient for a liberal supply for 20,000 persons, or about double the number assigned to the high level district. A 15-inch pipe to within a mile and a quarter of the lake and a 20-inch pipe connected through the intervening distance to the lake would deliver 2,000,000 gallons per day at the higher levels and 3,000,000 per day at a level of 100 feet above tide. He also suggested that in future an intermediate system might be obtained by catching a portion of the Long Lake water at an elevation of 50 feet above the lake and forming a reservoir and running a line of pipes to town. In January, 1867, the city council adopted this report. Work was commenced on the 17th April, 1868, on the dam and pipe line, and the work was finished in the following year.

By an act of legislature, passed 18th April, 1872, the powers and functions hitherto exercised by the commissioners of water supply were to cease on the 30th September of the same year, and a committee of the city council called the board of works was vested with all the said powers and functions. The following quotation is taken from the first report of Mr. E. H. Keating, the first city engineer of Halifax, in 1873. Adverting to the formation of the commission in 1861, he said: "The new commission seemed to work well, and great praise is due to the gentlemen who comprised the board for the energetic manner in which they grappled with the difficulties with which they had to contend, and for the manner in which the work

of the department was planned and executed. To them is due the credit of establishing the works as we have them to-day, and if unsatisfactory it is through no fault that can be attached to the plans that were adopted, but rather through the neglect of enforcing stringent ordinances, the necessity for which I am informed was repeatedly urged upon the council by the board." Since 1872 the works have been under the control of the board of works and managed by the city engineer of the city of Halifax.

As may be gathered from the foregoing history of the works, the district supplied by the Long and Chain Lakes lies at an elevation below 150 feet above mean low tide, and that supplied by the Spruce Hill Lake system above this elevation. The former is called the low service district and the latter the high. Both are supplied by gravitation. One of the great difficulties in connection with the high service shortly after its introduction, was the constant and urgent demand of the consumers near the higher levels of the low service district, as the pressure became lower through the increased consumption for the letting down of this service to the lower levels. While this was combatted strongly by the commissioners and subsequently by the city engineer, it was frequently done, and greatly impaired the efficiency of the high service system. However, since the introduction of the 27-inch low service main the supply has been kept back nearer its proper level. At present the lowest points supplied by the high service are the Victoria General Hospital and poor house, where the ground is at an elevation of 100 feet, and on Uniacke Street, at an elevation of 120 feet.

*Low Service Gathering Grounds and Storage Reservoirs.*

The water shed of the low service system comprises an area of 4,455 acres, including the lakes—904 acres in the Chain Lakes and 3,551 acres in the Long Lake gathering grounds, the water area in the former being 97 acres and in the latter 459 acres. Included in the Chain Lakes water shed is Bayer's Lake

with an area of 16 acres. The run-off from this water-shed has never been measured, although some measurements of the flow from the Bayer's Lake portion have been made, and the calculation of its yield has to be made from the rainfall. In estimating the capacity of the gathering grounds there must be considered the extent and character of the drainage area, the average and minimum yearly rainfall, the distribution of the rains through the various months of the year, the average and least percentages that are carried by the streams, the storage capacity that can be secured and the evaporation from the surface of the area.

The slopes of the drainage area of Long Lake and Chain Lake are steep, and consist chiefly of rock formation with scanty soil and not very much vegetation. The rainfall is measured by the Dominion meteorological agent in the city of Halifax, and at the lakes by the city water department. The gauges at the lakes are set in such a position that they should measure accurately the precipitation. The average yearly rainfall in the city of Halifax, from 1869 to 1905, is 56 inches and the minimum 45.808 inches in 1894. In Mr. Keefer's report of 1876 the rainfall for the years 1859 to 1865 is given, and during this time a minimum of 39 inches is recorded for 1860 and an average of 51.62 inches for the seven years. It is not known by whom these records were made.

The writer is unaware of any studies to determine the evaporation having been undertaken in Nova Scotia, but the generally accepted rule here is to allow that one-half the rainfall will be lost from this cause and all that falls on the water surface of the drainage area. In his opinion this would cover the loss on the low service water-shed as there are few swamps or shallow places where the water lies, and as before mentioned, the slopes are fairly steep. In fact, taking the area of the water-shed, the amount flowing over the waste weirs, the amount estimated to be delivered in town, the loss from leakage at the dams and the amount delivered to the mill owners,

the writer is of the opinion that an average of 50 per cent. throughout the whole year is available as the run-off from the Long Lake drainage area. Since 1889 the quantity running to waste yearly over Long Lake waste weir has varied from 250,000,000 gallons to 2,173,000,000 gallons. The reservoir has always been full during those years in either March, April or May.

To increase the available flow, it is necessary to store the water in time of flood and thus equalize the distribution of the rainfall. There are three low service reservoirs,—Long Lake, with waste-weir level at 206.00 feet, having a surface area of 423 acres, an available depth of 8.20 feet and a capacity of 871,522,000 gallons; Upper Chain Lake, with waste-weir at same level and sluice at 194.70, an area of 37 acres and a capacity of 107,674,000 gallons; Lower Chain Lake, with waste-weir at same level of 206.00 feet, main pipe at level of 192.24 feet, and an area of 42 acres and a capacity of 157,374,000 gallons; giving a total available storage in the low service reservoirs of 1,136,570,000 gallons—sufficient to supply the legitimate wants of a population of 50,000 for a period of 225 days, allowing 100 gallons per capita. But to show the enormous draught on this system, in November of 1905 all but 60,000,000 gallons of this storage had been exhausted in supplying 18,000 consumers between the 15th of June, when the reservoirs were full, and the 15th of November, the rainfall during this period amounting to 12.683 inches. The lowest level to which Long Lake has been drawn down being 8 feet below waste-weir on the 14th November, 1905. At the end of December, 1905, the level of Long Lake waste-weir was raised one foot, which will increase the available storage by 115,000,000 gallons.

#### *High Service Gathering Grounds and Storage Reservoir.*

The water-shed of Spruce Hill Lakes amounts to 1,009 acres, including a water area of 218 acres in the lake and 6

acres in Fish Pond. The geological formation is similar to that of the Long Lake water-shed, but the slopes are somewhat flatter. Mr. Keefer estimated the yield from this gathering ground in the driest year at an average of one and one-quarter million gallons per day, and that in wet years this amount would be doubled. The storage capacity of the lake is estimated to be 700,000,000 gallons, or sufficient for a population of 31,000 for 225 days, allowing 100 gallons per day per capita.

*Cleaning Lakes.*

In raising the Spruce Hill Lakes, the area flooded was thickly covered with trees, brushwood and moss, which apparently had never been cleaned out, and which after a short time died and greatly contaminated the water.

The effect was so bad that for a few years previous to 1876 the water became unfit for domestic use. In that year the lake was drawn down to a level of 7 feet 9 inches below the waste-weir, and the bed of the lake was cleared of fallen trees, brushwood and decomposed vegetable matter, and the stumps were grubbed out. The trees and stumps taken out were covered with a green slime. When Long Lake was raised, the shores were thoroughly cleared, but in common with all the lakes certain forms of vegetation thrive between high and low-water level, and it has to be periodically cleaned out.

*Growths.*

The growth of algæ was first noticed in 1878. In that year samples of water, algæ and mud from Chain Lakes and water from Long and Spruce Hill Lakes were collected in September when the water was low and sent to Professor Lawson to analyze. His analysis of water from Long Lake yielded a dry, solid residue, as follows:—

Inorganic matter.....	1.71	grains to the gallon.
Organic “ .....	2.13	“ “ “
Total .....	3.84	“ “ “



Another sample, taken from Chain Lakes near the pipe-house, gave:—

Inorganic matter.....	2.48	grains to the gallon.
Organic “ .....	2.68	“ “ “
Total.....	5.12	“ “ “

The inorganic matter consisted chiefly of alumina and iron, with silica (soluble), common salt and a mere trace of lime. The water belonged to the class of soft waters such as are collected in districts where there are no rocks capable of yielding soluble substances. The sources of the impurity taken up by the water in its passage through Chain Lakes was discovered in the form of a very peculiar deposit found in Upper Chain Lake extending over the greater portion of the lake bottom, of a thickness of over five feet in level places. It varied in consistency from that of soft cheese to that of baker's bread, and in color from whitish to dark ferruginous brown, in some places nearly black. It consists to a very large extent of the remains of microscopic organisms belonging to the class of infusoria. The chemical analyses of four samples is as follows:—

No. of sample.	Color.	Insoluble in H. Cl.	Soluble in H. Cl.	Total Inorganic matter.	Organic matter.	Water.
1	Pale brown.	38.40	11.36	49.76	11.32	38.92
2	Pale whitish.	38.96	9.44	48.40	9.60	42.00
3	Between 1 and 2.	38.16	11.04	49.20	8.72	42.08
4	Dark fur. brown.	.....	.....	24.70	11.85	63.45

This deposit has no doubt originally consisted of swamp muck formed by the remains of plants, infusoria, etc., but by the long subjection to the action of water passing over it has lost much of its organic matter.

A few specimens of fresh-water sponge (*Spongilla*), whose decay gives a very offensive odor to water, were found in Upper Chain Lakes in 1878, and in 1883 the growth was increasing

to such an extent that men were sent to collect all the specimens that could be found, since which date no more have been observed. In 1877 a microscopic alga called *trichormus flos aqua* was found in Spruce Hill Lake, which had the effect of giving the surface of the water, especially near the shore, a brilliant green color. This is not known to be injurious, but is regarded as an indication of water being stagnant or containing organic matter. It has not reappeared, and was probably removed by clearing the lakes of vegetable matter. In 1885 new forms of algæ appeared in Chain Lakes, consisting of a gelatinous substance forming in detached masses, from the size of a marble to a large apple, and adhering but slightly to the soil and stone under water, a light breeze being sufficient to detach quantities of this substance and carry it to the screens in the pipe-house where, if allowed to collect, it would soon cut off the supply to the city. Lime scattered along the shores of the lakes seems to kill this growth, and a certain amount is deposited yearly to prevent its starting.

An analysis of the water from the various lakes was made in 1890 by Mr. Maynard Bowman, with the following results:

SOURCE OF SAMPLE.	SOLIDS.			NITROGEN AS			Chlorine.	Phosphoric Acid.	OXYGEN ABSORBED.		Valuation.	Class A.	Class B.
	Blackend.	Loss on Ignition.	Dry at 100° C.	Albuminoid Ammonia.	Free Ammonia.	Nitrates.			In 15 minutes.	In 4 hours.			
Ragged Lake .....	25	42	.1470	.0471	Trace	4.7	None	2.347	6.057	137.5	III	VI	
Lower Chain Lake .....	35	47	.1814	.0400	"	5.3	"	2.460	6.117	146.1	III	IV	
No. 55 South Street .....	28	43	.1743	.0413	"	5.2	"	2.360	6.039	141.3	III	IV	
No. 66 Bedford Row .....	28	50	.1671	.0314	"	5.8	"	2.460	6.160	144.9	III	IV	
Spruce Hill Lake .....	21	36	.1671	.0400	"	6.3	"	2.620	6.314	50.3	III	IV	
Wellington Barracks .....	28	46	.1814	.0400	"	6.3	"	2.614	6.243	151.7	III	IV	
Quinpool Road .....	28	46	.1814	.0314	"	6.3	"	2.558	6.173	148.7	III	VI	

There are two points in the above that require special consideration, viz., the high figures for albuminoid ammonia and the oxygen absorbed. An opinion based on those leads to but one result, that the water is impure.

According to Wanklyn, Chapman, and Smith, the limit for albuminoid ammonia is 0.066 parts per million for a good water, while here we have from 0.1470 to 0.1814, which is a very large excess.

This impurity is chiefly attributable to contamination with animal matter, but situated as the lakes are and considering their surroundings its origin is not apparent. Nevertheless, there is no question but that Lower Chain Lake must in the spring receive a large amount of impurity from the accumulations of the winter washed into it from the road along its banks. Ragged Lake under this head is the least of all, though its figures are much higher than they should be. As to the oxygen absorbed, 3 parts per million is considered to be the limit of a water of medium purity, while we have here more than 6.

This does not necessarily condemn the water, peaty water not being considered injurious. Still the figures are high, and the water carries a large amount of organic matter and should be filtered before use in all cases.

The following is extracted from a report of Prof. George Lawson on the foregoing analysis:—

“The result of analysis showing Ragged Lake water to contain 0.1470 parts per million of albuminoid nitrogen and the other samples from 0.1671 to 0.1814, the average of the whole being 0.1714, affords sufficient evidence of organic impurity in all the waters. The high rate of oxygen absorbed tells the same tale. In such cases it is usual to regard the albuminoid nitrogen as having its origin in sewage or animal matter, hence the great stress laid by water analysts upon the albuminoid nitrogen. Without further knowledge of them,

these three waters, with the exception perhaps of Ragged Lake, would be regarded by most water authorities as impure, unfit for use, or at least, doubtful. It may be, and I incline strongly to this view, that the acidity of our waters enables it to give results by the ordinary ammonia process which tends to exaggerate the apparent amount of albuminoid nitrogen. It is still more likely that a large proportion of the albuminoid nitrogen is due to vegetable sources. The avidity for oxygen is probably owing to peaty and other vegetable substances, as well as ferrous salts, all of which we know exist in the water and are not injurious in the way in which decaying animal matter and sewerage are. For these reasons, I see no immediate cause for alarm, but there is certainly good reason for thorough investigation as to the sources of the apparent pollution. Dr. Fox, in his book on sanitary examinations of water, etc., gives an analysis of a water closely resembling the Halifax samples (albuminoid ammonia=0.18, free ammonia=0.08, nitrates and nitrites=0.1, chlorine=4.5) and remarks, 'Such a water when the nitrates and nitrites and chlorides are insignificant cannot be condemned, but would simply be described as somewhat dirty.' It may be that our Halifax water is not essentially impure, but only somewhat dirty. Those who use it are impressed with this latter feature of the water by observing its color and sediment. As a natural water accumulated in a silicious and granitic, rocky, comparatively uninhabited district it ought to be pure and no doubt will be when measures are taken to preserve its purity. The first thing to be done is to make a thorough survey of the shores of the several lakes and their tributary streams, and of the deposits and accumulations in the lake bottoms. In this way the sources of pollution can be reached. It may then be possible to avoid or remove them and to supply Halifax with as pure water as is within reach of any city on the continent."

In October, 1905, samples were collected and analyzed by Prof. E. MacKay, Dalhousie College, with the following results:—

SOURCE OF SAMPLE.	AMMONIA.		Chloride.	NITROGEN.		Required oxygen.		Total solids.
	Free.	Albuminoid.		Nitrate.	Nitrate.			
Long Lake .....	.01	.222	19.5	.425	.....	9.870	12.8	118.0
Tap, Young Avenue...	.014	.224	10.9	.400	.....	9.80	13.4	122.8
Spruce Hill Lake ....	.026	.120	8.0	.300	.....	9.68	14.1	103.2
Tap, Dalhousie College.	.020	.124	7.8	.300	.....	9.60	14.1	107.9

The above are given in parts per million.

In his report Prof. MacKay says: “All samples had a somewhat yellowish tint due to dissolved vegetable matter. Of the total dissolved solids more than 70 per cent. was found to be of vegetable origin. The amount of vegetable matter is relatively large, and to this is due the high values found in ammonia. The analyses showed all samples to be wholly free from indication of essentially injurious constituents or contamination.”

In a paper read before this Institute, Dr. Campbell said he found the Halifax water remarkably free from bacteria.

*Dams and Waste-Weirs.*

The dam at the foot of Long Lake was built by the Halifax Water Company in 1848. It was 950 feet long and 29 feet high. The original design called for a structure 20 feet wide on top, 29 feet high above the surface, the inner slope to be 3 to 1 and the outer 1½ to 1; a puddle-wall to be built 6 feet thick, its front in line with the inner edge of the top, to be backed with 6 feet of coarse gravel, the whole surrounded with fine gravel and loam; the outer slope to be covered with

stones, the toe of the inner slope to be composed of coarse gravel and small stones; the level of the waste-weir (which was a wooden structure) to be 200.00 feet above mean low tide.

In 1877 the dam was raised and strengthened by putting rafts of brushwood and straw covered with fine material in front where leaks had developed, and raising the dam five feet, widening the top to twenty-four feet and flattening the outer slope to  $2\frac{1}{2}$  to 1. The water side was protected by a heavy sloping wall surmounted by a granite coping 18 inches high and forming a low wall along the front. The dam was lengthened to 1,018 feet to the west of the waste-weir. In 1892 the dam was raised two feet and strengthened by depositing 5,000 cubic yards of good material on the face. The present waste-weir at an elevation of 205.99 feet above low tide was constructed in 1878 of massive granite masonry and strengthened in 1888 by the addition of a concrete wall at the front. It is 62 feet 6 inches long and the crest is 3 wide and level, the fall from the crest to the apron being  $3\frac{1}{2}$  feet. The latter is constructed of granite slabs about six feet long with granite paving outside. There is a sluice-way closed with an iron gate at the eastern end, 62 inches wide and 50 inches high and at a level of 198.90.

In December, 1905, iron staunchions were secured to the top of the weir and the sill raised one foot, or to an elevation of 207.00 by placing two 6-inch timbers in position.

The highest level to which the water has risen over the weir is 25 inches on the 19th October, 1896.

In 1873 leaks were reported in the Long Lake dam by the city engineer, and in June, 1877, thermometrical observations were taken in the lake and at each of the runs of water along the foot of the dam, when it was found that the two largest runs were from leaks and the rest from springs under the embankment. Weirs were placed on these, and the actual amount of leakage was found to be 14.7 gallons per minute from the

eastern one and 6.6 gallons per minute from the western one. As the results of the improvements made in 1892 these leaks have been very materially reduced, in one case a flow of 2 inches over the measuring weir dwindling to  $\frac{1}{4}$  inch and the other stopping altogether.

When Lower Chain Lake was raised in 1894, a new dam was constructed outside the existing one. It is practically two dams joined by a natural hill, the north one also having a hill projecting into and buttressing it. The north part of the dam has a concrete core-wall 4 feet wide on top and 6 feet at bottom carried down to the solid ledge-rock and continued into the banks on each side and running through the waste-weir. The embankment is formed of gravel and loam laid in thin layers and well compacted. The old 12-inch pipe used to let down water to the mill owners runs through the dam, also the 24-inch main to the pipe-house, which is at the foot of the outer slope. A leak developed where the 24-inch came through the core-wall, but it was repaired with concrete and has shown no signs since. The length of this dam is 550 feet, the top width 12 feet. The outer slopes are 2 to 1, and the inner 3 to 1, paved with heavy stones. The waste-weir is at the northern end of the dam at an elevation of 206 feet, and is of similar design to the Long Lake weir, the dimensions being 16 feet long, width of crest 3 feet, and a fall of  $9\frac{1}{2}$  feet broken by a ledge  $5\frac{1}{2}$  feet from the crest. The apron is paved with heavy granite slabs and concrete. A 20-inch exit pipe runs through the weir to be used as a waste pipe. The south part of the dam is constructed to the same design as the northern part, with a gate-house in the centre of it. The top and outer slopes of both this dam and Long Lake dam were covered with street sweepings hauled from town and sown with grass seed and in a year were covered with a strong, thick sod. There are two small dams between the two Chain Lakes, the south one built in 1883, with a sluice 24x36 at a level of 194.70; the north with the old waste-weir built in 1886.



The main dam at Spruce Hill Lake is an earthen structure 1,200 feet long, 12 feet wide on top the slopes, both inner and outer, being built of granite about 16 inches thick. There is no puddle or core-wall through it, but it was built by simply compacting layers of the best available material. There are two smaller dams about 300 feet and 250 feet long respectively, of the same section as the main dam. The dams were constructed in 1868 and the granite face wall in front of the dam was built in 1891-3 and the dams raised at that time. The present waste-weir was built in 1883 at an elevation of 362.79. It is constructed of granite with four openings of 9 feet 3 inches each in the clear, separated by cast-iron standards to receive stop logs to retain the surplus water. There are three such timbers in place, each 6 inches square, thus raising the level to 364.29.

#### *Gate-Houses.*

There are two gate-houses at Chain Lakes. The north one, originally built in 1857, is located at the north part of the dam at the toe of the outer slope, and consists of an iron tank built in sections, bolted together and caulked. The water is drawn from the lake to this chamber by a 24-inch pipe. It was raised in 1894 by bolting a section to the existing chamber. The 24-inch supply main is connected with this house.

The south gate-house was built in 1894, over the channel which led to the old south pipe house, which was the original one built in 1848 and destroyed when the new one was completed. The new one is built of concrete and is 16 feet deep by  $12\frac{1}{2}$  feet wide by  $16\frac{1}{2}$  feet long with walls 4 feet thick. It is drained by a 12-inch pipe. Both the 24-inch and the 27-inch mains connect in this house, but may be separated should occasion arise. There is a straining wall about 100 feet long in front of this gate-house built of loose stones, 4 feet 6 inches thick on top with slopes of 1 to 4. The new house is ample in size and avoids the difficulty always had with the north house which is too small to vent the water freely, and was always in

danger of choking up owing to the small size of the screen chambers. There is a weir near the north gate-house to measure the water let down by the 12-inch pipe to the mill owners.

The original Spruce Hill Lake gate-house was of similar design to the old ones at Chain Lake, consisting of an iron tank with three divisions, an inlet, screen and outlet chamber, and was built about 150 feet north of this dam, a 20-foot pipe running through the dam and connecting with the lake. In 1889 a permanent structure of brick, concrete and granite was built in the dam of the following dimensions: 16 feet deep by 10 feet 4 inches wide and 8 feet 5 inches long, with walls 4 feet thick.

The screens are made of No. 19 brass wire, and have sixty-four meshes to the square inch.

Employees of the water department live both at Spruce Hill Lake and at Chain Lake dams, whose duty it is to look after the dams and gate-houses. The screens, in summer when the water is low, require changing frequently as they become choked with leaves or other impurities suspended in the water. During the fall of 1905, when the water was at its lowest, two men were on duty day and night continually changing the screens, otherwise the supply could not have been kept up to the city through them.

#### *Canal.*

As has already been stated, the water was conducted from Long Lake to Chain Lakes by a canal, which was originally constructed in 1848 by an open cut, and was intended to be low enough to draw the water of Long Lake down seven feet below the waste-weir level, but during construction, owing to difficulties met with by the contractor, the grade line was raised 1 foot 3 inches, thus, only allowing 5 feet 9 inches of Long Lake water to be drawn off. The conduit was 2 feet by 2½ feet, and was entirely too small to pass the water in sufficient volume to give full effect to the storage of Long Lake. The present

conduit, rebuilt in 1886, is 1,300 feet long,  $3\frac{1}{2}$  feet wide and  $4\frac{1}{2}$  feet high, built of 4-inch by 4-inch hemlock deal, with four manholes throughout its length. Its upper end is at an elevation of 196.20, with a fall to Chain Lake of six inches.

### *Ice.*

The experience with the formation of anchor ice has been similar to that of other places. With a sheet of open water at a temperature of 32 degrees F., and the temperature of the air varying from 5 degrees to 20 degrees above zero, and a high wind blowing, the ice forms in small detached needles or crystals. Thin portions of it accumulate in spongy masses and float along at or below the surface, their specific gravity differing but little from that of water. They adhere readily to all solid bodies with which they come in contact, and grow rapidly when once they have secured a centre of crystallization. It will not form in bright sunshine—on the contrary, it rises to the surface in spongy masses, and when the surface freezes over it lets go its grip. The lee side of a reservoir gets most of its anchor ice, and whenever we have been troubled with it the wind has always been from a north-westerly direction. Between 1883 and 1893 no trouble was had from ice, and it is thought that this was due to the fact that a screen of stout pickets driven into the bottom, capped on top with a boom rising and falling with the level of the water, was placed in front of the gate houses. In 1892 this was removed, and on the 11th December of that year ice closed the sluice gate at the south gate-house cutting off the supply to the 24-inch main, and continued until four o'clock in the morning, when the wind subsided, and the ice stopped running. In 1898 the filter wall already referred to was built in front of the south gate-house, but ice formed inside the wall, and there was danger that the gate-house would freeze up solid, so the screens were removed until the danger had passed. This is the last time there has been any trouble from it.

*Riparian Rights.*

When the Halifax Water Company decided to bring the water from Chain Lakes there were several mills situated on the stream flowing from the lakes and enjoying the privilege of the water from them. Some difficulty having arisen in securing the rights to the water, it was seriously contemplated by the company to bring the water direct from Long Lake. However, an agreement was eventually made in 1849 with the owner of the privileges, that for a consideration of £500 the water company could build dams and take the water from Chain Lakes, provided that they would not interfere with the natural flow through the lakes as heretofore enjoyed by the mill owners. The first difference arose in 1863, when the commissioners of water-supply received a letter from the attorneys of the mill owners, stating that the mills had closed down for want of water, and that in previous years the water company had let down a supply in dry weather. The commissioners on this occasion gave orders to their superintendent to let down enough water to fill Chocolate Lake, on the understanding that this was not to be taken as a precedent or to act as any acknowledgment of the rights of the mill owners to the supply, and on April 13th, 1863, they presented a lengthy report dealing with these claims. From that time to this there has been constant friction with the mill owners as to the amount of water which should be let down to them under the agreement. This has culminated in an action being brought by them for a declaration of their rights and an injunction restraining the city from interfering with their supply. As this is now before the courts the question may not be discussed fully, and is mentioned only to serve as an example of the necessity for looking to the demand for a largely increased supply always following the introduction of water to a town in a short time, and of the advisability of either securing all the rights to a watershed, or at least, having a definite agreement as to the actual quantity to

be allowed the owners, and the method by which said quantity should be measured.

### *Mains.*

The water was originally brought from the Chain Lakes to the city by a 12-inch main to St. Andrew's Cross, laid in 1848, and was assumed by Mr. Jarvis to be capable of delivering at this point 800,000 gallons daily. It was of cast iron, and was ordered in Scotland through Messrs. Kidston & Son, of Glasgow, and cost £7 5s. per ton delivered, the freight being 15/ per ton. 2,550 feet of these pipes were to be  $\frac{5}{8}$  inch thick, to be tested to withstand a pressure of 160 pounds to the square inch, and 13,650 feet to be  $\frac{1}{2}$  inch thick tested to 145 pounds. All pipes were to be 9 feet long. 550 of these pipes were ordered with spigots cast on them to fit a  $\frac{3}{4}$ -inch iron service pipe, so that the water would not have to be turned off in making connections. The pipes were uncoated and were laid with lead joints.

In January, 1856, the water company ordered from Kidston & Sons 284 lengths of 15-inch pipe, 9 feet long,  $\frac{3}{4}$  inch thick, to be laid in the valley of the North West Arm, and 1,341 lengths  $\frac{5}{8}$  inch thick; the pipes to be tested to 165 and 135 pounds respectively. These pipes were laid during that year alongside the 12-inch. The estimated delivery of this pipe was over 1,000,000 gallons per day at St. Andrew's Cross. Messrs. Kidston wrote to the directors recommending the use of a coating (Smith's patent varnish) which was then just coming into use, and the directors wrote saying that if this coating had the approval of authorities in Great Britain to put it on the pipes; but subsequently, fearing it would reduce the capacity of the pipes, passed the following resolution, a copy of which they sent their agents:—

Resolved,—That the directors having ordered a 15-inch pipe, which was larger than was contemplated for the very purpose of preventing the pipes filling up, do not consider that the

glazing mentioned will be necessary; but if the glazing is considered an advantage that all the small pipes ordered be glazed.

Fortunately, before this letter was received, the order had been placed and the pipes came out coated. These pipes were laid with wood joints. The cost was £5 14s. 10d. per ton, exclusive of freight.

In 1862 the commissioners of water-supply took up the original 12-inch main and substituted therefor a 24-inch main. These pipes were ordered from Glasgow. The quantity required for the North West Arm valley to be 1 inch thick, tested to 200 pounds; and the remainder to be  $\frac{3}{4}$  inches, tested to 150 pounds. All pipes to be 9 feet long and coated with Smith's patent coating. They were laid with wooden joints and cost £4 4s. 3d. per ton, exclusive of freight or duty, or £6 18s., exclusive of truckage. The total cost of laying this main was \$54,994.39, or an average cost of \$4.00 per lineal foot. The estimated capacity was  $5\frac{1}{4}$  million gallons when new. There is a 12-inch exit pipe at the Dutch Village Road. On the introduction of the "high service" in 1868, the 15-inch main laid in 1856 was used as a part of the supply main and was extended to within  $1\frac{1}{4}$  miles of Spruce Hill Lakes, this latter distance being laid with 20-inch pipe. These are  $\frac{5}{8}$  inch thick and the 15-inch are  $\frac{3}{4}$  inch. They are 9 feet long and coated with Smith's patent varnish and are laid with wooden joints. That portion of the old 15-inch lying in the valley of the Arm was uncovered and lead joints substituted for the wood. On the 14th January, 1869, the commission had a report from their superintendent, complaining that the 15-inch pipes laid the previous year were giving considerable trouble from the fact of the unequal casting, a number of pipes breaking under a pressure of 68 pounds. On examination these pipes were found to be only  $\frac{3}{8}$  inch thick on one side and full  $\frac{7}{8}$  inch on the other, and during the winter the pressure was regulated so as not to exceed 45 pounds at Chain Lakes pipe house. The pipes split along the thin side. The

estimated capacity of this main when discharging at an elevation of 250 feet was 2,485,000 gallons. There are exits in this main at the end of the 20-inch, at Beaver Dam Brook, at head of Chain Lakes, and at the Dutch Village Road.

In 1893 a new low service main, 27 inches in diameter, was laid from the Chain Lakes. This main follows the route of and is laid alongside the other two supply mains, to the brow of the hill on the western side of the Dutch Village Road, thence striking across the valley in a straight line to Bayer's Road near North Kline Street, thence along Bayer's Road and in prolongation thereof to Kempt Road, and then to Young Street at the corner of Gottingen Street, connecting there with a 24-inch main running to Cogswell Street, where the latter joins the 12-inch and 15-inch running from the 24-inch at St. Andrew's Cross. The specification for this pipe calls for three thicknesses— $\frac{3}{4}$ ,  $\frac{7}{8}$ ,  $1\frac{1}{2}$ ,—the first to test to 250 pounds, and the latter to 300 pounds per square inch, and while this test is being applied the pipes to be struck a series of sharp blows at various points throughout their length with a 3-pound hammer attached to a handle 16 inches long. The pipes are 12 feet long with turned and bored joints, and coated inside and out with coal-pitch varnish. The contract price delivered in Halifax, free of all charges, was \$32.05 per 2,000 pounds for plain pipe and \$56.10 for special castings. The contract for excavating the trench was let for \$1.85 per cubic yard for rock and 28 cents for earth excavation; measurement limited to a trench 4 feet wide. The cost of the 27-inch main laid was \$5.71 per lineal foot, inclusive of all charges. The cost of the 24-inch laid in Gottingen Street was \$5.52, inclusive of all charges. This main slopes from the lake and from Gottingen Street to the Dutch Village Road, where a 12-inch exit pipe is placed.

#### *Coating.*

The coating on the high service main and on the 24-inch was ordered as "Smith's patent varnish." This is probably the

coating process of Dr. Angus Smith, which was first introduced in the United States in 1858. The weight of experience seems to show that in uncoated pipes the first ten or twelve years of their life results in more or less rapid corrosion. After they have become thoroughly tuberculated very slight changes take place. If this is removed by scraping or cleaning it begins to form again, and the life of the uncoated pipe becomes much reduced.

The interior of coated pipes become tuberculated in the same way, due to a large extent to defects in the coating, but very much less quickly, and when removed by scraping the iron is uninjured. The writer was present recently when a piece of pipe was cut out of the 15-inch main, and when the deposit was rubbed off the coating was as sound and good as when first put on. The outside of the pipe was also in good condition. The pipe had been cleaned a year previous, and the tubercules had not begun to form, but there was a slight deposit over the face of the pipe. The following points should be observed in coating cast-iron water pipes:—

That the ovens in which the pipes are heated before being dipped in the coal tar bath shall be so arranged that all portions of the pipes shall be heated to an even temperature.

The pipes should be heated to a temperature of 300° F. before being dipped.

The varnish to be heated to a temperature of not more than 300° F., and kept at this while the castings are in the bath.

The pipes should not be submerged for less than five minutes, and when taken from the bath should be evenly coated.

#### *Joints.*

There are three kinds of joints in use in the water system, —lead, wood, and turned and bored. These latter joints have been in use since 1890, but they do not seem to find favor with engineers in America and are very little used in Canada or the United States; although in the Metropolitan Water Works of



Mass., for the crossing of the Charles River, one of the three kinds of joints used was described as follows: Three turned grooves were made in the bell instead of the single one so as to hold the lead more securely, and the spigot was smoothly turned with a straight taper to a standard pattern so as to be interchangeable. After inserting one of these tapering spigots in the bell of the pipe and running the joint with lead the spigot could be withdrawn, and when again inserted would make a tight joint. This is practically one pattern of a turned and bored joint. In the pattern used in Halifax a lip or rim is cast on the spigot end of the pipe, varying in length from  $2\frac{1}{4}$  inches in a 27-inch, to  $1\frac{3}{4}$  inches long on a 6-inch pipe, tapering about 1-24 of an inch in its length. A finished lip or rim is cast in the hub, the pipes are then centered in a lathe and the rim on the spigot end is turned and the rim on the hub end is bored by the same movement of the lathe. Care is taken that the pattern is made to give a full size casting so that when planed down the ends fit accurately. The total depth of the hub varies in the different sizes from 4 to 5 inches.

In laying, the pipe is lowered into the trench with the joint smeared with oxide paint, and placed in position on the blocking, entering the faucet of the last laid pipe. The next pipe is then lowered and held in its slings while the men in the trench swing it backwards and forwards and thus ram the last laid pipe tightly home in its place. A block of hard-wood between the pipes are lowered with a derrick. Should there be any slight diameter are held in slings by four men on the bank; larger pipes are lowered with a derrick. Should there be any slight weepage the joint soon rusts tight. In the fifteen years' experience with this form of joint there have only been two discovered leaks through them, one in the 27-inch main near Young Street, and one in the 6-inch main in Young Avenue. In the latter case the pipe was laid in the sewer trench. As the back filling of the latter settled, the blocking of the pipe was disturbed and the pipe settled and drew one joint. In the

case of the 27-inch, a leak developed during the winter following the laying of the pipe, and on digging down to the main a joint was discovered to have drawn out about  $\frac{3}{4}$  of an inch. This was caulked with cold lead and gave no trouble until the following winter, when it again showed signs of leaking, and on investigation the joint was found to have drawn another  $\frac{1}{2}$  inch. The blocking of the pipes on each side had apparently not settled out of place, being laid on the top of the ledge rock. It was thought that this drawing apart of the joint might have been due to the contraction of the pipes. Assuming the difference of temperature to have been 30 degrees, which is a fair estimate between the temperature of the pipes when laid and when the leak developed, the contraction to open the joint  $\frac{3}{4}$  inch would have to take place through 324 feet of pipe. If this took place on each side of the defective joint there would be a strain on the joint of over 16 tons, the pipes weighing a ton and a quarter to the 12-foot length, if the leakage was from this cause, it should close up again in the summer when the temperature of the pipe rose. Unfortunately, the  $\frac{1}{2}$  inch which is said the pipes separated in the second winter was not measured accurately, but was estimated by the foreman and may have been overstated; but assuming it to be correct, the writer cannot advance any theory for the increase in the opening from this cause, as there would not be any more difference in the temperature than the amount given above. It is possible that the joint may not have been driven home, and as at this point there was only about four pounds pressure when testing, the oxide paint used may have prevented the leak showing when the pipe was tested on being laid, and a settlement may have occurred in one or two lengths of pipe distant from the leak dragging the pipe apart at the weakest point.

It will be seen from the description of the method of laying, that the process of lowering and blocking is exactly the same as for plain pipe, except the ramming home, which takes but very little more time than the extra care required in centering the pipe for a lead joint and then the joint is complete; whereas,

with the plain pipe the process of joining has not yet been begun and necessitates considerable labor and material being employed to finish the work. To get the best results with lead or wood joints also requires a higher class of labor. The pipes can be sprung around curves, but in this case should be caulked with lead.

Previous to the introduction of the turned and bored pipes, wooden joints were used extensively for pipes of 6 inches and over. They have the merit of cheapness as compared with the lead joint and are durable, but possess the defect of being liable to be blown out with a sudden increase of pressure, and most of our trouble with discovered leaks has been from this cause. The faucets of the 24-inch and 15-inch for this kind of joint were made tapering  $\frac{1}{8}$  inch inwards. The joint is made as follows:—After the pipe is inserted in the socket it is raised up by means of a tool called a raising iron and soft pine wedges or staves, thoroughly seasoned and cut to the radius of the pipe, are inserted on the lower side for about  $\frac{1}{3}$  of the circumference of the pipe. The pipe is then lowered, and raising irons are driven in the top and on each side of the joint, at intervals of about 3 to 5 inches. The wedges are then driven in with a sledge-hammer beginning from those already laid and working up both sides, the raising irons being withdrawn as the work proceeds. When all the wedges are in, keys are driven where necessary between them to tighten the joint.

The wood joints in the 15-inch main, where under the water of the Chain Lakes, were strengthened by adding an angle strap of wrought-iron bolted closely to the pipe in front of the wedges. The difference in cost of turned and bored, and plain pipes, has varied from 55 cents to \$1.00 per ton, the former being the difference in the tenders for the 27-inch and 24-inch pipes laid in 1893. The net saving over lead joints in laying the 27-inch main amounted to \$3,147. Taking the cost of turned and bored pipes at 75 cents per ton more than plain pipes, the following table gives the detailed cost of laying mains with turned and bored, lead, and wood joints.

Cost of Laying and Jointing, 9 feet lengths of C. I. Pipe with Wood, Lead, and Turned and Bored Joints.

Size in inches.	WOOD.										LEAD.					TURNED AND BORED.				
	Weight of 9' length.	No. of pipes six men will lay and test in 10 hours, costing \$10.20.	Cost of labor per length.	No. of staves @ 1 1/2".	Cost of staves and wedges.	Cost of one length laid, jointed and tested.	No. that 6 men will lay and test in 10 hours, cost \$0.20.	Cost of labor per length.	Lbs. lead @ 3 1/2c.	Cost of lead.	Lbs. gasket @ 6 1/2c.	Cost of gasket.	Cost of one length laid, jointed and tested.	No. that 6 men will lay and test in 10 hours, cost \$10.20.	Cost of labor for each length.	Extra cost of pipe per length @ 7 1/2c. per ton	Cost of one length laid, jointed and tested.			
24	2077	10	\$1 02	22	\$0 44	\$1 46	10	\$1 02	50	\$1 75	1	\$0 04	\$2 81	15	\$0 68	\$0 75	\$1 43			
20	1263	12	85	19	38	1 23	12	85	40	1 40	1	04	2 29	18	56	47	1 03			
15	1128	15	68	16	32	1 10	15	68	30	1 05	2	02	1 75	23	44	42	86			
12	680	20	51	13	26	77	20	51	24	84	1	02	1 37	32	32	25	57			
9	500	25	41	12	24	65	25	41	17	60	2	02	1 03	40	25	19	44			
6	280	30	34	9	18	52	30	34	12	42	1	01	77	50	20	11	31			
4	156	.....	.....	.....	.....	.....	40	26	8	28	1-10	01	55	60	17	05	22			
3	130	.....	.....	.....	.....	.....	50	21	21	21	1-10	01	43	.....	.....	.....	.....			

*Incrustation of Pipes, and Cleaning.*

In 1875 the old 3-inch water pipes laid by the Halifax Water Company having become almost choked up with rust and sediment, they were cleaned out during the succeeding year by a scraper attached to iron rods and propelled by hand. The scraper had four arms or knives, attached to a center and sprung outwards by a thick rubber disc. This method was not practically applicable to pipes of a larger diameter than 12 inches. The cost of cleaning was 14 2-10 cents per lineal foot. In 1880 about a mile of 12-inch pipe was cleaned by a self-acting mechanical scraper, imported from Scotland, and known as the Kennedy scraper. 1887 Mr. Keating, the city engineer, at that time, constructed new scraping machines which differed from the others in having additional springs for the cutters and pistons. These scrapers consist of an iron rod to which are attached two pistons and two sets of cutting tools, one in front of the other. The cutters are each made up of four strips of steel  $2\frac{1}{2}$  inches broad, sloping backwards from the rod, and at their outward termination sharpened like the barbs of an arrow, thus they can yield when necessary and the cutting diameter can be altered by moving the steel strips. The pistons are of iron, lead and leather to which are added rubber springs. All the main supply pipes were cleaned in that year at an average cost of 2 8-10 cents per lineal foot. The immediate results were that the average pressure on twenty-five hydrants on the wharves increased from 34.2 pounds in February, 1881, to 52.4 pounds in February, 1882. These were on the low service. On the high service there was a pressure of 19 pounds on hydrants where in the previous year there had been no water at all. The pipes have been cleaned periodically since that date and usually twice a year.

In cleaning the mains the water is turned off at the gate-house and the exit opened and pipes emptied. A section of pipe, jointed with collars and bolted together, is removed and

the scraper inserted by hand into the main. The piece taken out is then replaced and secured. The water is turned on, and by its power forces the scraper along. As it passes the exits they are turned off by men stationed there, and the scraper continues its course to the end of the main where a length of pipe has been removed. A sufficient quantity of water escapes through the valves ahead of the scraper to wash the incrustation removed and keep it from sticking. The water is allowed to run for some time until the sediment disappears, when it is shut off and the length of pipe inserted again and the water turned on to the distribution pipes. The average cost of cleaning the 24-inch low service main for the past twenty years has been 15.07 for each cleaning of 13,400 feet, and of cleaning the high service main \$18.80 for each cleaning of 36,340 feet. Between 1882 and 1904, both inclusive, there has been cleaned 223 miles of mains at a total cost \$732.07, or at an average rate of \$3.28 per mile.

#### *Distribution Mains.*

The pipes in the distribution system are of cast iron, all those laid since 1855 being coated, and those 6-inch and over laid before 1890 having mostly wooden joints. They range in size from 3 inches to 24 inches in diameter, the mains to the hydrants being, with few exceptions, taken from a 6-inch pipe or larger. Some of the old 3-inch mains lately removed and replaced with larger pipes, when cut, were found to be so choked that there was barely room to insert a lead pencil through the opening. These were old, uncoated pipes and the metal had deteriorated badly. The mains are generally laid on the north and east sides of the streets, with valves set in line with the street lines. Iron pipes with sleeves were first used for stopcock boxes about 1862, before that wood had been used. The valves used for letting the high service into the low for purposes of fire protection are kept clear from ice and snow during the winter.

In 1905 there were 69.68 miles of mains and distribution pipes, and 804 valves.

#### *Hydrants.*

There were 424 hydrants in use at the end of 1904. A large number of these are of an old style set in a brick-well or chamber below the sidewalk inside the curb. The chamber is covered with a cast-iron plate, provided with a hatch, by which access is gained to the bottom of the hydrant where it joins the branch from the mains. This arrangement, while admitting of the easy removal of the hydrant, is objectionable on account of the difficulty and expense in keeping the valves free from ice, and the large iron plate becoming smooth and dangerous to pedestrians. These hydrants are gradually being replaced by a hydrant of a special pattern. The main valves and guide-rod, which also forms the waste valve, are similar to the Matthews' hydrant. A brass and leather attachment to the valve rod forms the waste valve. There is a waste hole bored in the center of the flange in the stand pipe against which this valve works. The hole was formerly at the bottom of the hydrant, but owing to the difficulty of reaching it, it has in the later patterns been placed in the side. The main screw of the valve rod is protected from the action of frost and water by a partition and stuffing box. The frost jacket is securely bolted to the iron seat, and when once set need never be removed. It forms an air chamber which prevents the frost from reaching the valve. A third nozzle is added to take the suction hose of the fire engines. The hydrants are examined and opened twice a day by the employees of the water department all through the winter.

#### *Service Pipes.*

When the city took over the works in 1861, only about one quarter of the number of families on the line of pipes were supplied with water directly by service pipes to their houses, the remainder obtaining their supply from the free domestic hydrants paid for by the city. These service pipes were in all cases  $\frac{3}{4}$  inch cast iron pipes connected to the distribution mains

by spigots cast on the latter. When on the assumption of control of the works by the city, a general assessment was levied to provide the funds necessary to maintain them, all citizens on the line of pipes applied for service pipes to their properties. There had been considerable doubt in the minds of the directors of the water company as to the material to be used for service pipes, and in 1846 they asked Mr. Jarvis for a report as to the merits of tin-lined lead pipes for this purpose. He replied that three-quarters of the service pipes used in New York at that time were common lead pipes, and adds that there was considerable discussion then going on as to the injurious effects of lead pipe on water. He had no doubt they injured a pure water, but that the length is so short that no material influence is produced. However, the water company, as before stated, laid all service pipes of cast-iron. The commissioners of water-supply decided to use lead pipes, and during their first year in office they laid over  $6\frac{1}{2}$  miles of lead service pipes to supply water to 1,058 takers. A large number of these were renewals as the old  $\frac{3}{4}$  inch iron pipes were found to be badly choked and corroded. Since that time all services have been lead pipes. While Halifax water is a very soft water, and as such, from general observation elsewhere, should be injuriously affected by lead pipes, such has not been the case, the experience being that after a short time a film or layer of sedimentary deposit forms over the surface of the pipe which prevents the water coming in direct contact with it. No cases of lead poisoning from using the water have been reported since the introduction of lead pipes for services in 1861. Under the regulations of the water department, each building is entitled to one  $\frac{1}{2}$  inch service pipe laid at the department's expense from the main to the street line. In the event of a larger pipe being required the difference in cost is paid for by the person desiring the same. In the winter of 1882-3 a very large number of underground leaks were discovered and were found to result from the service pipes being severed at the connection with the



main. The gas company had the same trouble during this winter, and the city engineer at the time suggested that the only cause of this could be from shock of earthquake felt on the peninsula on the 31st December, 1882. Subsequent to the explosion of the Acadia Powder Company's works at Waverley (about 12 miles from Halifax) on the 1st January, 1905, the gas company had the same trouble with a number of their service pipes, especially on Coburg Road and in that vicinity, but the water pipes escaped injury.

At one time in the history of the works eels were a constant annoyance in choking service pipes, but latterly it is quite rare to have any bother from this cause. An exception to this was in 1896, when owing to the danger of ice blocking the screens at the pipe house they were removed, and the following spring there were several complaints of service pipes being choked by eels.

The total number of service pipes laid up to the first of January, 1904, was 6,939.

#### *Consumption and Waste.*

In January, 1906, three Venturi meters were received from the makers, to measure the quantity of water flowing into the city. One of them the 15-inch, was installed, and it was hoped that results would have been obtained before the reading of this paper, but owing to delay in sending the registering apparatus no records have as yet been obtained.\*

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\* The Venturi meters having been set and put in operation during the period between the reading of this paper and its publication, the exact consumption has been obtained, and this note is added giving the revision of the figures in accordance with the information thus gained. For the 24 hours ending at 1 p. m. on the 6th December, 1906, the following quantity of water passed through the meters:—

Through the 14" meter	2,291,500	gallons.
"    24"    "	4,492,500	"
"    26"    "	4,586,000	"

Making a total of 11,370,000 imperial gallons flowing into the city. This would give a consumption of 140 gallons per day per consumer on the high and 477 gallons per consumer per day on the low service, or an average of 321 gallons per day per consumer, or taking the whole population of the city, an average consumption of 277 gallons per capita per day. The figures given in the body of the paper were conservatively estimated, and while startling enough, were considerably below the actual results, which are unequalled by any other city of which the writer has any knowledge.

The Venturi meter is different in principle, design and operation from the water meters generally used for measuring water, it consists of two truncated cones of cast-iron, joined at the smallest diameter by a short throat lined with brass having a diameter varying in different meters from one-quarter to one-half of the diameter of the large ends of the cones, the three parts making what is known as the meter tube. At the up-stream end and at the throat small holes are drilled into the tube, from which pipes are carried to the register. The operation of the meter is due to the fact that when water is flowing through the tube the pressure at the throat is less than at the up-stream end, and that the difference in pressure is dependent upon the quantity of water flowing through the tube. The differing pressures at the up-stream end and throat of the meter tube are transmitted through small pipes to the register, which can be located at any convenient point within 300 to 400 feet of the tube. In the register the differences of pressure affect a column of mercury which carries a float. The position of the float is thus made dependent upon the quantity of water passing through the meter; and by suitable mechanism the quantity is recorded by a counter, and the rate of flow at intervals of ten minutes is recorded upon a chart, so that the fluctuations in the flow throughout each day can be observed. Although the pressure at the throat of the meter is often several pounds less than at the inlet or up-stream end, the lost pressure is almost all regained by the time the water reaches the outlet end of the tube, so that the net loss of pressure caused by the meter is seldom more than one pound under ordinary conditions of use. The meters in Halifax are set on a by-pass so as not to interfere with the operation of the scraper in cleaning the mains.

As there has been no direct means of measuring the water used it has had to be estimated by finding out the loss of pressure by friction in the pipes by gauges placed on hydrants at different points, and to estimate the co-efficient to use

in the Chezy formula. In a report on the water system of St. John, N. B., it was found, by experiment, that the co-efficient to use there was 65. For new pipe this should be about 120, so that the discharge from their 24-inch main laid in 1873 would be a little more than one-half that of a new pipe. The 24-inch and 15-inch in Halifax have been cleaned regularly twice a year for some time, although the usual fall cleaning was omitted last year on account of the lowness of the water in the lakes; but from an inspection of the condition of the pipes where cut this year, the above co-efficient of 65 is considered much too low for the mains of the Halifax water-works system, and 80 would be nearer the mark, although this is considered a minimum. However, assuming 80 to be applicable, the amount of water flowing into the city on the 8th of January, 1906, was 3,288,600 gallons through the 24-inch main, 4,294,000 gallons through the 27-inch main, and 1,600,000 gallons through the 15-inch main, or a total of 7,582,600 gallons for the low service and 1,600,000 for the high, or 9,182,600 for the whole city. The day was mild and there had been but little frost for some days previously. There are 19,000 consumers on the low service and 16,400 on the high. This would mean an average consumption for all the water takers of 260 gallons per capita per day, or 399 gallons per capita on the low service and 98 gallons per capita on the high.

Our population as given by the last four census returns is as follows:—

1871 .....	29,582	1881 .....	36,100
1891 .....	38,437	1901 .....	40,332

The figures for per capita consumption were given for the actual number of consumers. The better and usual practice is to give the per capita consumption for the total population as there may be some industries using large quantities of water, the employees of which may not be using water for domestic purposes. The figures given above would show a consumption

for the entire population (assuming it to be 41,000) of 224 gallons per capita per day. From exhaustive investigations undertaken by the Metropolitan Water Board of Massachusetts, the conclusion arrived at was that a liberal supply for domestic purposes is 25 gallons per day, for manufacturing, mechanical and trade use 23.5 gallons, and for public use 7 gallons, making a total of 55.5 gallons per capita per day. Taking these figures as being applicable to Halifax, the consumption should be 2,275,000 gallons per day, which means that 6,907,680 gallons per day are being wasted. The average daily consumption through 144 meters on dwelling houses of various values in the city amounts to 105 gallons for each service pipe. Allowing five persons to a family, this would give 21 gallons per capita per day, which agrees practically with the amount stated above as being a fair and liberal allowance for domestic use. Another proof that the figures of the daily consumption are under estimated, is the fact that during the past year on the low service supply over 1,000 million gallons of storage was used up during 155 days which would equal 6,500,000 gallons per day.

If 60 gallons per capita per day be assumed as a fair allowance, it follows that at least 170 gallons per capita per day brought into the city is wasted either through leaks in the mains or water pipes and fittings in private premises. There is no doubt considerable leakage from the mains, particularly on the low service where so many of them are laid with wood joints; and a number of them are laid through or near old drains and sewers, so that the leaks do not show at the surface but the water runs off through drains. In Milton, a small town in Massachusetts, where all the services are metered and where the total quantity of water supplied is measured, and there are 35 miles of pipe laid, the leakage from the mains amounts to about 3,600 gallons per day per mile of pipe. In Fall River it amounts to 10,000 gallons per day per mile of pipe, although in their case they have only 96 per cent. of their services

metered, and the consumption for the other 4 per cent. is estimated; and in seven cities having over 86 per cent. of the services metered the amount of water unaccounted for varies from 3,500 to 23,000 gallons per mile per day (these amounts are in United States gallons). Waste from pipes and fittings on the premises of water takers is due to defective plumbing or to negligent or wilful waste in allowing the water to run from the taps. In a house with modern plumbing the chief cause of waste is from a leaky ball-cock in the tank supplying fixtures. In one instance a meter was put on a pipe supplying a closet where the valve in the flushing cistern was worn and did not fit its seat properly. The waste was but a trickling stream, but the consumption was 1,073 gallons a day, while after the valve was repaired it was reduced to 43 gallons. In other houses closets supplied with hopper-cocks are the chief cause of waste. There are at present about 450 of these in use in the city. In 1891 a test was made on nine of these closets, and applying the results then obtained there would be a waste from this source alone of three-quarters of a million gallons per day. During the cold weather an enormous amount of water in the aggregate is allowed to run to prevent pipes freezing. As up to the present there has been no means of accurately measuring the water supplied to the city, this amount cannot be stated in gallons; but the pressure at night at the various permanent gauges throughout the city drops from five to ten pounds below that of the day time. The modern method of controlling waste is to supply each taker through a meter, so that each consumer pays only for the water used. There were on May 1st, 1905, 6,939 service pipes, of which 5 per cent. were metered. In October, 1905, when owing to the small rainfall there was danger of the supply becoming exhausted a house to house inspection by the police was ordered, and wherever any leaky fixtures were found the water was turned off and only turned on again when repairs had been made and on payment of a fine. The immediate result of this was a gain of eleven pounds

pressure all over the city, notwithstanding there was a loss of  $3\frac{1}{4}$  pounds owing to the lowness of the lakes. This in conjunction with the fact of the pressure lowering at night would seem to prove conclusively that the waste from the mains bears a very small proportion to that from negligent and wilful waste.

The following table of the data of the consumption of water of eleven cities about the size of Halifax gathered from late reports is here inserted to enable a comparison to be made, and also to show the effect meters have on the consumption of water. It will be noticed that the average consumption of those cities having over 50 per cent. of their services metered is 41 United States gallons, and those under 50 per cent. 91 gallons, or 50 and 197 imperial gallons per capita respectively:

TOWN.	Population supplied.	Number of services.	Percentage of services metered.	Miles of pipe.	CONSUMPTION.	
					Daily.	Night rate.
Brocton .....	37,800	.....	90.	.....	36	.....
Woonsocket .....	34,474	.....	86.7	.....	28	.....
Newton .....	35,400	.....	86.	.....	54	.....
Malden .....	36,900	6,700	63.4	82.	47	25
Haverhill .....	37,200	.....	10.	.....	95	.....
Waltham .....	24,550	.....	6.	.....	99	.....
Quincey .....	26,800	4,850	3.1	83.7	89	57
Salem .....	36,250	.....	3.	.....	79	.....
Everett .....	28,000	4,670	1.	42.	81	55
Chelsea .....	35,000	6,251	2.	38.7	94	65
Halifax .....	35,400	6,939	5.	69.6	260	.....

*Financial.*

The rates are levied from four sources,—meter, fire protection, domestic and special.

The meter rates vary from 15 cents to 7 cents per 1,000 gallons by a sliding scale, depending on the quantity of water used per day. A meter rental is charged on all meters except

those on domestic supply. The consumer pays only for the actual quantity used, and there is no minimum rate for this class of consumer. The fire protection rates are levied on the assessed value of all lands and premises and are paid by all classes of consumers.

The domestic rates are levied on the assessed value of properties and also on the number of fixtures, the minimum rate for fire and domestic purposes being \$4.00 where no meter is on the premises.

Water is supplied to the military and naval properties and the Intercolonial railway under special agreements, in the former cases at so much per fixture and in the latter by actual measurement of water consumed, with a lump sum added for fire protection. No mains are extended in the distribution system unless a bond is executed guaranteeing the interest at 5 per cent. on the actual outlay required. This business-like method of making extensions has been the means of assuring the revenue keeping pace with the expenditure. The following statement shows the amount of the funded debt and annual cost of maintenance in five year periods since the city took over the works.

1860	Funded Debt, £	71,900	—	The cost of the works, £56,000 paid for this year
1865	“	\$ 640,000	—	Nova Scotian currency.
1870	“	669,653.33	—	Dominion currency.
1875	“	740,973.33		
1880	“	740,973.33	-	Maintenance \$55,496.46
1885	“	740,973.33	“	58,605.76
1890	“	633,906.48	“	66,534.96
1895	“	990,266.67	“	65,894.91
1900	“	1,056,600.00	“	69,252.38
1905	“	1,056,600.00	“	83,511.77*

\* Includes cost of renewing old 3-inch mains with 4-inch mains.