sumption in metered cities. In a gravity system this means double the outlay for collecting and conserving the water, and double the expenditure for conduits and mains.

This matter has been presented to you so often by your City Engineer that it may have ceased to interest you, but unless meters be generally adopted it will be necessary to secure an additional supply of water. Nothing more can be drawn safely from Chain Lakes, Long Lake and Spruce Hill Lake. The limit has been reached—in fact they have supplied, and are now supplying more than the designing engineers estimated upon.

Frequent house to house inspections may serve to locate wastage, but the benefits of this system are not permanent in a City where inferior plumbing and carelessness of consumers have been the rule for half a century.

Comparative statistics demonstrating the efficacy of metering might be tedious, but some recent examples of what has been done to restrict waste in a few American cities are worthy of consideration.

At Atlantic City meters were decided upon in 1895, and within two years 71 per cent of the services were metered decreasing the consumption by more than fifty per cent.

At Milwaukee and at Cleveland where the supply is only limited by the sizes of the mains and the capacity of the pumping machinery, they decided that it would be more economical to meter the services than to duplicate mains and pumps.

In 1901 only six per cent of the services in Cleveland were metered, the per capita consumption than being 169 gallons per day.

In 1904 with 49 per cent of the services metered, the consumption had been reduced to 137 gallons, a saving of 32 gallons per capita.

The Superintendent is of opinion that with all services metered an additional 41 gallons per capita may be saved. At the end of 1904 over 30,000 meters had been set in Cleveland.

At Milwaukee the consumption of 113 gallons per capita in 1887 dropped to 102 in the following year, by the setting of 1800 additional meters. In 1904 with 80 per cent of the services metered, the consumption was 89 gallons per capita.

Richmond, Virginia, is another example worth studying. In 1885 the population was 70,000, and the consumption 24,000,000 gallons per 24 hours. This would be at the rate of 12,000,000 U. S. gallons per day for a City of 35,000, about the same as the consumption to-day at Halifax. This is over 340 gallons per capita.

In 1897 the Superintendent reported that nearly 500 houses were without water in the second stories during the day, and in 1899, after adopting meters, he wrote as follows :—

"It was mains or meters. Additional mains carried with them additional pumps; the estimated cost was $270,000. From the beginning I was convinced that the meter system was a necessity for a City like ours, and from the first had urged its adoption. It is the same old story of opposition and postponement. Finally, after years of pleading, complaint became so loud that something had to be done. In the spring of 1897 the City Council appropriated $15,000 for the purchase of meters, and I was empowered to place them where I deemed best. I commenced setting the meters in June of this year, and placed them, irrespective of the size or condition of the premises, on the lowest plane. Nearly all the taps in this section supplied small dwelling houses, having two fixtures, a hydrant and a closet. The average consumption at each tap per month was nearly 30,000 gallons, and in a few instances reached as high as 140.000 gallons per month. This great waste was at once checked by the meter, or rather the bill, and at the end of the year the pressure at the high points had increased 40 per cent. Another appropriation of $5,000 for meters was made in 1898. They were set in the low district. At the end of the year the pressure had increased 100 per cent. at the high points. All complaint for want of water had ceased, and we had the same pressure at these points that would have been obtained by expending $270,000, which would have entailed an annual expense of $17,000. Prior to placing the meters our water power pumps were insufficient to keep up the supply, and we were often compelled to run the steam pump, which increased the cost of pumping $2.500 per annum. This pump has not been used for the past eighteen months. It will be seen, therefore, that the saving per annum amounts to $19,500, nearly equal to the entire outlay for meters. The per capita consumption for last year, 1898, was 99 gallons per day, a reduction of 41 per cent. from that of 1890, and the quantity of water used now is 27 per cent. less than in 1890, while the population has increased 20 per cent. Another advantage from the meters: In the past, during freezing weather, it was the general custom to leave fixtures running and wasting to prevent frozen pipes, the result was little or no pressure, reservoirs rapidly emptying, in the face of the fact that all the pumps were worked to their full capacity. Recently we have experienced the severest weather known in my section of the country, the thermometer for days being at or below zero."

In 1904, with 41 per cent. of the services metered, the consumption per capita at Richmond was 129 gallons.

Yonkers, N. Y., with a population of 60,000, and all services metered, consumed 94 gallons per capita in 1904. This represented 60 per cent. of the water pumped, the balance being unaccounted for, that is, 40 per cent. was lost through leakage in the mains and services and in the slip of pumps.

Many other examples might be cited of the efficiency and permanence of the results of general metering. At Atlanta, Ga., the consumption was reduced 60 per cent. in four years; at Harrisburg, Pa., 32 per cent. in six years; at Lowell, Mass., 39 per cent. in three years; at Madison, Wis., 60 per cent. in thirteen years; at Hartford, Conn., 36 per cent. in five years.

There can be no reasonable doubt that by metering the services in the City of Halifax that the consumption would be reduced to 3,000,000 gallons per day, as registered by the meters on services.

The uncontrollable waste from mains and services in their existing state would, however, probably amount to 4,000,000 galls., making a total of 7,000,000 gallons per day, as registered by the three large Venturi meters on the conduits at Chain Lakes.

After metering the services the mains that are responsible for the large leakage can be located and the pipes uncovered and rejointed if necessary. Any large leakage can be determined by pitometer or by tapping the main on each side of a gate valve by an inch pipe, setting a meter on the by-pass and noting the flow, with the gate valves on main and on all services closed. Tests of this character are definite, but can only be made at night. The capacity of an ordinary inch disc meter is 30 to 50 gallons per minute, sufficient to measure the leakage from two or three miles of properly jointed pipes.

TYPES OF METERS.

There are five types of meters differing in principle of action as follows :—

(1) Disc meters, in which an oscillating disc usually of hard rubber, moves the recording mechanism.

To this class belong the Hersey, Pittsburg, Niagara, Trident, Nash, and Keystone.

Meters of this class are simple, cheap and reasonably accurate.

(2) Rotary Disc Type—of which the Crown, Union, Empire, Columbia, Hersey, and Lambert are examples.

These meters are probably more durable than these of the disc type, more expensive, and probably more liable to stoppage.

(3) Reciprocating Piston Type—built on the principle of a steam piston, designed for extreme accuracy. The Worthington Duplex is an example.

(4) Current Type—made on the principle of a water wheel, suitable for large discharges, of which, the Torrent, Gem, Eureka, Trident-Crest., and Standard are examples.

(5) Venturi Type—for large discharges which depend upon the principle that with water passing through a contracted pipe or throat the velocity increases and the pressure is reduced, the difference in pressure indicating the velocity of flow, and therefore the quantity being discharged.

This meter is adapted for low velocities in large pipes. It is not accurate for small flows, and the registering apparatus is complicated and expensive.

The disc and rotary types are in general use in the United States and Canada on domestic services. They may be depended upon to register within two per cent. of the correct quantity passing through the service pipe with a trifling loss of pressure, they are easily repaired, readily tested, durable, and can now be delivered at reasonable prices.

In Halifax all the largest consumers of water are now supplied through meters, leaving about 6,200 live services unmetered. Disc and rotary meters would prove quite satisfactory for these services, of which fully 4,500 would be five-eights inch meters, the remaining 1,700 being of larger sizes, which we may assume would be as follows :—1,000 three-quarter inch ; 300 one inch ; 200 one and one-half inch ; and 200 two inch.

OBJECTIONS TO METERS.

Many plausible objections have been urged against meters, those having the greatest weight being as follows :—

(1) Meters would restrict the use of water, and thus affect the health of the citizens.

(2) The revenue from water takers would be materially reduced.

(3) The first cost and maintenance would be excessive.

It has been proven beyond question that meters do not in any way restrict the lavish use of water, neither have meters any effect upon the health rate. Whether the revenue be affected or not depends upon the tariff adopted.

The item "Meter Rental" is distasteful to consumers, and should be avoided, but a minimum annual fixed charge should be made on each service, sufficient to meet the interest and sinking fund on the first cost, and to cover the operating and maintenance charges.

The fixed charges on the cost of a water works system must be met in some way, as well as the expenses for operation and maintenance.

That the City at large should be assessed for a large proportion of the annual outlay is reasonable, but the parties using the water, the actual consumers, should also pay for the water used, and meter rates may be so adjusted that the revenue from consumers will equal that received from flat rates. At the present time the unmetered consumers in Halifax are paying less than one and one-half cents per 1,000 gallons for water they consume, while the metered consumers are charged over nine cents per 1,000 gallons.

With a meter on every service this unfair inequality in rates would disappear.

The original cast of installing a general meter system has deterred many cities and towns from adopting the system but frequently this cost has been grossly exaggerated

It may be safely stated that the average cost of installing meters in Halifax would not exeed $16.00 per service.

The life of meters has been variously estimated. It has been demonstrated however, during late years that twenty years is too low rather than to high.

Maintenance of Meters.

The annual charges for meters would be made up of the following items, interest on first cost, depreciation, repairs and renewals, inspections, reading meters and bookkeeping. The interest and depreciation may be taken as nine per cent.

The remaining items may be bulked together, and statistics show that about $1.00 per annum per service will be sufficient.

The average annual expenditure will therefore amount to about $2.50 per meter.

Fire Protection.

The volume of water required to cope with a serious fire in the business district of Halifax has been prescribed by the Fire Underwriters as 3,200 imperial gallons per minute, or sufficient to supply sixteen standard fire streams concentrated upon one block or square, this supply to be over and above that required for domestic consumption. The pipe system must also be of sufficient capacity to convey the water to the hydrants.

In Halifax the line of demarcation between the high service district and the low service district follows closely a contour line 120 feet above the sea.

The pressure at the fire hydrants in the lower district varies from 10 pounds to 60 pounds. Along Lower Water Street the average pressure is about 42 pounds, and along Upper Water Street about 8 pounds higher. These pressures are sufficient to extinguish an incipient fire in a low building.

To give a proper pressure steam fire engines are employed, the supply being drawn from the fire hydrants. Boston, New York, Montreal, Toronto and nearly all the larger cities rely almost entirely upon steam fire engines for fire protection.

To lessen the waste in the lower parts of the low service district certain gate valves on the mains are now kept closed, or partially closed. Upon a fire alarm being given it is the duty of the Water Works Department to open one or more of these valves in the vicinity of the fire. This is certainly a most undesirable state of affairs, even if the water supply were ample.

If all the valves were open, the water mains in the business portions of the City are now too small to convey the proper supply, in fact they are useless, except for domestic purposes.

The following mains in the heart of the business districts might be removed without impairing the fire protection :—

Argyle,—Blowers to Jacob.

Granville,—Salter to Buckingham.

Hollis,—South to Salter, and from Sackville to Buckingham.

Bedford Row,—Sackville to Duke.

In the important congested business districts, the mains on the cross streets are now depended upon for fire supply, all fed from one fifteen inch main on Grafton Street, which is taxed to its full capacity at times to convey the domestic supply. These cross mains should be fed from both directions, or from two additional larger mains laid on streets parallel with Grafton.

Along Lockman Street and Upper Water Street, fire protection is given by hydrants supplied with water from pipes laid on cross streets fed from the 12 inch main on Brunswick ; all these cross pipes being 6 inches in diameter, except one 12 inch on

Cornwallis. It is doubtful if ten fire streams could be concentrated on the I. C. R. Station, or on premises north or south, with every pipe and valve open.

If the daily consumption of water in the low level district were reduced to what might be considered as a reasonable quantity, the sizes of the mains in the existing system would not be sufficient to fulfil up-to-date fire requirements.

The fire pressure in the high service district varies from 4 to 40 pounds at the hydrants, depending upon the elevation.

With the exception of Gottingen Street and Agricola Street, this district is chiefly residential, but it contains a number of important public institutions such as schools, asylums, hospitals, colleges, barracks, exhibition buildings, etc.

If the flow in the 15 inch main were available for fire service on Quinpool Road, possibly ten standard fire streams might be supplied, but as the entire flow is now taken by the domestic consumers, it follows that proper fire protection cannot be given at any point in the district, except along Gottingen Street, where a supply may be drawn from the 24 inch low service main, and possibly at some other points where large low service mains are available. It may be broadly stated, however, that although the conduit is now taxed to its full capacity, there is no water for fire protection in the higher parts of the district.

At Dalhousie College it is doubtful if more than two standard streams could now be drawn from the hydrants by steamers, and at the Exhibition grounds the supply would be less.

It is evident that some large mains should be laid in this district and an adequate supply of water provided at all times for fire protection.

The new distribution mains required, should be laid from the proposed source of additional fire supply to those points where the supply is now inadequate. The route for the mains as shown on plan, may be modified or changed, if desired, provided 4,000 gallons per minute in addition to the domestic demand be conveyed to any point in the low service district between Smith Street and the Refinery, and 2,000 gallons per minute in addition to the domestic demand to any point in the high service district.

The 15 inch on Grafton may be of sufficient size to give fire protection to the congested business districts, but you should not depend on one main. Another main should be laid on some parallel street, taking up the old leaky main now in use.

The cross mains on Duke and Proctors Lane, should be replaced with larger pipes, also the pipes on Gerrish east of Gottingen, North, east of Brunswick; and Russell east of Gottingen. South from Park to Pleasant should be relaid with a large main.

If the mains on Hollis and Lockman Streets be replaced by larger pipes, some of the cross mains mentioned may be omitted, and a better service given.

In the high service district 12 inch mains should be laid on Almon Street, Oxford Street, and South Street, also a 14 inch or 16 inch on Robie Street from Young Street to South Street.

If the mains on Hollis, Beford, Granville, Argyle and Lockman are jointed with wood, they should be removed and replaced by larger pipes.

It may be of interest to compare the number of fire hydrants in Halifax with the number in other Canadian cities:

PLACE.	Population.	Distribution.	Fire Hydrants.	Static pressure at hydrants.
London	42,000	81 miles	497	40 to 90
Hamilton	57.500	106 "	952	40 to 100
Ottawa	15,000	105 "	867	100
St. John	39,000	55 "	350	20 to 60
Halifax	42.000	58 "	424	10 to 50

The hydrant pressures at Halifax are so extremely low that upon a fire alarm coming in from the congested districts certain valves are opened and others closed by the Water Department, thus concentrating the flow. This dual control of the valves is most undesirable, and tests made by the Fire Underwriters also show that by concentration the supply is inadequate.

The accompanying skeleton plans of the distribution systems in the business districts of Toronto, Hamiliton, London and Ottawa may be of interest. Toronto is now adding a high pressure fire system in part of the area shown. At London, where the fire supply is but little better than at Halifax, improvements that may cost half a million dollars are now under consideration.

HIGH PESSURE SERVICE.

Many of the larger cities in the United States and Canada have installed, or are now installing, high pressure water systems, for protecting the congested business districts, the mains being designed for high pressure given by powerful pumping machinery, the entire system being independent from the domestic supply system, and only operated during fires.

In some places the pumping machinery is placed on fire boats, from which heavy fire streams may be thrown, or the water forced into a pipe system on shore.

The pressure carried varies from 200 lbs. to 300 lbs. to the square inch, the hydrants are provided with three, four or five nozzles, and in some places fitted for three inch fire hose. Steam fire engines may be dispensed with in the district thus served.

Sea water has some slight advantages over fresh water for extinguishing fires. The volume would be limited only by the capacity of the pumps, and the domestic supply would not be affected.

The pumping machinery for a high pressure system may be operated by steam, gas or electricity. The last mentioned would be the cheapest in first cost, but possibly not as reliable as steam or gas. There would be but little choice between the two latter, but gas engines may be started in much less time than steam engines. Machinery to pump against a water pressure of 300 lbs. would be much more expensive than machinery for 100 lbs. pressure, and would require three times the power.

The installation of a high pressure system in Halifax, taking sea water from the harbor, would, however, be an expensive undertaking, owing to the great length and narrow width of the territory to be protected, and the great difference in elevations. The adoption of this system would mean the duplication of mains on many streets, the cost of which might better be expended in taking up the existing leaky pipes and relaying with larger mains.

Again, if only a part of the business district were included in the system the fire service in the remaining portions of the low district and in the entire high service district would not be improved except indirectly.

You now have an ample supply of fresh water available for fire protection throughout the entire City at a less cost than a high pressure sea water system.

Pumping Station.

By installing a pumping station on the line of any one of the three conduits, the supply of water flowing into the City, or the pressure, or both might be materially increased as desired for fire service, or to improve the domestic service in some districts.

As the 24 inch and 15 inch conduits are provided with wood joints except at and near the Dutch Village Road it would not be prudent to increase the pressure in these pipes, but this objection does not apply to the 27 inch main, which should stand any reasonable working pressure up to 120 pounds to the square inch.

The best location for this pumping station would appear to be on the City property east of Kempt Road, along which there is now laid a railway siding.

By means of properly arranged by-pass pipes and valves, water could be drawn from Chain Lakes through the 27 inch main, and forced under increased pressure into the low service system, or into the high service system. For such a variable service, turbine pumps would be specially suitable.

This pumping station would ensure a full fire supply in either district at any time, and would in addition permit water being taken from the low service main to improve the pressure in the high service district if desired.

The 27 inch conduit is of sufficient capacity to supply about 2,000 gallons per minute in addition to the quantity now flowing through it. When the waste is checked, the 24 inch conduit alone will supply the domestic demand, and the 27 inch can easily supply 6,000 gallons per minute to the pumping station or sufficient for thirty fire streams.

The maximum power required would not exceed 300 H. P., perferably subdivided into two or three independent units.

The source of power may be steam, gas or electricity, the final additions depending upon reliability rather than first cost or operating expenses.

Gas engines operated by City gas or producer gas, may be started almost instantly, and the operating expenses would be less than steam or electric power.

If gas from the mains of the gas company were used, the first cost of the plant would not exceed the cost of a steam plant. A producer gas plant would be more expensive but you would then be independent of the Gas Company.

Electric motors may also be promptly started, but a fire at the generating station or along the transmission line might at any time paralyze the system. Electric power should not be adopted in Halifax for the further reason that the only available power is owned and controlled by a private company.

The operating expenses in a steam power plant would cost more than in a gas plant, as it would be necessary to maintain a working steam pressure on one or two boilers at all times.

The coal required for banking fires and heating building, would probably not exceed one ton per day. If it could be arranged to combine a Fire Station with the Pumping Station but one additional main would require to operate the machinery otherwise three men.

Turbine pumps are better suited for this service than reciprocating pumps, and the first cost would be less, although not so economical, but economy in power is of secondary importance.

The increased pressure in the 24 inch main on Gottingen Street would increase the leakage slightly in the entire low service system.

It may be asked, why not lay another conduit to Chain Lakes, thus securing an additional fire supply without pumping.

The advantage of the pumping system over a conduit is this, that a proper fire supply may be given at any point in the high service district as well as the low service district upon demand. Further, by operating the turbine pumps in series the pressure may be doubled at the pumping station, thus giving fire pressure at the hydrants in the lower parts of the city.

For the present one turbine pump with a capacity of 4,000 gallons, and a seeond of 2,000 gallons per minute, with direct connected engines, should be installed with three water tube boilers. Space should be provided in the pump room for duplicate machinery and in the boiler room for an additional boiler.

RESERVOIR.

Mr. Laurie in his report of 1860 recommended a reservoir to be built on Camp Hill of sufficient capacity to contain 48 hours' supply. In 1866 the matter was referred to Mr. T. C. Keefer, who considered a reservoir in town as unnecessary.

The highest ground within the City limits is Hungry Hill. formerly called Shafforths Hill, in the north end, which has an elevation of 240 feet above the sea. Longard Street crosses the summit of the hill near Cabot Street. A surface reservoir at this elevation enclosed by an embankment or wall would give storage, but would improve the domestic pressure but little.

By constructing a water tower or standpipe to contain about half a million gallons the pressure in the high service district would be equalized, and the stored water would improve the fire supply. If full, 500,000 gallons would supply the high service district from six to eight hours. The tower might be filled by a small pump and held in reserve for fires and other emergency purposes.

ACCESSORIES.

The temporary meter house at Chain Lakes, erected in 1906, should be replaced by a suitable building, in fact all the buildings at Chain Lakes should be replaced by permanent structures properly designed.

At this meter house a self-recording pressure guage should be set on the 15 inch conduit.

At the Dutch Village Road a battery of pressure relief valves should be set on each of the three conduits, as well as a blow-off valve. These valves would relieve the conduits from excessive strains due to the sudden opening or closing of valves and hydrants in the City. Suitable chambers should be constructed around or over these relief and blow-off valves, and pressure gauges should also be set in these points.

Self-recording pressure gauges should also be installed at the City Hall, on both conduits at Quinpool Road Fire Station, and at some point on the 27 inch main near Kempt Road or Gottingen. Standard hydraulic gauges should also be set at all the fire stations and the records entered in books kept for the purpose.

The recording pressure gauges should be set at once before any of the recommended improvements have been commenced.

SUPPLEMENTAL SUPPLY.

The country in the vicinity of Halifax is dotted with numerous small lakes, as a rule containing water of good quality for domestic purposes. From time to time it has been proposed to increase the present supply by simply adding the watershed of some lake contiguous to the watershed of Long Lake or Spruce Hill Lake.

An inspection of the accompanying general plan will show that the adjoining watersheds are either too small to be considered, or too low to permit of diverting water into the existing systems.

By pumping, the water of Governors Lake might be discharged into Chain Lake, and Ragged Lake may be diverted into Long Lake, but these additions would not increase the supply to the City without laying another conduit from Chain Lake.

The Birch Cove Lakes lying north of Governor's Lake, were suggested as an additional source of supply as far back as 1860, when the first important extension of the original system was contemplated.

In the report of J. Laurie, C. E., to the City Council, dated May 15th, 1860, the area of these lakes is given as 400 acres, the overflow about two thirds the overflow from Long Lake, and the elevation as 239 feet.

From levels taken in 1905 the elevation of Quarry Lake, which is the lowest of the chain, and the one nearest the City, was found to be 243 feet instead of 239 feet. The area of the watershed is approximately 3,500 acres.

Taking into consideration the area of the watershed, and of the lake areas, the run-off should equal four fifths of that from Long Lake and Chaln Lakes.

It can be safely assumed that the Birch Cove Lakes may be depended upon to yield from 6,000,000 to 7,000,000 gallons per day.

To convey this quantity of water to the City would require a conduit about five and one-half miles in length, and 27 inches in diameter. The additional head due to the extra 37 feet of elevation over Chain Lake is offset by the friction in the additional length of main.

By pumping from the conduit at the City end at Young Street, the capacity would be increased to 8,000,000 gallons per day,

The largest body of fresh water within twenty miles of Halifax is Pockwock Lake, which lies sixteen miles due north west of the City. This lake discharges south westerly through North East River into St. Margaret's Bay. At the outlet of the lake a low dam has been constructed that raises the water three or four feet above the natural level, and gives a head of about eight feet for the small sawmills located at this point.

The drainage area of the lake has not been determined, but judging from the volume of flow at the outlet in May 1905, and information received from parties residing at the mills, the run-off would exceed the requirements of the City.

The lake itself has an area of about 3.60 square miles, and an elevation of 395 feet above the sea.

From preliminary examinations made along Hammond Plains Road and Sackville River Valley, and from a study of the plan of the country, it would appear practicable to divert water from Pockwock Lake to Tomahawk Lake by the construction of an inexpensive canal or conduit about one-half a mile in length, the maximum cutting being about twenty feet. Tomahawk Lake, which is about 40 feet lower than Pockwock, discharges into Big Lake on the Sackville River.

These lakes would doubtless yield an abundant supply of excellent water, but the construction of a conduit from Tomahawk Lake to the City, a distance of sixteen miles by way of the valley of the Sackville River and Bedford Station, would be an expensive undertaking. By making Big Lake the City Reservoir, the length of conduit might be reduced to fourteen miles following the river valley.

By instrumental surveys, a more direct route and possibly a cheaper, might be discovered via Sandy Lake, but whatever route were ultimately adopted, a large part of the conduit line would be in rock.

The great advantage of the Pockwock supply would be, that by adopting a conduit of sufficient diameter, the entire City could be supplied by gravity from this one source.

The maximum quantity of water now used by the City could be delivered through a 36 inch conduit from Tomahawk Lake, and give a slightly increased pressure in the high level district. A conduit 48 inches in diameter would deliver practically double that of a 36 inch, but would cost from 20 per cent. to 25 per cent. more.

If the existing Water Works System were to be discarded, or if the City were now without a water supply, the Pockwock Lake project might be carefully investigated, and complete surveys and plans made, but as the present supply is ample for all requirements, further consideration of this scheme may be deferred until your City has doubled in population. The water is there, and you can get it when you require it.

FINANCIAL.

In the year 1861 the works were acquired by the City at a cost of about $211,000. Since that date the distribution system has been greatly extended, the high service system added, the two large conduits laid, and many permanent improvements made at the lakes.

The cost of the works, revenue, operating expenses, etc., were as follows on May 1st, 1904 :—

Cost of works	$1,128,200
Funded debt	1,056,600
Paid off	71,600

REVENUE.

On Assessed Valuation (1903.)

$16,000,000 @ 12 cts. per 100	$19,200	
8,000,000 @ 14 cts. per 100	11,200	
		$30,400
From Meters	13,600	
" Special rate on fixtures	26,600	
		40,200
Total revenue		$70,600

EXPENDITURE.

Interest	$47,100	
Maintenance	20,000	
Sinking Fund	2,500	
Short collections	1,000	
		$70,600

It may be of interest to compare the foregoing statement with that of the City of London, Ontario :—

Population of City the same as Halifax	42,000
Population supplied with water, about	38,000
Average daily consumption	3,400,000 gallons.
Number of services laid	10,500

Cost of Water Works System.........$868,385

REVENUE.

From consumers	$95,670	
" City	16,390	
" interest and rentals	1,290	
		$113,350

EXPENDITURE.

Maintenance and cost pumping	$34,045	
Capital expenditure	10,225	
Interest and Sinking Fund	42,550	
Surplus	26,520	
		$113,350

Although a larger amount has been expended upon the Halifax system than at London, the entire supply at London is pumped against a head of 250 feet, about one-half being pumped by water power and one-half by steam power. The pump house expenditure amounts to $7,660 annually. The sum of $6,740 is expended yearly on the dam and the pump house grounds known as Springbank Park.

These two large items of expenditure ($13,400) if capitalized will bring the first cost of the London system up to that of the Halifax system. Eliminating these two items, the revenue and expenses are as follows:—

	HALIFAX.	LONDON.
Revenue from assessments	$30,400	
" " City		$ 16,390
" " Consumers	40,200	95,670
Total revenue	$70,600	$112,060
Interest and Sinking Fund	$49,600	$42,550
Maintenance	20,000	20,645
	$69,600	$63,195

At London $25 per annum is charged the City by the Board of Water Commissioners for each fire hydrant, about 500 now being supplied. The item of $16,390, which includes the hydrant rental, is assessed over the entire City. If the revenue from the City were increased to $30,400 at London, the consumers would then be called upon to pay $81,660, instead of $95,670.

It would appear from the foregoing that the rates at Halifax are only about half what they are at London, and it may be advisable to revise your tariff.

The total revenue from the Halifax Water Works System may be sub-divided as follows :—

From assessments	$30,400
From 327 metered consumers	13,600
From 6,250 unmetered consumers........	26,600
Total........	$70,600

The average amount received from the unmetered services is less than four dollars and fifty cents per annum.

As the average receipts throughout Eastern Canada are about ten dollars per service, and in the West much higher, it would appear that in Halifax the amount raised by the general assessment is too high.

At about nine cents per thousand gallons, which is a fair price for water, the 327 metered services consumed in 1903 about 147,300,000 gallons, or less than half a million gallons per day, yielding $13,600, or say one-third the total revenue from consumers.

The amount flowing into the City through the conduits averaged about ten million gallons per day. Assuming that four million gallons represents leakage from the mains that cannot be checked, there remains six million gallons per day to be accounted for. Of this six million gallons, less than one-twelfth part yields one-third the revenue, and over eleven-twelfths only two-thirds. This is certainly unfair to the metered consumers.

Taking into consideration the existing conditions of the Water Works System, and the necessity for extensive improvements involving a large expenditure, it would appear prudent to advance the rates to consumers.

If the water used and wasted by the ordinary consumer were charged at meter rates, the annual revenue would be increased from $26,600 to $180,000, allowing nothing for the 4,000,000 gallons now assumed as leakage from the mains.

The amount collected is now barely sufficient to make the Water Works System self-sustaining, and only a trifling amount has been set aside for depreciation.

ESTIMATE OF COST.

"A"—Birch Cove Lakes Scheme.

To introduce an additional supply of water from Birch Cove Lakes would probably cost between $250,000 and $350,000. The wide difference between the two amounts given is accounted for by the fact that location surveys have not been made, and further that claims for diversion of water from mill owners cannot be closely determined in advance.

	ITEM.	FROM	TO
(1)	30,000 lineal feet of 27 inch pipe	$115,000	$120,000
(2)	Specials, valves and other materials	2,000	3,000
(3)	Labor trenching and laying	25,000	35,000
(4)	Rock additional	30,000	70,000
(5)	Dams	15,000	20,000
(6)	Gate houses, etc.	5,000	7,000
(7)	Riparian claims and land	25,000	40,000
(8)	Contingencies 15%	33,000	55,000
	Totals	$250,000 to	$350,000
	Annual charges	$16,000 to	$22,000

Mr. Laurie in 1860 estimated the total cost as $353,980.

If this scheme were carried out the supply of water would be increased by about 6,000,000 gallons per day, but it would be necessary to lay additional mains to convey this extra supply to different parts of the City. The amount of this piping may be taken as follows for comparing estimates :—

"B"—*Extensions of Mains.*

IN LOW SERVICE DISTRICT.

South	from	Summer to Hollis	3,340 feet.
Duke	"	Argyle to Water	700 "
Proctor's Lane	"	Brunswick to Water	530 "
Gerrish	"	Gottingen to Water	1,300 "
North	"	Brunswick to Water	800 "
Russell	"	Gottingen to Campbell	1,330 "
Hollis	"	South to Salter	1,800 "
Salter	"	Hollis to Granville	200 "
Granville	"	Salter to Buckingham	2,100 "
Total			12,100 "

Estimated cost of above mains laid complete, with 30 extra fire hydrants....................$40,000

IN THE HIGH SERVICE DISTRICT.

Kempt Road	from	Young to North	2,730 feet.
Robie	"	North to South	7,150 "
South	"	Summer to Oxford	3,700 "
Oxford	"	South to Quinpool	4,300 "
Oxford	"	Quinpool to Young	4,420 "
Almon	"	Kempt to Oxford	2,800 "
Longard	"	Young to Cabot	2,000 "
			27,100 "

Estimated cost of above mains laid complete, with 40 extra fire hydrants.................... $ 90,000

Total for new mains	$130,000
Annual charges	7,800

If the extensions above enumerated involve an expenditure that is considered too large, in view of the other works that are necessary, the pipe system may be reduced by omitting some of the mains, but the following are essential:—

IN LOW SERVICE DISTRICT.

South	from South Park to Hollis	2,370	feet
Duke	" Argyle to Water	700	"
Proctor's Lane	" Brunswick to Water	530	"
Gerrish	" Gottingen to Water	1,300	"
North	" Brunswick to Water	800	"
		5,700	"

Estimated cost of above mains laid complete, with 20 extra fire hydrants $20,000

IN HIGH S RVICE DISTRICT.

Kempt Road	from Young to North	2,700	feet
Robie	" North to South	7,150	"
Almon	" Kempt Road to Oxford	2,800	"
		12,680	"

Estimated cost of above mains laid complete, with 20 extra fire hydrants $40,000

Total for new mains $60,000
Annual charges 3,600

"C"—Pumping Station.

Building	$25,000
Three 150 H. P. water tube boilers	12,000
Forced or induced draught apparatus	2,000
Pipes, valves and connections	3,000
Two turbine pumps of 4,000 imperial gals. per minute capacity, with direct connected compound engines	14,000
One turbine pump of 2,000 gals. per minute capacity with direct connected engine	6,000
Foundations	4,000
Contingencies	6,000
	$72,000

Annual charges:

Depreciation and interest	$ 7,000
Operating expenses	4,000
Total	$13,000

For the present one of the large turbine units may be omitted decreasing the first cost by $23,000, and the annual charges by $2,200.

"D"—General Meter System.

Cost of meters delivered at Halifax, duty paid:

	4,500	⅝ in. and ½ in.	@ $10.00	$45,000
	1,000	¾ in.	" 13.00	13,000
	300	1 in.	" 20.00	6,000
	200	1½ in.	" 30.00	6,000
	200	2 in.	" 45.00	900
Total	6,200	meters.		$70,900
	Cost of setting 6,200 meters @ $3.00 each			18,200
	Contingencies 10%			8,900
	Total			$98,000

Annual charges:

Interest	$ 4,000
Depreciation or Sinking Fund	6,000
Maintenance and operating charges	6,000
Total	$16,000

"E"—Water Tower.

Cylindrical steel water tower, 50 ft. diameter, 60 ft. high, on concrete foundations $22,000

or

Reinforced concrete water tower, 50 ft. diameter, 60 ft. high, on concrete foundations 30,000

Annual charges:	
Steel tower, 10%	$ 2,200
Concrete tower, 7%	2,100

"F"—Accessories.

Two gate houses at Chain Lakes	$ 8,000
One meter house at Chain Lakes	3,000
Three Venturi meters	2,000
Recording gauges, relief valves and connections	2,000
Two chambers for relief valves	1,000
Total	$16,000
Annual charges	1,000

SUMMARY OF ESTIMATES.

	Desirable.	Essential.
Meter system	$ 98,000	$ 98,000
Distribution system	130,000	60,000
Pumping station	72,000	49,000
Water tower	30,000	
Accessories	16,000	16,000
Totals	$346,000	$223,000
Annual charges	$ 39,900	$ 31,400

REVENUE.

The annual charges, which include interest, depreciation and operating expenses, may be met by adopting a reasonable meter rate.

The City now charges about nine cents per thousand gallons for large consumers. If this rate be applied to all consumers the revenue would be greatly increased.

Assuming that the consumption as registered by the meters on the services be reduced to 3,000,000 gallons per day, or about 75 gallons per capita, this would produce a revenue of $300 per day, or $109,500 per annum, more than sufficient to meet all annual charges on the existing works, and the proposed extensions and improvements as well.

It would probably be better to retain the present revenue from assessments, abolish the flat rates and special rates, and adopt a lower meter tarriff, in which event the annual revenue would be as follows :—

From assessments, as at present	$ 30,400
Fixed charges for 6,700 meters, say $2 each	13,400
3,000,000 gallons water per day at eight cents per 1,000 gallons	87,600
	$131,400
Annual charges at present	$ 70,000
Annual charges on proposed new works	40,000
	$110,000
Annual Supplus	$ 21,400

If we assume that the consumers should become so extremely economical that the consumption be reduced to 2,000,000 gallons, the revenue at 8 cents per 1,000 gallons with the same fixed charges would amount to $92,200 per annum.

A meter rate of eight cents per 1,000 gallons is probably lower than any domestic rate in Canada or the United States.

If the works recommended be carried out the reduction effected in the insurance premiums on buildings in the business portions of the City, and the contents thereof, would probably exceed the estimated additional annual expenditure, or in other words, the proposed improvements will involve no additional tax, as the rate-payers are now paying more in excessive insurance premiums than the annual charges will amount to.

The additional capital expenditure recommended is a sum well within your means, whether your borrowing powers or valuation be considered, and the total cost of your Water Works System will then not exceed the cost of the average gravity system in other cities, nor will the total be unreasonable.

Nearly every large City in Great Britain, the United States and Canada that constructed or acquired a system of water works prior to 1870 has practically re-constructed its entire system during recent years, and in many instances enormous sums have been expended to procure an ample supply of pure water for present and future requirements.

Respectfully submitted,

WILLIS CHIPMAN,
Civil and Sanitary Engineer.

Nearly every large City in Great Britain, the United States and Canada that constructed or acquired a system of water works prior to 1870 has practically re-constructed its entire system during recent years, and in many instances enormous sums have been expended to procure an ample supply of pure water for present and future requirements.

Respectfully submitted,

WILLIS CHIPMAN,

Civil and Sanitary Engineer.

HALIFAX WATER WORKS.

H. W. JOHNSTON, Assistant City Engineer, Halifax, N. S.

Read before the N. S. Institute of Science, January, 1906.

(Published by Permission of the Institute.)

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 1½ 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 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 feet. 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 2¼ 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 up 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 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 said 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, Thos. Hosterman, W. A. Black, Wm. Lawson, Jr., Wm. B. Fairbanks, James N. Shannon and Wm. 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. Chas. 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 2½ miles long situated about 1¼ miles from the head of the N. W. Arm—by a line of pipe 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 runs. 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 diem 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 gals. per day when new, but only 700,000 when incrusted, 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 5,000,000 gals.

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 considerations 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 any 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 the 29th September, 1848. (The 6 inch main originally laid on this street wes taken up in 1905.)

A contract with the City was made 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 had 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 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 attentiou 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 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 satisfactory arrangements could be made with the 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, provided 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 50 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 resevoir on Shaffroth's Hill, from whence the water be distributed by three lines of pipes, one suppling 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 tha 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 were 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. This Commission was composed of J. A. Bell, Chairman and Messrs J. L. Barry and E. V. 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 committee on water supply with Mr. Henry E. Pugsley as Chairman was appointed by the City Council and they engaged Mr. James 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 7136 people using the water; but as the barracks, navy yard and City counted as single tenants and a large number were using water from the 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 two twelve-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 83⅓ 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 with a storage capacity for 160 days would be obtained at an estimated cost of $70,070.00.

2nd, Birch Cove Lakes.—These lakes consisted of several bodies of water connected by narrow passages having a surface elevation of 239 ft. above mean low tide and an area of 241 acres with several other lakes emptying into them. The natural summer 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 2¼ 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 4½ 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 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 92½ acres, and was 153 feet above Long Lake, and the third lake an area of 70 acres, and about 2½ feet higher than the second. He recommended a dam across the outlet of the second lake, raising the water 7½ feet, which would allow, say, 6 feet of water to be drawn from the second lake and 3½ feet from the third, and would yield 217 millions of gallons, or 108 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. Thos. 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 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 Council called the Board of Works was invested 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 at the 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 4455 acres including the lakes—904 acres in the Chain Lakes and 3551 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 watershed 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 Water Department. The guages 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 watershed 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 watershed, 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 opinion that an average of 50% 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 ft., main pipe at level of 192.24 ft. 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 day 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 ft. below waste weir on 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 & Storage Reservoir.

The watershed of Spruce Hill Lakes amounts to 1009 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 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.

Growths.

The growth of algae was first noticed in 1878. In that year samples of water, algae 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 the late 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	2.44	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 source 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. C. L.	Soluble in H. C. L.	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, &c., 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 Algae appeared in Chain Lakes, consisting of a galatinous 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.
	Blackened	Loss on Ignition.	Dry at 100° C.	Albuminoid Amonia.	Free Amonia.	Nitrates.			In 15 minutes	In 4 hours.			
Ragged Lake........		25	42	.1470	.0471	Trace	4.7	None.	2.347	6.057	137.5	III	IV
Lower Chain Lake......		35	47	.1814	.0400	"	5.3	"	2.460	6.116	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	IV

There are two points in the above that require special consideration, viz: the high figures for Albuminiod 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 chiefiy 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, through its figures are much higher than they should be. As to the oxyen 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 by Prof. Geo. Lawson on the foregoing Analysis:

"The result of analysis showing Ragged Lake water to contain 0.1470 parts per million of Albuminiod 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 analysis 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 water 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 proper 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. MaKay, Dalhousie College, with the following results:

Source of Sample.	Amonia.		Chloride.	Nitrogen.		Required Oxygen.		Total Solids.
	Free.	Albuminoid.		Nitrate.	Nitrite.			
Long Lake	.01	.222	10.5	.425	.....	9.870	12.8	118.2
Tap Young Avenue	.014	.224	10.9	.400	.....	9.80	13.4	123.8
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. McKay 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 for 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 bacteriae.

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 2½ to 1. The water side was protected by a heavy sloping wall surmounted by a granite coping 18 inches high forming a low wall along the front. The dam was lengthened to 1018 feet to the west of the waste weir. In 1892 the dam was raised two feet and strengthened by depositing 5000 cubic yards of good material on the face. The present waste weir at an elevation of 205.99 feet above low tide was constructsd 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 feet wide and level, the fall from the crest to the apron being 3½ feet. The latter is constructed of granite slabs about 6 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 six inch timbers in position.

The highest level to which the water has risen over the weir is 25 inches on the 19th Oct. 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 gals. per minute from the eastern one and 6.6 gals. per minute from the western one. As the result 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 ¼ 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 shewn 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 slopes 3 to 1 paved with heavy stones. The waste weir is at the northern end of the dam at an elevation of 206.00 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 9½ feet broken by a ledge 5½ 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 24 x 36 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 1200 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 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 inch 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 concete and is 16 feet deep x 12½ feet wide x 16½ feet long with walls 4 feet thick. It is drained by a 12 inch pipe. Both the 24 inch and 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 inch 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 9 inch deep x 10 feet 4 inch wide and 8 feet 5 inch with walls 4 feet thick.

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