REPORT NO. 1

ON

WATERWORKS IMPROVEMENTS

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REPORT NO. I ON WATERWORKS IMPROVEMENTS.

To the Chairman and Members of the Board of Control:

Gentlemen :

In accordance with instructions received from your Board, we herewith submit our report upon the present condition and the future requirements of the Hamilton Water Works System.

During the time that has elapsed since receiving your instructions, we have had soundings taken in Lake Ontario opposite the Basin, taken measurements along the condufts and around Pumping Station, determined the elevations or Reservoirs in respect to Pumping Station and City datum, prepared several plans and profiles, examined reports and data on file in Engineer's Office, etc.

WILLIS CHIPMAN.
ANDREW F. MACALLUM.

Toronto, August 19th, 1911.

Topography. The greater part of the 6,000 acres upon which the City is built, lies between the rock escarpment, known as the "Mountain," and the south shore of Burlington Bay, this area being a comparatively level tract, with a rise of about 120 feet from the Bay to the base of the Mountain. A cross ridge, extending south-easterly from Dundurn Park at the south-west part of the City, to the foot of the Incline Railway on James street, divides the City into two parts, the smaller draining westerly to Coote's Paradise Bay, and the other draining northerly to Burlington Bay, the shores of which are indented with a number of inlets, some of which extend nearly half way to the Mountain.

The southerly boundary of the City follows the brow of the Mountain, excepting for a distance of about one mile, for which distance the boundary jogs southward, enclosing about 100 acres. This small area has an elevation of about 400 feet above the lake, and has a population of about 1,500 people.

There can be no doubt that within a very few years the entire area to the road allowance between the fourth and fifth concessions of the Township of Barton will be annexed to the City.

Population. The following table gives the population of the City, with the increase or decrease from year to year :

Year.	Population.	Increase or Decrease.	Remarks.
1847	6,832		
1850	10,312		Incorporated as a City.
1856			
1858	27,500		An Act authorizing construction of Water Works.
1860			
1861	19,096		Water Works in operation.
1871	25,947		City took over Water Works.
1872	28,000		
1873	30,201	2,053	
1874	31,957	1,756	
1875	32,216	259	
1876	31,708		
1877	32,641	933	
1878	33,511	870	
1879	34,208	697	High Level System added.
1880	35,000	792	
1881	35,359	359	Beam Engines enlarged.
1882	36,946	1,587	20 inch main laid.
1883	38,196	1,250	
1884	39,215	1,019	
1885	39,985	770	
1886	41,280	1,295	
1887	41,712	4.	
1888	43,082	1,370	
1889	44,299	1,217	
1890	44,653	354	Two Osborne-Killey Pumping Engines installed.
1891	45,423	770	
1892	46,767	1,344	
1893	47,031	264	
1894	48,238	1,207	
1895	48,500	262	
1896	48,803	303	
1897	49,427	624	
1898	50,038	611	
1899	51,011	973	
1900	51,561	550	
1901	52,665	1,104	
1902	53,781	1,116	30 inch force main laid.
1903	54,035	254	
1904	54,761	726	
1905	57,561	2,800	James Street Reservoir completed.
1906	59,543	1,982	
1907	61,443	1,900	
1908	64,067	2,624	
1909	66,967	2,900	
1910	70,221	3,254	Air Lift System completed.
1911	73 42	5,321	Two electric pumps installed. New boilers installed.

Original Water Works. In the year 1856, Mr. T. C. Keefer, now of Ottawa, Ontario, presented a preliminary report upon a Water Works System, recommending pumping from Lake Ontario in preference to a gravity supply from Lake Erie or from Springs near Ancaster. The estimated cost was given as £187,537 ($913,295). This report was adopted

and the works constructed under a Board of Water Commissioners in the years 1857-58-59-60. In March, 1861, the system was taken over by the City.

As originally constructed, the water supply was obtained from a basin, excavated in the sand at the Lake shore, this basin being 1,200 feet long and 78 feet wide at the surface, and 16 feet deep.

Until 1871 a sufficient volume of water filtered through the sand to the basin to supply the City, there being no intake or connection between the lake and the basin.

From the basin the water was conveyed to the pumping station through a 33 inch circular wood stave pipe 1,920 feet in length.

The pumping machinery comprised two beam engines of 100 H. P. each, and four boilers, furnished by John Gartshore, of Dundas, at a cost of $95,810. These engines had a combined capacity of 3,300,000 gallons per 24 hours, but were enlarged to 5,250,000 gals. capacity in 1880.

From the pumping station the water was forced through an 18 inch cast iron pipe to a reservoir on the mountain side, distant about 17,000 feet in a south-westerly direction. This reservoir contains about 11,000,000 gals. and the surface elevation being 187 feet above Lake Ontario.

A branch main also 18 inches in diameter was laid along Main street to James street, from which sub-mains were laid.

About $600,000 had been expended upon the works when they were assumed by the City.

Extensions. In 1871 the consumption exceeded the infiltration from the lake, and an opening was made from the basin to lake.

In 1876-7 the filtering basin was lengthened by 400 feet, and a second basin 1,086 feet long constructed to southward of the original, the two being connected by a 36 inch pipe. A new conduit 36 inches in diameter and 1,870 feet in length was also laid from the new basin to the pumping station.

In 1878 the Ferguson avenue High Level re-pumping station was erected. The main floor of this station has an elevation of 99 feet above Lake Ontario. The pumps, of 3,000,000 gals. capacity, raised the water to a small reservoir 196 feet above them, the capacity of reservoir being 400,000 gallons.

In 1880 the pumping cylinders of the beam engines were enlarged from 24 inches diameter to 30 inches in diameter, increasing the capacity to 5,250,000 gallons per day, and the four old boilers were replaced by four tubular boilers.

In the following year the 18 inch force main was parallel to the Barton Reservoir by a 20 inch pipe, with a branch to the City along King street to James. This work cost over $100,000.

The next important improvement was made in 1886, when a contract was awarded the Osborne-Killey Company for two steam pumping en-

gines, each of 5,000,000 gallons capacity. The contract for five boilers was awarded the following year. Including the new buildings, this duplicate pumping station cost about $80,000.00.

In 1889 a 20 inch intake pipe 850 feet in length was laid from the central part of the north basin into the lake.

The water enters through a timber crib 20 feet long, 17 feet wide, and 10 feet high, the depth of water over crib being 10 feet.

A second duplex engine was installed at the High Level Station in 1890, with a capacity of 400,000 gallons.

In 1900 the ratepayers authorized the expenditure of $200,000 for another force main and improving the basins, also for several large distributing sub-mains in the City. This 30 inch force main was laid along Barton street as far as Sherman avenue, thence a 24 inch pipe to Wellington street and a 20 inch to James street. The basins were enlarged to double their former capacity, and another inlet to lake provided. The foregoing works were completed in 1901. The laying of this 30 inch force main and large submains increased the pressure at the City Hall about 25 lbs.

The James Street Reservoir, containing two and one-half million gallons, was constructed in 1903-4 at a cost of $30,000.00. This reservoir has an elevation of 243 feet above the lake, or 54 feet above the Barton reservoir. A vertical pipe 60 feet in height at the Barton reservoir, connected with the inlet pipe thereto, permits water being pumped to the James street reservoir, the Barton reservoir being cut off from the system, the supply therein being held in reserve for emergencies, giving a gravity supply, if the pumping machinery should be unable to fill the James street reservoir, as was the case in July, 1911.

In the year 1901 a 36 inch intake was laid from the southerly end of basin to lake, but not of sufficient length to prevent obstruction from ice.

In 1907 the basins were cleaned and weeds removed, and electrically operated pumps decided upon.

In 1909 the air-lift mountain system at the Wentworth Street Incline was constructed to raise water to the section of the City on the Mountain. The two basins were converted into one in this year and thoroughly dredged out.

The two electrically operated turbine pumps were installed in 1910, each with a nominal capacity of 6,000,000 gallons. This year nine of the old boilers will be replaced with new ones.

Capacities. The capacities of the different parts of the works, as they now exist, are approximately as follows:

1. **Intake and Basin—**

Intake 20 inch—Under 4 ft. head, 5,500,000 gallons per 24 hours.
" 3 " 4,800,000 " "
" 2 " 4,000,000 " "

The infiltration to basin from lake may be taken as about 50 per cent. additional.

The capacity of intake and basin may therefore be taken as between 6,000,000 gallons and 8,000,000 gallons per day, depending upon the height of the water in Lake Ontario.

2. **Conduits—**

The 33 inch conduit can convey 11,000,000 gallons to the pump wells with the water in basin one foot lower than the lake when at normal level.

At low water stage in the lake, which is two feet below normal, the capacity of this conduit would be materially reduced.

With the water in basin 3 feet below low water in lake, practically nothing would flow through this conduit, this being due to the height of invert at the Lottridge Creek crossing.

At the lowest stage of the basin the 36 inch conduit has a capacity of 18,000,000 gallons per 24 hours, which also represents the minimum available capacity of both conduits.

3. **Pumping Machinery—**

Two steam units, vertical, Nos. 1 and 2	5,000,000 gallons
" " " Horizontal, Nos. 3 and 4	8,000,000 "
" electrically operated turbine units, Nos. 5 and 6	12,000,000 "
Normal total capacity per 24 hours	25,000,000 "

The vertical engines should only be relied upon as a reserve, which reduces the total to 20,000,000 gallons.

4. **Force Mains—**

When pumping at the rate of 8,000,000 gallons per 24 hours to the James Street Reservoir, through the three existing force mains, the pressure on gauge in pump room (No. 3 and No. 4) is 105, representing a friction loss of 6 pounds. When pumping at the rate of 12,000,000 gallons the friction loss will increase about 12 pounds.

If for any reason the 30-inch main should be out of commission, the 18 inch and 20 inch would fail to supply the City. Forcing the entire supply through the two smaller mains would so increase the friction head that the pressure capacity of the turbine units would be exceeded.

The safe combined capacity of the three existing mains may be taken as not exceeding twelve million gallons per 24 hours, with the turbine pumps, and about 15,000,000 gallons with the steam pumps.

5. **Reservoirs—**

The capacity of the Barton Reservoir, when full, is 11,000,000 gallons, which is held in reserve. About once per week some water is drawn from it and replaced.

The James Street Reservoir, containing 2,500,000 gallons, is merely a compensating reservoir, fluctuating with the City consumption.

6. High Level—

The Ferguson Avenue Re-pumping Station has a pumping capacity of 700,000 gallons per 24 hours, with storage of 400,000 gallons in the reservoir above.

This system has been taxed to its limit this season, and there is no reserve plant.

The compressed air lift at Wentworth street is said to have a nominal capacity of 65 gallons per minute, or about 93,000 gallons per day. This small system has also been taxed to its limit of capacity.

7. Distribution—

The following schedule gives the lengths of mains of different sizes:

30 inch	3.68	miles, or	.80	per cent. of total
24 inch	0.38	"	0.29	" "
20 inch	9.64	"	7.34	" "
18 inch	6.16	"	9.64	" "
16 inch	1.40	"	1.07	" "
12 inch	9.91	"	7.55	" "
10 inch	1.74	"	1.33	" "
8 inch	0.96	"	0.73	" "
6 inch	90.32	"	68.79	" "
4 inch	7.10	"	5.41	" "
Total	131.29	miles		

Total number gate valves	931
" " fire hydrants	1,335
" " water services	19,772
" " meters	350
Percentage services metered	1.77

New Works—

The original system was among the earliest municipal works in the Province, antedating the Toronto works by about fifteen years.

The original system was outgrown in a few years, the enlarged system, as it exists to-day, cannot be considered as equal to the demands upon it, and there is practically no reserve for fire protection in case of accident to works in connection with the supply, a burst in force main, or breakdown in pumping machinery.

We consider the following new works should be provided, the relative importance being in the order given:

1. New intake from Basin to Lake Ontario.
2. Complete new High Level Pumping Station.
3. Additional machinery at Beach Pumping Station.
4. An additional force main from Beach Station to centre of City.
5. Several submains throughout the City.
6. An additional corduit from Basin to Beach Station.
7. Storage reservoirs.

Intake—

During the winter months drift ice is frequently piled up by gales to a height of fifteen feet or more above the level of the lake, the loose ice being cemented together by the freezing of spray and waves.

The ice accumulations may extend to a depth of twenty feet of water, and slush ice may occasionally be found at greater depths.

The inlet of the existing 20 inch intake is subject to interference from ice, and may be blocked any winter. This intake must also convey to the basin large quantities of sand in suspension, which can only be removed by dredging.

We would therefore recommend that a new intake be laid from the southerly end of the basin, this pipe to be 48 inches in diameter and 2,000 feet in length, the water end to terminate in a timber crib 24 feet square and 12 feet in height, provided with inlet screens.

The openings in crib for the entrance of the water should be of sufficient area to prevent a too rapid current in the vicinity.

The pipe should be of riveted steel, laid in a dredged channel well beneath the bed of the lake, the trench to be refilled after the pipe has been laid. It will be necessary to provide flexible joints and expansion joints at proper intervals, and within the basin a concrete gate house should be built, with gate provided to close intake.

We would further recommend that the existing 20-inch intake and crib should be examined by a diver, and repairs made if required. After the new 48 inch pipe has been laid a 20 inch branch pipe should be laid to the discharge at the north end of basin, and thus eliminate the dead water at this point.

We estimate that the foregoing works will cost as follows:

1. Intake crib	$5,000 00
2. Intake pipe laid	40,000 00
3. Gate house and gate	1,500 00
4. Extension of 20 inch, with gate house and gate	5,500 00
5. Contingencies, 10 per cent.	5,000 00
6 Engineering and superintendence, 6 per cent.	3,000 00
	$60,000 00

High Level Station. The steam pumping machinery at the Ferguson Avenue Station is of low duty type, of insufficient capacity, and old enough to be retired to the reserve list.

We would recommend that a new pumping station be constructed adjoining the present building, in which new machinery be installed.

For the existing service two electrically operated units should be adopted, each with a capacity of one million gallons per 24 hours.

For the area now known as the high level district north of and below the Mountain turbine pumps may be adopted. For service to the high Mountain plateau above, force pumps, operated by gearing, would prove

much more economical, but owing to the noise would be objectionable. Two units of one million gallons capacity each should also be installed for the higher service, either of which might, in an emergency, be used for the lower service. This would make four units, each of one million gallons capacity.

For the higher service a steel force main would be required up the mountain face, and a storage tank of reinforced concrete or of steel, at a sufficient elevation to give any desired pressure on Mountain above. In case of fire in the lower district this extra supply might be drawn upon by using proper equalizing valves.

We propose that the station be supplied by a new 20 inch main.

We estimate that the works above mentioned will cost as follows :

(7) Pump House	$12,000 00
(8) Two Pumping Units, each one million gallons capacity	12,000 00
(9) Two heavy pressure pumping units, each of half million gallons capacity	18,000 00
(10) Force main to tank, 2,500 feet of 12 inch pipe	12,000 00
(11) Elevated tank, capacity 100,000 gallons	8,000 00
(12) Contingencies 5 per cent	2,500 00
(13) Engineering and superintendence	2,500 00
	$67,000 00

Air Lift System. To place the Wentworth Street Mountain Pumping System in an efficient condition, constructing a tank of sufficient capacity alongside the station, and by duplicating the pumping plant, would cost approximately $2,800.

While this would be quite suitable and safe for a certain length of time, we do not feel assured of its permanent operation under the best conditions, and would therefore not recommend its continuance, except as an auxiliary. In fact, the Mountain top can be more efficiently supplied from units in the Ferguson Avenue Pump House, and would thus obviate the engagement of two extra men, reducing the cost of operating and maintenance.

Taking into consideration the condition and capacity of the Wentworth street air pumps, together with the unsatisfactory nature of the service now given to the Mountain top from this station, we would recommend the enlargement of the Ferguson Avenue Pumping Station, with the pumping units above mentioned ,together with the pipe up the Mountain side to supply the entire plateau above.

The Ferguson avenue steam plant, and the air lift station at Wentworth street, should, however, be thoroughly overhauled and maintained in an efficient condition for emergency service, until such time as the City secures electric power strictly in duplicate from the point or points were generated.

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efficient condition for emergency service, until such time as the City secures electric power strictly in duplicate, from the point where generated.

Beach Pumping Station. In recognition of the faithful services performed by the original Gartshore engines, the City can well afford to maintain them in commission for emergencies. They are doubtless the oldest water works steam pumping engines in Canada, but still capable of efficient service. The old pumping station should also be retained in its present condition as a monument to the men who designed and constructed your first water works system, one half a century ago.

All suggestions for removal, or remodeling the old pumping station, or for utilizing the building for additional machinery, or for other purposes, should be promptly suppressed.

In all probability the daily consumption of water will never fall below 7,000,000 gallons per 24 hours, and the maximum next year will be 12,000,000 gallons. In each instance the rate of pumping during the day may exceed the average of 50 per cent., and the night rate may fall to half the average. This variation may be set forth in tabular form as follows-:

(See City Engineer's Report, 1905, P. 11.)

Average for Day.	Maximum Rate in Day.	Minimum Rate at Night.
Minimum 7,000,000 gals.	10,500,000 gals.	3,500,000 gals.
Maximum 12,000,000 gals.	18,000,000 gals.	6,000,000 gals.

During 1912 we may therefore expect the rate of consumption to vary from three and one-half million gals. to eighteen millions. Year by year the average daily consumption will increase in proportion to the population, but the maximum and minimum rates will probably continue to bear the same ratios.

As it is the intention to operate the pumping machinery by electric power, the existing steam plant of 13,000,000 gallons nominal capacity should be maintained in perfect working order, to insure which each engine should be operated periodically one half day per month at least

A third electrically operated unit of 6,000,000 gallons should be installed in ample time to meet the peak load of next summer, and a fourth should be added as a reserve, that is, the capacity of the present plant should be duplicated.

If a suitable site for a new reservoir cannot be secured, it might be preferable to adopt one unit of 3,000,000 gallons capacity and one of 9,000,000 gallons, instead of two of 6,000,000 gallons, but this change will not affect the cost.

The installation of this additional machinery will involve the extension of Pump House, and reconstruction of wells and connections.

We estimate the cost of these works as follows :

(14) Two 6,000,000 gallons pumping units	$30,000 00
(15) Extension Pumping Station, and foundation for machinery	20,000 00
(16) Reconstruction Pump Wells and connections	10,000 00
(17) Contingencies	6,000 00
(18) Engineering and superintendence	4,000 00
Total	$70,000 00

Plunger pumps geared to motors would be more efficient than turbine pumps, but the first cost would be materially higher, and this would occupy more floor space.

It is quite probable that you will find it advisable to periodically replace the impellers with new ones, as it has been demonstrated by experience that the efficiency of a turbine pump falls away with use, owing to wearing and pitting of impellers.

Force Mains. The existing force mains, three in number, are of sufficient capacity to convey to the City the present maximum consumption without subjecting them to pressures exceeding the safety limit. As the population increases the demand for water will increase proportionately, and this will increase the pressures, not only on the mains but on the machinery, if the present reservoir be maintained in the City.

If for any reason the 30-inch force main should be out of commission, the extra pressure necessary to force the supply through the two old force mains might cause their failure.

As a matter of insurance against accident to the existing mains, and to meet the immediate demands which will be called upon by the time the new main can be constructed, we would recommend that a 36-inch force main be laid from the Beach Pumping Station westerly along the Beach Road to Ottawa street, thence southerly along Ottawa street to Barton street, at which point a cross connection should be made with the existing 30-inch force main.

The proposed new main, laid along an independent route more or less remote from the existing main, will ensure a proper service if one or more of the present mains were broken, or seriously damaged, necessitating the use of the remaining two mains at present built. There is always a possibility of one of these mains on the pipe line bursting and creating such an excavation as to put the other two mains out of commission. For this reason we have recommended the proposed route mentioned above.

At Barton street the new main may be reduced to 30 inches, and continued at this diameter along Ottawa street to Cannon street, thence westerly along Cannon, Senator and Wilson streets to Catherine street.

From Wilson street the force main should be continued as a 24-inch pipe on Catherine street to Charlton avenue, thence easterly along Charlton avenue to Ferguson Avenue Pumping Station, and westerly to a connection with the existing 20-inch main on James street leading to the James Street Reservoir.

This proposed new force main ,with branches to James Street Reservoir and the Ferguson Avenue Station, would immediately decrease the

pressure on pumps by about ten pounds. Year by year, as the consumption increased, the pressure would increase.

We estimate the cost of the above described force main as follows:

(19) 36-inch main from Pumping Station to Ottawa street, 11,200 feet; 36-inch on Ottawa street to Barton street, 1,700 feet, at $10.00	$129,000 00
(20) 30-inch on Ottawa street, from Barton to Cannon streets, 1,500 feet; thence westerly along Cannon, Senator and Wilson streets, 12,300 feet, at $7.50	111,000 00
(21) 24-inch main on Catherine street and Charlton avenue, 6,000 feet, at $5.75	34,500 00
(22) Contingencies, 5 per cent.	13,500 00
(23) Engineering and superintendence, 3 per cent.	8,000 00
Total	$296,000 00

This new force main, with the Catherine street and Charlton avenue branches, will practically duplicate the capacity of the three existing force mains.

For some years there will be an extension of the Sewerage System in the eastern part of the City, necessitating tunnelling under or excavating near the existing force mains, at some points in rock.

Notwithstanding the fact that all precautions may be taken to prevent accidents, there is a possibility of such occurring. The proposed new main laid along an independent route, more or less remote from the existing mains, would ensure a proper service if one or more of the present mains were broken or seriously damaged.

Submains. To improve the fire service in the central part of the City, and to provide a domestic supply to the rapidly growing southwestern suburbs, we would recommend that the following submains be laid:

(a) Lottridge street, from Senator street to King street, 20-inch		300 ft.
(b) Gore street, from Catharine street to James st., 18-inch	1,200 ft.	
Vine street, from James street to Bay st., 18-inch	1,300 ft.	2,500 ft.
(c) Main street west, from King street to Queen street, 20-inch		4,300 ft.
(d) Markland street, from James street to Queen street, 16-inch		2,700 ft.
Total length of proposed submains		9,800 ft.

We estimate the cost of these proposed submains as follows:

(24) Lottridge street, 300 ft. of 20-inch, at $6.00	$ 1,800 00
(25) Gore and Vine streets, 2,500 ft. of 18-inch, at $3.75	9,375 00
(26) Main street west, 4,300 ft. of 20-inch, at $4.50	19,350 00
(27) Markland street, 2,700 ft. of 16-inch, at $3.00	8,100 00
	38,625 00
(29) Contingencies, 5 per cent.	1,875 00
(30) Engineering and Superintendence, 3 per cent.	1,500 00
Total	$42,000 00

In addition to the foregoing, the following should be laid in the near future:

(e) Emerald street, Wilson street to Stinson street, 20-inch	2,600 ft.		
Emerald street, Wilson street to Mars avenue, 20-inch	4,300 ft.		
Mars avenue, Emerald street to Wentworth street, 16-inch	1,400 ft.	8,300 ft.	
(f) Bay street, Vine street to Barton street, 16-inch	1,600 ft.		
Barton street, James street to Locke st., 16-inch	4,100 ft.		
Locke street, Barton street to York st., 16-inch	800 ft.	6,500 ft.	
(g) Homewood avenue, Queen street to Dundurn st., 16-inch	2,900 ft.		
Homewood avenue, Dundurn street to Linwood avenue, 16-inch	1,300 ft.	4,200 ft.	
			19,000 ft.

The estimated cost of these proposed future extensions, if constructed at the present time, is as follows:

(31) Emerald street, 6,900 ft. of 20-inch, at $4.50	$31,050 00	
Mars avenue, 1,400 ft. of 16-inch, at $3.00	4,200 00	$35,250 00
(32) Bay street, Barton street and Locke street, 6,500 ft. of 16-inch, at $3.00		19,500 00
(33) Markland street, 4,200 ft. of 16-inch, at $3.00		12,600 00
		$67,350 00
(34) Contingencies, 5 per cent.		3,350 00
(35) Engineering and Superintendence, 3 per cent.		2,300 00
		$73,000 00

New Conduit. The capacity of the 36-inch conduit at the low water stage of Lake Ontario exceeds by about one-third the maximum rate of consumption in 1911. The 33-inch conduit cannot be depended upon for a supply at low water. The minimum capacity of the two conduits may not exceed twenty million gallons in twenty-four hours.

During the period when certain repairs were being made to the 36-inch conduit in 1911, the City supply was seriously interfered with, and the electric pumps could not be worked to their full capacity, as the water in the wells was drawn down so low that the foot valves for these pumps were exposed, with a consequent suction of air, lack of efficiency and pumping capacity.

Another conduit should, in our opinion, be laid from the Basin to the Beach Pumping Station, and we would recommend that it be 48 inches in diameter. Reinforced concrete pipe would prove quite as satisfactory as cast iron, and much cheaper. This conduit would have a minimum capacity of thirty-seven million gallons per day.

We estimate the cost of this conduit as follows:

(36) 2,000 feet of 48-inch concrete conduit laid	$25,000 00
(37) Gates and chambers	2,000 00

(38) Contingencies, 10 per cent.	2,000 00
(39) Engineering and Superintendence, 3 per cent.	2,000 00
Total	$30,000 00

Reservoirs. We have not as yet discovered a satisfactory site for a reservoir of large capacity at the elevation of the existing James Street Reservoir. Southwest of the Barton Reservoir and across the G. T. R. track an irregular area of rocky land may be secured. We estimate that a reservoir of ten million gallons capacity at this site would cost about $110,000.00, including the land.

The greater part of the excavation would be in rock, and a heavy embankment would be required along the north side.

Southwest of James Street Reservoir it might be practicable to construct another reservoir with a capacity of ten millions, or perhaps more, but owing to the abrupt slope at the base of the Mountain such a reservoir would necessarily be long and narrow. The requisite land at this site would cost much more than in the vicinity of the Barton Reservoir, and the cost of construction would not be less. This reservoir, including site, would probably cost $130,000.00.

Whatever the reservoir capacity may be, or wherever located, its contents would only serve as a reserve in case of an interruption in the pumping, or of failure of one or more of the force mains.

Although the water in Barton Reservoir has remained remarkably pure, partly through careful attention and partly through changing a percentage of the water each day, yet the fact remains that in large open reservoirs with paved or concrete sides, the quality of the water stored may deteriorate seriously if not frequently changed, owing to the aquatic growths, vegetable and animal. These growths may impart to the water offensive odors and tastes that are difficult to remove, and engineers now favored covered reservoirs, to exclude sunlight, and collection of dust, leaves, etc., in the summer and autumn, and to prevent the formation of ice in the winter.

To construct covered reinforced concrete reservoir would probably increase the cost from forty to fifty per cent.

In the Hamilton Waterworks System reliance for domestic supply and for fire protection must be placed in the pumping machinery and the force mains, and not upon storage reservoirs. Taking into consideration the expense of constructing large reservoirs, we are of the opinion that the sums estimated may be expended more advantageously in machinery and mains.

Waste. We cannot close this report without reference to the problem of waste prevention. That fifty per cent. of the water pumped at the Beach Pumping Station is wasted, may be confidently stated, twenty per cent. being uncontrollable through leaks in mains and services, and thirty per cent. through defective plumbing and wilful waste by the householders.

Your average daily consumption is now approximately 7,500,000 gallons per day, or 100 gallons per capita.

Taking into consideration the character of the ground in which the mains are laid, and that the pipe system is of cast iron with leaded joints, the leakage from the mains and services should not exceed 10,000 gallons per mile of main, or 1,500,000 gallons per day, or 20 gallons per consumer. For public and commercial purposes about the same quantity may be allowed, leaving 4,500,000 as the domestic consumption, or 60 gallons per capita.

The legitimate domestic consumption may be reduced to 30 gallons per capita by metering the services.

At the Ferguson Avenue Pumping Station the cost of repumping 130,000 gallons daily is now approximately three and one-half cents per thousand gallons.

The service pipes supplied by this system, and the Wentworth street air lift, should be metered.

Summary of Estimated Costs of Proposed Improvements and Extensionse now essential.

(a) Intake and Crib	$60,000 00
(b) High Level Station	67,000 00
(c) Beach Station	70,000 00
(d) Force Main	296,000 00
(e) Submains	42,000 00
(f) Conduit	30,000 00
Total	$565,000 00
Less amount now authorized by by-law	35,000 00
Amount required for present extensions and improvements	$530,000 00

Estimated Cost of Additional Improvements and Extensions.

(g) Additional Submains	$73,000 00
(h) Reservoir	120,000 00
(i) 2,000 Meters, set	27,000 00
	$220,000 00

Respectfully submitted.

ANDREW F. MACALLUM,
City Engineer.

WILLIS CHIPMAN,
Civil and Sanitary Engineer.

Hamilton, October 7th, 1911.

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