REPORT

OF

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ON THE

WATER WORKS

OF

THE CITY OF MONTREAL.

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REPORT.

MONTREAL, 10th June 1868.

J. W. McGAUVRAN, ESQ.,

Chairman Water Committee.

Corporation of Montreal.

SIR,

On the 1st instant I received the letter of the City Clerk dated 30th May asking, on behalf of the Water Committee, that I would "favor them at my earliest possible convenience "with my opinion as to the course to be adopted in order to "obviate the difficulties experienced in the water supply dur- "ing the last winter."

I arrived here on the 2nd inst., and have since made examinations with respect to the different measures possible, and now beg to submit the following recommandations.

1st. Remove the winter regulation of the water from the Rock Stop Gate, which is two miles below the head of Aqueduct, to the entrance bridge at the head.

2nd. Run a line of crib work from below the present entrance, in at least twelve feet water for a distance of three to five hundred yards, up stream and as much further as you can now afford to do.

The effect of regulating the water at the head will be to make it possible to reduce the ice troubles within the Aqueduct to a minimum. Hitherto the aqueduct has been open to the winter fluctuations of the St. Lawrence and its floating frasil [anchor ice detached] from the head or entrance as far down as the Rock Stop Gate, a distance of over two miles. The character of these fluctuations may be inferred from the following levels of the St. Lawrence at the Aqueduc entrance.

January	1st	1865.	35.90
"	4th	"	37.10
"	6	"	35.95
"	9	"	37.75
"	13	"	36.25
"	17	"	37.35
"	19	"	36.55
"	21	"	37.75
"	23	"	36.10
"	24	"	37.15
"	25	"	36.00
"	27	"	35.60
"	30	"	37.10
February	4th	"	35.55
"	7	"	37.20
"	14	"	36.00
"	26	"	35.00
"	29	"	35.35

Above summer water Montreal Harbour.

Ice difficulties.

When the ice has taken and attached itself to the banks of the aqueduct it does not rise with the sudden elevation of the St. Lawrence but is overflowed by it, its thickness and weight increased by the immediate freezing of the cold overflowing stream and by the conversion of its overlying snow into ice. The superincumbent weight then presses down this ice and a sudden fall in the river causes it to descend and again attach itself to the banks at a lower level, or else break and leave the broken edge forced down to contract the waterway beneath.

With the contraction of the water way the strength of the incoming current to supply the wheels is increased, and then the frasil, which is stealing along shore, rising from the bottom or blown by the wind into the open improtected mouth of the Aqueduct, is sucked under the Aqueduct ice and pressed up by its buoyancy to the underside of the latter where it attaches itself, thickening the sheet from below, or packing itself in upon the slopes.

By placing the gates at the entrance, where provision is made for them, the fluctuations can be kept out of the Aqueduct, and by forming a large deep water basin, covered with ice, under which no frasil can form,—and which may be

drawn in or blown in, will have ample room to lie up without interfering with the water way and the points of its accumulation will be removed from a comparatively narrow entrance to a much wider one so far distant from the throat of the Aqueduct as to prevent a necessary repetition of that dangerous glacial diptheria to which the aqueduct has been hitherto exposed.

These simple measures I believe will have the effect of diminishing, by at least one half, the ice difficulties in the Aqueduct.

The Water Power and Wheels.

But with these difficulties reduced to a minimum, there is the danger that a low water winter may render the Aqueduct unable to afford sufficient water for pumping the present winter supply with the present arrangement of Machinery.

The Breast Wheels, as will be seen by referring to my preliminary report of 1852, were intended to be placed two feet lower than they now are. After they were contracted for, the Victoria Bridge which was only a dream in 1852 became a reality, and on my return from England in August 1853 I endeavoured to procure a discharge for the Tail-Race below this Bridge. The history of the movement is on record, and I need only say here that after securing the right of way as far as the Lower Lachine Road, the combined influence of the Government and Grand Trunk arrested the movement. I then wrote Mr. Fairbairn that we would be obliged to raise our wheels, and he replied that their construction was too far advanced for alteration, and they were therefore raised as they were, as the least of two evils, and with the hope that for some years the Reservoir would compensate for the few days, in winter, when (from the Record of guaging up to that date) they might not be able to do full duty. In such winters as last, therefore, these wheels are powerless, not because there is not sufficient water power in the Aqueduct to work one or both, but because that power cannot, from the elevation of the sluices, be let in to the wheels at all.—I think that to have cut down the sluices of one or both of the wheels, and thus to have enabled

them to work at a lower Aqueduct level, would have enabled them to do a better duty than the Turbine under the same head ; but now it may become a question, should other measures be adopted, whether it will not be found better to lower the wheels altogether instead of the sluices, and thus gain the fifteen per cent additional power lost in their elevation. I have not had time te investigate this matter, but I think it will be found that the Breast Wheels can work, with the exception of a few days, throughout the winter, without back water, if lowered two feet.

Although I had committed myself to the opinion that the construction of the Bridge with the solid approaches which fill up so much of the water way of the St. Lawrence at Point St. Charles would not injuriously affect the level of the river, I did not feel warranted, with our limited Reservoir capacity, in risking a stoppage of the wheels from back water, during an ice shove particularly, during the construction of the Bridge. The Water Works were opened in 1859, and the Bridge was not completed for several years after, during which period the river was blocked up with the coffer dams, false works, etc., of construction ; and, (having failed to get the Tail Race carried below the bridge) it was evident that the Breast Wheels could not be worked constantly in winter at any lower level, at least until after the completion of the Bridge.

The water immediately above the Bridge at Point St. Charles is now 4 feet 4 inches higher than immediately below but I do not think it will be found that the level at the mouth of the St. Pierre is generally higher than before the construction of the Bridge.

Had the Tail Race discharged below the Bridge it would have obtained in summer about seven feet additional fall to that it now has or the power of an 18 to 20 feet fall of all the waste water, and surplus water, of the Aqueduct,—for utilization in various ways during the shipping season. It may yet be deemed desirable to consider the praticability of this scheme and until this is decided it would be well to suspend the further sale of the Tail Race lands.

The guage in St. Lawrence at the Tail Race has only been established for the last two winters. In the winter before last, which was a high water one, the river on 10th December stood about an inch higher than the bottom of the Breast Wheels, and on the 12th was about four inches lower, leaving a fall of that extent between the Wheel House and the river, a distance of three fifths of a mile.

The back water is greatest for a few days in January and April when the ice is shoving—and when your Reservoir capacity is increased you can afford to have the wheels stand for a short time if necessary. The Breast Wheel is the true winter wheel for the Aqueduct, because it *cannot* let the ice down ;—the Turbine can only be prevented from doing so by an amount of watchfulness not to be expected.

The Turbine Wheel which is a fine machine, and apparently very efficient under a full head, is not calculated to work advantageously under a low one, and therefore has not been able economically to take the place of the Breast Wheels during the period of very low water, when I understand it becomes a mechanical maelstrom into which a very large quantity of water disppears without producing proportionate results.—Placed as it now is with its discharge into the new Tail Race, which is above the level of back water in the St. Lawrence, all the peculiar advantages of a Turbine—viz : its power to work in backwater are lost ; and designed as it is—it is not calculated to utilize economically the lower to head which it is now restricted. Had it been placed between the Breast Wheels and the St. Lawrence, instead of between these and the Reservoirs, and provided with a Tail Race of its own at a lower level, it would have been able throughout all last winter to have worked under a head six to eight feet lower than it did,—and under these conditions—with the exclusion of frasil and fluctuations—a full supply for the City should have been praticable.

For these reasons I would recommend, as the third measure, the erection of a new Turbine on the river side of the Wheel-house, so placed as to utilize all the fall in summer as well

in winter, and so designed as to work economically under a *low* head;—under a high one, economy of water is not required, as the high head is due to a superabundance of water. In a low-water winter such a wheel would have more head and fall than the present Turbine has in summer, and would be able to do more work with a less consumption of water, and with a quantity which the present Aqueduct should be able to pass in any winter we have yet known. In summer the new wheel would have always a head of over twenty-five feet. At the present moment the head would be nearly twenty-eight feet. With this head the city can be supplied with the Aqueduct level drawn down to a point just sufficient to pass the water required to work the wheel, and by this means the enlargement of the Aqueduct can be carried on without interfering with the supply of the city.

Pumping Power of Aqueduct.

Within the last week I have tried the waterpower of the Aqueduct, starting all the wheels, and pumping at the rate of 11,207,808 gallons in twenty-four hours, into the Reservoir under a pressure of 85 pounds, and with a fall in the Aqueduct at the rate of three inches per mile. While this was being done, there were 3½ inches of water flowing to waste over the stop log, for a width of 46 feet; a quantity representing an additional power, which, had there been machinery enough, would have raised the duty to 15,000,000 gallons per diem. To test the capacity of the mains,—I shut off one and drove the whole quantity through the other with an increase of pressure in the guage not exceeding ten per cent.

The Aqueduct flowing a depth of five feet of water, gives nearly seventeen horse-power for every foot of fall. Reduced to this depth there would still be an available summer fall to a wheel discharging into the level of the St. Lawrence at the tail race of about twenty feet and affording about 350 horse-power, a power much in excess of what is now required to supply the city.

These considerations will assist the general public in forming an opinion upon the practicability of lowering the Aque-

duct level in order to carry out the enlargement. With the present head and pumping power, the wheels might be stopped almost every alternate day, and thus afford an opportunity of carrying enlargement further down.

Winter power of Aqueduct.

I may here be permitted to refer to the *Winter* power of the aqueduct, which I believe to be much greater than it has hitherto got credit for. It is admitted that in the winter of 66 and 67 the Aqueduct responded to all demands made on it, and that almost throughout that winter the Reservoir was maintained at full level. A daily average of five millions was pumped under Reservoir pressure throughout the four months of December 1866, January, February and March 1867. The water with the exception of two or three days was high throughout, standing at a level of between 38 and 39, on an average nearly three feet higher than last winter. The impression prevails that during this high water winter the 5,000,000 gallons daily average was all the Aqueduct *could* do, but I cannot find that this idea is based upon any thing better than the f[illegible] that it was all it *did* do. No attempt was made to prove how much it could do,—but for some reason, on 26th Decr. nearly nine millions of gallons were sent up, under Reservoir pressure in 24 hours. On the 18th Feb. mid winter for the aqueduct, 5,700,000 gallons were pumped incidentally and there is nothing to prove that on that day nine millions could not have been sent up, as well as on 26th December previous. I am informed that the Reservoirs though full were shut off to secure a fire supply, and that the pressure was maintained by the wheels, but as the guage shows Reservoir pressure the work done was equivalent to lifting the water to the Reservoir. Under these circumstances whatever economy there may have then been practised in the consumption, it is quite evident that so long as the wheels were working constantly, which it appears they did, they sent up all the water the City would take, and that they did not pump more, only because more was not then wanted. Had the demand exceeded the supply, with the

Reservoir cut off, the water would have run away from before the pumps and the pressure have instantly fallen which it does not appear at any time to have done.

It is possible that any considerable increase of pumping might have placed the Aqueduct hors de combat with the present state of the entrance and the present mode of regulating the water,—still it is, I think, to be regretted that some opportunity was not afforded-during that winter to have tested the power of the Aqueduct under its winter covering, when it would have been accompanied with so little risk. Several experiments have been made to test the summer power, but none in winter, and it is natural that no risks should have been incurred. The experience of the previous winter 1865 and 66 when it was found necessary to bring out the military, no doubt produced great caution and care in regulating and handling the water, and thus its real power was not tested. The importance of such a test must be admitted since it is upon the work of that winter and not upon the power that the probable effect of extension has been estimated.

We have however some records which bear upon this point and are too important and too encouraging to be passed over. On the 5th January 1866, the day previous to the first trial of the Turbine and the last day in which the two Breast Wheels were the only pumping Machinery, their work was as follows

Breast Wheel No. 1	3,256,349
" " No. 2	3,291,347
Total	6 547,696

with an entrance level of 36.70, 35.50 at Wheel House and a fall of 1.20 in the Aqueduct and the Thermometer 17o below zero !

On the 6th January the Turbine commenced working and on the last day of the month though the entrance level was raised to 37.15, that at the Wheel House had fallen to 34.90 creating a full of 2,25 in the surface of the Aqueduct, which fall was by the end of February increased to 4.61 feet, the ice let down, and the military brought up. This was a low

water winter and a cold one, yet it appears that on one day at least in mid-winter the Aqueduct, with an Entrance level of two to three feet lower than that which obtained in the following year, pumped 25 per cent more water.

I have made the following extracts from the records.

Date.		Level of water at entrance.	Level of water at settling Pond.	Fall in Aqueduct	Temperature.	Pressure in Air vessel.	Hours worked. No. 1 Breast.	Hours worked. No. 2 Breast.	Hours worked. Turbine.	Total Gallons Raised.	Turbine not pumping full height. Press're in air vessel.	Turbine not pumping full height.
1866												
Dec.	25	38.52	36.90	1.62	36	80	1.40	19.40	22.20	7,789,026		
"	26	38.55	36.37	1.68	25	80	..	24	24	8,813,694		
"	28	38.50	37.05	1.45	25	81	..	24	24	1,884,808		
1867												
Jany	4	38.45	36.60	1.85	24	82	24	..	24	6,396,208		
"	6	38.20	36.80	1.40	10	80	6.15	6.15	24	7,068,292		
"	19	39.20	36.10	3.10	-2	78	14.30	24	13.45	6,260,306		
"	20	39.00	36.10	3.90	-4	78	..	24	24	6,671,956	60	3,864,840
"	21	39.20	36.10	3.10	6	80	..	24	24	8,008,036	60	4,797,763
"	22	39.10	36.10	3.00	19	78	..	24	24	8,043,846	55	4,904,322
"	25	38.85	36.10	2.75	11	75	24	24	3	6,645,962		
Dec.	20	37.40	36.33	1.07	8	78	12.30	12.30	11.30	6,452,334		

Extension of Aqueduct.

It is from the foregoing results (as well as from calculation) that I believe after making all allowance for necessary ice obtruction, the extension of the Aqueduct for a distance of nearly two miles, that is, to a point opposite the church below Lachine, which would insure a minimum winter level higher than the highest level in the winter of '66 and '67, would without enlargement give a winter pumping power sufficient for many years.

The guagings of last winter prove that an extension to the church would secure a low water level of about 40., sufficient to fill to overflowing the bank of the Aqueduct at the Wheel House. With the exception of two days (against which Reservoir provision should be made) the level was at and above 39.40. The *piling* produced by the extension itself would increase this measurably. If the extension be ever carried to the head of the Lachine Canal, which is about 3½ miles above the head of the Aqueduct, I think a minimum level of at least 42.00 would be obtained, or seven feet higher than the mini-

mum of last winter at the Aqueduct entrance; and to shew the value of a high *head* and low area, as compared with a low head and high *area* of water section for winter work, it may be well to consider the effect of a head of 42.00, assumming it possible to obtain that at the present Aqueduc entrance. This is the level of the top banks from the Rock section upwards, and would therefore exactly fill the prism of the Aqueduct, utilizing the whole expenditure incurred in its construction.

The present Aqueduct has a bottom width of 20 feet, a width between top bank of 55 feet and 14 feet depth with the banks filled.

Total sectional area of present Aqueduct at minimum level of 42.....	525	sqr. ft.
Deduct for 3 ft. thickness of ice..	153.75	" "
Leaving area for water.....	371.75	" "

About 31 horse-power per foot of fall.

The proposed new Aqueduct is to have 65 feet bottom width, a bottom level three feet lower than present Aqueduct, which at the minimum of 35 would give it a depth of ten feet.

Total sectional area of proposed new Aqueduct at a minimum of 35.....	850	sqr. ft.
Deduct for 3 ft. thickness of ice.	297	" "
Leaving an area for water of.....	553	" "

46 horse-power per foot of fall.

In the old Aqueduct you would have 20 feet head and fall or a total of 620 horse-power, while in the new there would only be 13 feet head and fall, or a total of 598 horse-power.

It is thus seen that three and one-half miles of extension could produce, on the basis of the foregoing calculation, the same results as nearly six miles of entirely new Aqueduct and extension, and if the cost were equal—I believe the narrower and deeper channel would be the most desirable: but I think it will be found that the extension will cost a great deal

less than the new work. I have made the comparison on the assumption that three feet of ice would diminish the *water way* to that extent equally in each channel, though I do not consider that when a level can be regulated to avoid fluctuations,—sheet ice has much effect in diminishing the *discharge*. If it did, there would follow an immediate change in the regimen of all our streams, canals, &c., affecting the mill power, as soon as our lakes and rivers freeze over,—which has not proved to be the case generally. I have therefore calculated the power due to the whole head and fall, but with the discharge due to the diminished area.

With respect to extension it will take much time to prepare plans and estimates and make the further surveys required, to determine the cost, but so far as I have been able to examine, all the conditions are very favourable. No rock has yet been found and the material appears to be that best adapted to afford a tight channel, and to be dredged advantageously, which is the cheapest mode in which it can be handled.

Whatever plan may be adopted, whether crib work or embankment, the dredge is equally indispensible. To effect any thing with rapidity it would be necessary to resort to crib work, for which the situation is extremely favourable to rapid execution. The cribs being near the shore could be moored by ropes and the material for filling would be picked up by the dredges, from the boulder strewn bed of the river alongside them. Could the necessary dredging power be obtained, and were it required to do so much work before December the extension could be carried up as far as would be now necessary in the coming five months by employing sufficient force. I have ascertained that the necessary quantity of timber could be had, but not the dredges. They were here two years ago and the proprietor Mr. Brown then offered to dredge this extension at 1s 9d per yard. I annex a letter and telegram from Mr. Brown.

Whatever is done above the entrance to arrest the frasil, will be so much of the extension and every rod it is carried up stream will increase the depth of water in the Aqueduct.

The enlargement and the extension can either be carried on together, or either may precede the other. The full benefit of the one cannot be obtained without the other. Either of them would meet the requirements of the present, could either be carried into effect before another winter, but this is not now possible, except partially.

Enlargement.

If the enlargement be decided on, it should not be delayed, but be commenced at once before the pumping power required to supply the city in summer becomes so great as to compel you to maintain a high level in the Aqueduct, while you are taking down the slopes. The enlargement can be taken down in the earth section considerably below water level, by leaving side dams. The rock section is ten per cent wider than the earth and may remain as it is for this year. It is quite possible that in proper hands much may be done this summer to improve the Aqueduct for winter work by enlargement at the worst portion—the deep cutting below the entrance—by running down the water as low as will drive the wheels—after stop-gates are put in at the entrance bridge—and excavating at the sides below the water line. The material is not rock, but firm—and the steep slopes of the Aqueduct are in favor of this work. An opportunity may be afforded of completing it at a future day when the Reservoir accommodation is extended to meet the rapidly growing wants of the city.

Reservoirs.

When the Reservoir question was before the Consulting Engineers in 1852, Mr. McAlpine urged the importance of large storage reservoirs, capable of containing one to three months supply, and seemed to prefer such a large Reservoir at the lower or Côte au Baron level, where it was then alone practicable, to the smaller but higher one proposed by me,—although he advocated both. Mr. Jervis, however, agreed with me in the importance of securing a high level, where the cost of elevating was so small, as compared with steam power, and thus obtaining a fire pressure,—the most valuable

feature in the works. Had there been means enough, both would have been adopted. As it was I advised the purchase of some thirty acres of the Priests Farm near Mr. Moffatt's, at a time when it could have been had for £100 per arp t. A Reservoir here could be made to give a head of over 100 feet upon the Bonaventure district, and, to the extent of the district which it could adequately supply, would have been a relief to the high levels in winter.

We have seen that the water power is capable of almost unlimited extension,—by enlarging,—by raising the head,—and lowering the Tail Race, and there will always be a very large surplus of pumping power from April to December—during which period Reservoirs of any praticable extent could be filled to be drawn upon in winter.

Your pumping machinery and rising mains will for many years be in advance of the wants of the City; and as it costs very little more to lift the water 100 feet higher, I think the time has arrived to consider the question of larger storage at a higher level. I examined many years ago the Hall estate in rear of the Hotel-Dieu nunnery, head of Upper St. Urbain street, with a view to its future use for a large area. I believe this ground is embraced in the proposed Park, and if acquired for that purpose a Reservoir in it could be made both useful and ornamental.

Doubtless another eligible site, with a shorter pumping main, could be had in the opposite direction towards Monklands. Perhaps a more distant site than either could be had where a small artificial lake could be made in easy excavation and on cheap ground, which would more than compensate for the extension of the pumping main.

If by the aid of storage Reservoirs the enlargement can be continued down to Aqueduct bottom, the extension, may be arrested—and it is only in the event of the enlargement not being carried thus far down that extension becomes necessary in order to raise the Aqueduct surface. It will be seen therefore that the cost of Storage Reservoirs at present may be set off against the cost of extension—as well as against that of

Steam or any other contrivance to aid in carrying out the enlargement. With a Reservoir containing only one month's consumption great relief would be afforded to the Aqueduct. Hitherto in the last twelve years no opportunity has been afforded for drawing off the water for any time and overhawling the banks or removing land wash from the Aqueduct.

Our canals have the water withdrawn generally every Spring, but this Aqueduct without the advantage of having his berm ditches kept open, as is done on the canals, but with an annual overflow of land water carrying sediment into it at various points, is found, on an official inspection, after ten years use to be unobstructed to such an extent as to impair materially the flow of water. (See Report of Superintendent for year ending 31st January 1867, page 5.) I do not believe as much can be said for any other artificial channel of its dimensions in this latitude, and I attribute its preservation with so little care to the plan of stone lining adopted throughout, and to the naturally hard material through which it was the misfortune of the contractors to work, but from which, whatever its first cost, the city has since derived this substantial benefit.

Cost.

I am not prepared to submit an estimate at present of the probable cost of the works I propose. At the entrance the outlay should not be less than £5,000. I annex an offer from Mr. McDougall for the proposed new Turbine Wheel. I think it will be desirable that its power should be enlarged, if time will permit, to seven or eight millions daily, or full work for one main. The cost of the building, head and tail race,—additional pumping main cannot be given until the necessary surveys and calculations establish where the works should be located. At present it would appear that the total outlay for works advisable for the next six months, exclusive of enlargement, will not be less than £30,000 or more than £50,000. A much larger outlay than this will be required either to supply the city by steam power in summer as well as in winter, pending the enlargement of the old Aqueduc,

or to pay the interest upon the cost of a new one.

If the water power plan be adopted an arrangement should be closed with Mr. McDougall at once. embracing the foundations for the pumps and construction of the Wheel House, at least so far as it may affect the progress of his work. If such work be put in other hands, you have a divided responsibility, and the contractor for the building may delay the contractor for the machinery. For all the other work required the time is sufficient if the work be placed in proper hands. It is very desirable that the services of a proper dredge should be secured, for a few weeks at least ,for the work at the entrance.

Future Operations.

For the future whatever more be done should be as part of a comprehensive plan. To determine all the features of this, estimates of the extension and enlargement of the Aqueduct, the lowering of the Tail Race and existing machinery and for the construction of Reservoirs, are required, and when the relative cost of each is ascertained, they can be taken up in the order of importance proportioned to the cost. If the Enlargement be carried on as far as the necessary flow to the wheels will permit and Reservoirs be now undertaken, it may be completed as far as necessary and much of the extension postponed. For,whatever may be expended in Reservoirs,value will be received, and it may be considered desirable when the estimates are obtained to undertake these at once. Extension can always be done and its completion may be left for another generation to do—but every year Reservoirs are postponed the cost of land will be enhanced—and every day enlargement is postponed the difficulties attending it will be increased, from the increasing volume required to supply the wheels.

St. Louis Hydraulic Co.

A pamphlet has been published in the interest of the St. Louis Hydraulic Company, an embryo Corporation, embracing some highly respectable names, which has a tendency to unsettle the public mind on the water works question ; and as the annual report of the Secretary of the Board of Trade

of the commercial capital of the Dominion has been made to give currency to certain statements as to water power and comparisons with Lowell, where water power is understood —it may be well to notice these.

This prospective Company proposes to dam the St. Lawrence where the winter level ranges from twenty to thirty feet above summer water Montreal harbour, and as the head of the Lachine Rapids is only thirty feet above the same point, with the Big Chute of the rapids for a waste weir, the total head and fall for a considerable portion of the winter would range from nothing to about five feet. On the 16th, 17th and 18th of January 1867 the water level stood at the site of this proposed dam thirty feet above summer level of Montreal harbour and as this is the level at the head of Ile au Heron there was then absolutely no water power at all. For a month in that winter the whole head and fall would not have reached an average of five feet. Even in last winter (the lowest known) the fall was reduced to five feet. The ice shoves at the foot of the rapids would make the maintenance of an open tail race or of building on the immediate bank of the river impracticable.

From this dam the pamphlet claims the power of 4,500,000 horses and to this point which was condemned fifteen years ago by competent Hydraulic Engineers it is now proposed to remove the pumping power of the Montreal Water Works.

In the comparison with Lowell in the pamphlet, the 4,500,000 horse power is claimed for this dam which it has been shewn at times could have no power at all ; but in the Board of Trade report the same power is claimed as existing between Lachine and Montreal, or over 100,000 horse power for every foot of fall if taken for the summer, and double that amount or 200,000 horse power for every foot of fall if the total available winter fall from Lachine to Montreal be taken. The summer power would require a river six miles wide with an average depth of forty feet, and the winter power a stream over twenty miles wide with an average depth of twenty feet with a velocity in both cases of one foot per second. The width of the

St. Lwarence between Lachine and Cauhgnawaga is one and a quarter miles and the average depth under twenty feet. The sectional area of the St. Lawrence here is under one hundred thousand square feet and it is doubtful if the perennial water power of the St. Lawrence exceeds 10,000 horses for each foot of fall. If we must give up the millions and be content with the odd hundred thousand we are at least relieved of the necessity for finding space whereon to apply usefully such a tremendous power.

Cost of New Waterworks.

Amid so much indifference to the value of figures, it is not surprising to find it stated that my estimate for the new waterworks was £150,000 and the cost $3,000,000, an excess of twenty-fold. As the waterworks have really suffered from the prejudice created by such statements it is time to set this question at rest.

In my preliminary report of 1852, I estimated "the Wheels "and pumps, rising main, Reservoir, with the land purchase, "masonry, bridges, enclosures, &c., at £150,000." This excluded the distributing pipes, hydrants, &c., on which large sums have been expended.

The cost is correctly stated in the following paragraph from "Montreal in 1856" published on the opening of the works.

"The total expenditure upon the new waterworks to 31st "October, 1856, is £285,000 of which £33,000 is for land pur- "chase, £30,500 for interest and discount, and about £10,000 "for distributing pipes, making the cost of the Aqueduct, "machinery, pumping main, and Reservoir, about £212,000."

Including the land purchase, the cost of the items embraced in my estimate of £150,000 was £245,000, £30,000 of this was due to an enlargement of the Reservoir from the original plan, of which enlargement, a Commission appointed in 1855 spoke as follows:

"Distributing Reservoirs. The dimensions of this fine "work have been largely and we think wisely increased "beyond the original design." For the two hundred acres of land required for the Aqueduct, £7,000 was provided on

the estimate of the late Mr. Somerville, Government Arbitrator through whose land the Aqueduct passed. Nearly five time this amount was paid—but not by me.

Thus the cost of the works, after deducting the Reservoir enlargement and the land excess, was about £190,000, some £40,000 in excess of the estimate. The excess as well as that for land purchase was explained as follows in a report printed in 1856: "Although I do not suppose that I will be held res- "ponsible for an expenditure not in my department, and over "which I have had no control, I will adduce one instance to "show the impossibility of providing for every case which "occur. When the survey was made in 1852, the line cross- "ed a farm which changed hands in March, 1853, at some- "thing less than £30 per arpent:—about the 1st of June fol- "lowing the Corporation took possession of one and three "quarter acres, and on submission to arbitrators an award of "£3,300 was made, being about £500 more for one and three "quarter acres, than had been paid for the whole farm of over "sixty acres only three months before. About two hundred "acres are occupied by the Aqueduct for which I estimated "an average of about £35 per acre. In the case above men- "tioned, the award was nearly £2,000 per acre, but had the "Corporation been fortunate enough to have purchased from "the party who owned the property when my estimate was "made, it is not probable that the demand would have been "one-twentieth part of the sum since claimed for it.

"The cost of the work embraced in my original estimate "has undoubtedly exceeded that estimate from various cau- "ses which have more or less affected all contracts upon "public works entered into in the early part of 1853 and "executed in 1854 and '55. The war (Crimean) raised the "price of provisions, of iron and freights, and the cholera "brought a scarcity and high value of labor and by retarding "the work materially increased its cost. But the principal "cause has been the quality of the excavation on the line of "the Aqueduct. In the five miles of Aqueduct the depth of "excavation varies from five to upwards of twenty feet. The

"quality of this work and the proportion of it which might "prove to be rock could only be inferred from test pits; these "were as numerous as usual, but it has proved in almost "every case that between the points where they were sunk "the rock rises nearer to the surface and the other excavation "is harder than these test pits indicated. There was not "only about double the quantity of rock which the original "test pits shewed but there was almost as great quantity of "cemented material overlying the rock which was blasted "with it and was equally as expensive to remove. But these "were not the only difficulties. The quality of the rock as "shewn by every test pit was that of a soft shale, but upon "working it was found to be traversed in every direction, "though at considerable intervals, with veins of trap or "*banc rouge*, one of the hardest rocks we have, and the re-"moval of which was the more expensive from its admixture "with the other. Nearly twenty five per cent of the whole "rock excavation was of this character."

A large extra expenditure was caused by wilful injury to the Culvert under the Lachine Canal after it had been completed. Lastly, it was because the work was let to experienced contractors considerably below the estimates that we ventured on the enlargemeut of the Reservoirs.

If the cost to date is $3,000,000, more money has been expended on the works since their opening in October 1856 than before. Any competent judge who goes over the eight miles from the St. Lawrence to the Reservoir will consider the Aqueduct, wheel house &c. pipe track, culvert. rising main and Reservoirs cheap at a million of dollars, I know of no place in America where so much has been done and so well done for so little money, and I think these remarks necessary that the people of Montreal may truly appreciate the value of their own property and do justice to it.

I have the honor to be
Sir,
Your obedt. servt,
THOS. C. KEEFER.

APPENDIX.

CALEDONIA WORKS,
Montreal, June 10th, 1868.

T. C. KEEFER, Esq.

Dear Sir,

I will undertake to make and erect at the Wheel House, for the Corporation of the City of Montreal, a Turbine water wheel eight feet in diameter, with two twenty inch pumps, capable of pumping 6,000,000 gallons in twenty four hours under Reservoir pressure, and with a minimum head of fifteen feet, with the gearing and other connections: I will agree to have the same ready in six months from the date of receiving the order. The whole to be done for the sum of thirty-two thousand dollars.

And if required by the Corporation, I would undertake to erect the building also.

I am, yours,

very truly,

JOHN McDOUGALL.

THOROLD, june 2nd 1868.

Dear Sir,

Just happened to be here when your letter was delivered to me by Mr. Lampman. And in reply beg to say that having so much work on hand this season I am sorry to say that I could not undertake to do the proposed work of the Montreal Water Works.

All my Dredges are engaged, two in the Welland Canal, two on the Ste. Clair flats, two at Bay City and two in Lake George Sault Ste. Mary's, besides two more that I built this season, which I am now fitting up for work, the largest and most powerfull yet built in America: any one who may under

take your work, will require to build a Dredge expressly for it as the material to be Dredged is of that nature that no ordinary Dredge can do it, that is, to make it pay at any ordinary prices.

Yours truly,
JOHN BROWN.
Per McPHERSON.

TELEGRAM.

WINDSOR, 10 Juin 1868.

THOS. C. KEEFER,

I cannot get down. The Dredge leaves Port Colbourne to day. All the Dredges employed would have to be built new.

JOHN BROWN.

ERRATA.—In page 6, in the 8th line of the 1st paragraph, instead of "opened in 1859," read "opened in 1856."