REPORT

ON THE

WATER SUPPLY

FOR THE

CITY OF MANCHESTER

BY

WILLIAM J. McALPINE,

CIVIL ENGINEER.

CAMPBELL & HANSCOM, PRINTERS.
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AN ORDER in relation to Water Works:

IN BOARD OF COMMON COUNCIL.

ORDERED, if the Board of Mayor and Aldermen concur, that a Committee, consisting of His Honor the Mayor, two members of the Board of Aldermen, the President and three other members of the Board of Common Council, be appointed with authority to employ one or more competent persons, or experts on the subject of water supply, who are to make full examination, and report as to the best source from which a sufficient supply of pure water can be obtained for the use of the city, and the most feasible method of introducing the same; said report to be laid before the City Councils as early as practicable, and the necessary expense be charged to the appropriation for Incidental Expenses.

Feb. 7, 1871. IN BOARD OF COMMON COUNCIL.

Passed; and the Committee in this Board consists of William R. Patten, President, and Messrs. Sawyer, Bean, and Towns.

WM. R. PATTEN, PRESIDENT.

Feb. 7, 1871. IN BOARD OF MAYOR AND ALDERMEN.

Passed in concurrence; and the Committee on the part of this Board consists of the Mayor and Aldermen Cheney and Thayer.

JAMES A. WESTON, MAYOR.

REPORT.

PITTSFIELD, MASS., May 27, 1871.

To the Mayor and Water Committee of the City of Manchester:

GENTLEMEN: —

At your request, a month ago, I addressed the citizens at considerable length on the subject of a public water supply, and I am informed that these remarks were published in one or more of the newspapers.

To present the subject in a connected form, it will be necessary to herein repeat more or less of that address.

It is customary, in reports of this kind, to preface the subject by a discussion of the value of a public water supply.

Wherever a public water supply has been introduced in a city, it has been found of superior quality, in greater quantity, and furnished at less expense, than it could be obtained by any individual method; and its introduction has always added to the comfort, convenience, and health of the citizens; has induced additional business; and has increased the growth of the city.

Your present supply of water for domestic purposes is chiefly obtained from wells, which, it is easy to demonstrate, is a far more expensive method, in proportion to the quantity of water obtained, than a judiciously arranged public water supply.

The luxury of hot and cold water in every dwelling, of baths and water closets, private and public fountains, and of street sprinkling, (all of which are furnished almost without cost) are only duly appreciated where they are enjoyed.

Water, under pressure and always available, is a preventative against conflagrations, and often saves more than the cost of such works, and invariably reduces the rates of fire insurance.

THE SOURCES AND QUALITY OF THE WATER.

On this subject I will make the following extracts from one of my former reports:

In all cities there are prejudices and fallacies in regard to this subject which it is advisable to remove by a statement of the received opinions of the sources of water and the changes which it undergoes before it is used, and there are some general principles which may be applied to determine the quality of water which any source will furnish.

Many of these statements are repetitions of what have been learned at school, but which have, to some extent, been forgotten by those engaged in active life.

Water, in its three-fold condition of vapor, liquid, and solid, performs some of the most important functions in the natural and artificial purposes of life. In the first, invisibly associated with the air, it nourishes vegetation; in the second, it forms one of the components of almost every substance in nature;* and in the third, it protects vegetation, and prevents the injurious effects of the low temperature which gives to it a solid form, and furnishes man with one of the most agreeable of modern luxuries.

The parent source of all the fresh water on the earth is the ocean, and the atmosphere is the vehicle by which it is conveyed over and precipitated upon the land, from whence, after performing its various functions, it flows back to the sea, to be again exhaled and distributed over the land, and has thus incessantly circulated for ages.

The amount of watery vapor in the air, at any given time, is determined by its temperature. As this increases, the air absorbs more vapor, and, as it diminishes, the excess is thrown off. The temperature of the atmosphere is changing daily, day and night, and even hourly; and, therefore, this process of absorption and precipitation is in constant action, and produces the palpable changes of drought and moisture, besides a vast, imperceptible action of the same kind in the growth, ripening, and decay of vegetation and animal life.

The winds, apparently so capricious, are governed in a general way by certain fixed laws. The increasing

* The extent to which water mingles with the most solid bodies is wonderful. The glittering opal is only flint and water. Of every 1,200 tons of earth, 400 are water. In every plaster of Paris statue, there is 1 pound of water to every 4 pounds of chalk. The air we breathe contains 5 grains of water to each cubic foot of its bulk, and a healthy man consumes nearly 2 cubic feet of air per minute. The potato contains 75 per cent, and the turnip 90 per cent of water, while the cucumber and melon contain 96 per cent.

The human body is one-half water, or, chemically speaking, is composed of 45 pounds of carbon, with the nitrogen and a few other elements, diffused through 5 or 6 pailsfull of water.

temperature, and velocity of the rotation of the earth, from the poles toward the equator, give the first general direction to the winds. These great currents, encountering the elevated ranges of land, are deflected, and produce eddies and irregularities near the surface of the earth; but there will, in all places, be found a general direction to the winds. The warm atmosphere, from towards the south, moving over the ocean, absorbs its moisture, which it discharges on the land in dew, rain, or snow, and then, returning to regions of higher temperature, is again warmed, and renews its absorption of watery vapor, to be again discharged on the land.

The water which is precipitated upon the earth is in part absorbed by growing vegetation, and the remainder flows off through the superficial water-courses to the brooks and rivers, and back to the ocean; or it penetrates the porous soil in drops, which unite beneath the surface in threads, veins, and strata, and, descending, meet some impenetrable stratum of earth or rock, over which they flow subterraneously and re-appear in seeping places, springs, and sometimes in streams of considerable size.

Springs derive their supply from the aggregation of these rain-drops which have penetrated the porous soil; and wells are merely the interception of these underground threads and veins of water; while ponds and lakes are formed in depressed places by the same drops collecting in a mass over a substratum of soil or rock, through which they cannot percolate, and then the water rises to the brim of the natural water-tight basin and is observed flowing over in a brook or river.

Water is never, in nature, found in a perfectly pure condition. In its vapory form, it has a strong affinity for the other gaseous substances with which the air is charged from effete matter; and, in its liquid form, it is a solvent of many substances which it is brought into contact with upon and beneath the earth. Water is most pure when it is first evaporated in mid-ocean, but, as the vapory winds are driven over the land, it absorbs the gases which are encountered in the air; and, when it falls to the earth and flows over or beneath it, takes up in solution decaying vegetable and animal matter, and the earthy salts, and other injurious soluble substances.

Rain, falling through a pure atmosphere—as outside of towns—upon a clean surface, is the purest form in which water can be found, and when it falls upon a pure sandy soil, free from vegetation, it is the next most pure.

Vegetation and animal life, while growing, are absorbents of deleterious matter in both air and water, but, when decaying, give out that which is noxious to both. Surface water is, therefore, least pure in the autumn, when vegetation begins to decay, and most so in the winter and spring, when no decomposition occurs, or when the vegetation is growing; while spring and well waters, which derive their principal impurities from earthy solutions, are nearly equally impure at all seasons of the year, according to the presence or absence of such soluble materials in the soil.

The foregoing description of the natural operations to which water is subjected is necessary to enable us to determine which is best for the purposes under consideration.

For drinking, water should be wholesome, clear, cool, and aerated; and for other domestic and manufacturing purposes it must be soft and limpid.

For public water supply, therefore, the water should be selected having the following characteristics in the highest degree possible, viz: First, purity; next, softness; and next, limpidity.

The atmosphere over a city is always contaminated with the gaseous products of combustion, and those arising from decaying animal and vegetable matter, garbage, which is strewn over vacant places so freely, and from manufactories, slaughter-houses, and sewage matter,—all of which are constantly sending upward volumes of noxious gases, which the descending water rapidly absorbs, or which are condensed in the upper strata of the air, and are precipitated upon the roofs and surface of the ground, where they will be absorbed by the first fall of water.

The roofs of houses are covered with these substances, and with soot, dust from fœcal matter in the streets, and decaying woody fibre on shingled roofs, and metalic oxides on metalic roofs. The rain water absorbs all of these, and when stored in close cisterns, loses its aeration and becomes insipid, and unless cooled with ice, is repugnant to the taste.

That such water is very impure, is evident from the rapid production of animalculæ in it, which shows the abundant presence of the food necessary to maintain that minute but vast quantity of animal life.

It is often asserted that the impurities of water may be corrected by filtering. In most of the filters in use the operation is merely to separate such matter as is held in mechanical suspension, the molecules of which are larger than those of the water, but they will not remove that which is chemically united. Turbid waters may be rendered clear by filtering, but the best one is quiescence, such as in a natural lake, or the engineer's imitation thereof, a reservoir.

The reservoir, or lake, also performs another important service in purification which artificial filters cannot do. Then the water is kept quiet, all foreign matter which is heavier than it is precipitated to the bottom, where it is no longer subject to decomposition; and all that which is lighter, floats, and, in warm weather, is dissolved into gases, which the wind drives away, leaving the water in its most pure condition.

Filters to separate the matter chemically united with the water are expensive, and must be changed with the constant changing condition of the water, and, practically, are never kept in use for any long period of time.

Carbon filters are used to absorb the impurities, but their capacity of absorption is, comparatively, very small when providing for a household which consumes a hundred gallons of water daily. English experiments show that this quantity of impure water will fill up such filters in a few days, and, thereafter, they will be useless.

Spring water is rarely found in a city, and is usually the least pure of the waters of the neighborhood, while, outside of a city, it is much more free from impurities.

The temperature of water from deep-seated springs is that of the earth at such depth, which is about the mean temperature of the place for the year. At the point of issue the temperature of spring water changes a little with that of the season. Spring water is usually highly charged with air, and this, with its low temperature in summer and high in winter, compared with that of the atmosphere, renders it grateful to the taste. The earthy salts in such water frequently renders it more pleasant to the taste, but they are not always healthful.

Water from wells in cities is always unfit for drinking, and, in most cases, is very deleterious to health. These contaminations are not the less real because they are not usually observed. The gases of dissolving matter frequently impart a sparkling life to well water, and a small mixture of earthy salts adds a flavor, and with a temperature lowered by ice, induces many to express a preference for such mixtures over more pure but, to them, less palatable water.

Thus popular fallacy often forms one of the strongest objections to any scheme of public water supply. Investigations have been made all over the country which show that some of the most serious diseases arise from the use of well water in cities.

In times of cholera, the progress and fatality of this disease has been traced, in a vast number of cases, directly to the use of impure water from certain wells, and their analysis, compared with that of other waters in the same cities, show that this frightful disease is promoted and rendered more fatal by the use of impure well water.

From what has been said before, it will be seen that well water becomes charged with all of the dissolving gases in the city atmosphere, and on the surface, with the solutions of decayed animal and vegetable matter, and mingled with the drainage of stables and privies which have entered the soil, all of which combine to render such water a most disgusting solution.

Several analyses which I have made of water taken from wells where the soil and other circumstances were similar to those of the wells in Manchester, show impurities of twenty-five to thirty-five grains to the gallon (equal to the half of one per cent) of which one-half is from organic animal matter, exactly similar to that derived from sewers and cess-pools.

Analyses of cistern water in other places have shown them to be also very impure, and when not well ventilated frequently become exceedingly offensive.

The cause of this offensiveness is well known. It is nature's method of purification. The vegetable and animal matter which water has absorbed is dissolved, and all of its lighter portions are thrown off in gases which are so evident to our senses.

Hence I am warranted in the assertion that stored cistern water is certainly unwholesome, and generally loathsome and unfit for use.

Water from wells is rarely found soft enough for washing, and resort is therefore had to cisterns of rain water. It has been ascertained that in the use of soap the difference between well water and tolerably pure brook water is equal to one dollar per annum for each inhabitant, and a saving equally great will be made in the wear and tear of clothes.

Mr. Soyer, the most eminent cook in the world, says that there is a difference of one-half in the time required to cook vegetables and meats in hard instead of soft water, and adds that one-third of the tea used in London is wasted by the use of hard water.

Mr. Sawyer has given some very interesting information on this subject in his report. For drinking, most persons only regard clearness, coolness, and flavor in water. The first can be attained either by quiescence, or filtering, and the second by ice—now so universally used, but which merely disguises many of its impurities.

Perfectly pure water is tasteless, and, when unaerated, is insipid, and if we depend on taste alone we would frequently select water for drinking which would be deleterious, as is no doubt the case with most of the well and cistern water in use in cities.

It will follow, from this discussion, that all of the water which is obtained from wells is that which the excavation intercepts as it flows subterraneously through the soil. The quality which any well will furnish depends merely upon the area of the land which drains into it, and the porosity of the soil to receive and store it.

If the ground around a well was level, and the soil equally porous in all directions, the quantity which it would furnish could be approximately determined. But wells under these conditions are rarely met with, and as water obtainable from this source (wells) can only be stored in the interstices of the surrounding soil, they can only furnish a limited supply, and will always be deficient in a dry time.

Occasionally such wells intercept some subterraneous flow of water from a source at a considerable distance, but, even in this case, the same law holds good, and the capacity of supply of the well depends simply upon its drainage area.

By an economical use of water, wells will generally furnish a limited supply for ordinary domestic purposes, but so many of them fail during the dryest times, that, as a rule, they must be considered as unreliable.

The waters of rapid brooks and rivers become highly charged with air, but their currents abrade the banks and bottom, and take up in suspension the alluvial matter, which renders them turbid, and, in that condition, unfit for domestic uses. When such water is discharged into a lake, or artificial reservoir, and allowed to stand quiet, it precipitates all the heavy portions of such suspended matter, and becomes clear and limpid.

These rapid streams also gather and carry forward with them a considerable amount of vegetable matter, which is of the same or less specific gravity as the water. A warm atmosphere dissolves the latter into gases, which arise and are driven off by the winds, and a process of self-purification goes on, which greatly improves the water thus stored.

Objections have been made to water which has been stored for use in reservoirs in some of our cities, because, at intervals of several years, it has become defiled for a few days during the warmest weather.

This defilement is generally produced by the rapid production, either of animalculæ or of aquatic vegetation, the seeds of which, perhaps, lie dormant within the body of the water, or are carried to it by the air, and are generated when the water has remained stagnant, at a high temperature, for a considerable time, and, probably, when the atmosphere is in a certain electric condition. The conjunction of all the causes necessary to generate this minute life occurs only at long intervals of years, and then only exists for a few days. The first fall in the temperature, or the first brisk breeze, destroys the conditions necessary to maintain this ephemeral life, and, following a general law of nature, it dies, and dissolves into gases as quickly as it was generated, and in a few days the water is as pure as before.

This class of aquatic vegetation, and also animalculæ, are brought into life and propagate with astonishing rapidity.*

The original purity of water is no protection against this contamination, though it doubtless lessens its extent and frequency.

It has been stated, with some degree of probability, that the appearance of such excessive quantities of these animalculæ, or of the minute aquatic vegetation which is sometimes found in water, is due to the sudden destruction of either one or the other; that all water is full of minute seeds, or spores of both animal and vegetable matter; and that nature has provided that exquisite adjustment by which animal life is produced sufficient to consume the vegetable matter, by which means the water is kept pure; and whenever, from any cause, there is a sudden destruction of animalculæ, the vegetable becomes excessive, and decays in large quantities so as to defile the water. These creatures are, therefore, nature's aquatic scavengers.

* Rain water, which one day shows no evidence of animal life, will the next be found teeming with animalculæ. In hot weather, the body of a dead animal will, in a few days, become a mass of living matter; and the shallow, stagnant pools of water by the wayside, under the influence of great heat for a few days, will be covered with "frog spittle,"—a species of vegetation. Another of this class will propagate in water in all directions at the rate of a foot an hour.

Again, if from any cause there is a sudden destruction of this minute aquatic vegetation, the animalculæ die suddenly for want of food, and their decaying bodies poison the water.

Stored water, however, always carries on a system of sub-purification.

So large a body of water as Lake Massabesic will, probably, never be contaminated in this manner.

On that plan, provision should be made to carry the water around the proposed reservoirs, directly to the city. So that if the water in the reservoirs should be fouled, a pure supply for the city would be maintained.

If it should happen that either of these receptacles should become contaminated, the first will furnish the supply until the other purifies itself.

Water does not receive or part with caloric freely, and, when stored in large and deep bodies, maintains nearly an equal temperature at all seasons of the year.

The fierce rays of the noon-day sun, and currents of hot air, in contact with the large bodies of water in the Lake and stored in the reservoir, would be tempered by that of the cooler nights and less warm days, so as to give a lower temperature in summer and a higher one in winter; and this water, conveyed in pipes below the surface of the earth, will be delivered at the houses at a very pleasant and equable temperature.

Professor Silliman says that decomposition does not take place to a depth of more than ten feet below the surface of water.

The reservoir proposed has been arranged for fifteen feet depth.

From the preceding discussion, the character of the water from the sources under examination can be aproximately determined without the aid of a chemical analysis.

The atmosphere surrounding the sources of the water is comparatively pure, and is not contaminated by gases of any considerable quantity of decaying matter.

The soil is chiefly the decomposition of the primitive rocks which have been washed by the rains of ages.

The water shed is covered with a strong growth of vegetation, the decomposition of which, in former times, has united with the soil, and, together with the semi-aquatic vegetation of the swamps and muck, has charged the water with some vegetable matter, and gives to it a slight color.

Whenever such water is collected in lakes or reservoirs, and especially when these lakes are large, compared with the water shed, this coloring matter has been mainly removed by the bleaching effect of sunlight—the only practical method of removing color from water. There is a decided difference in the color of water from Lake Massabesic and some of the other sources, although the waters of each are brought into contact with the same vegetation and soil.

I regret that I have been compelled to devote so much space to this branch of the subject. It has been necessary to meet certain prejudices, and popular but incorrect opinions which are commonly met with in discussions of this character.

In every other respect, except that of color, these waters are far superior to the well, or stored cistern waters in use.

The next part of this subject requires an examination of the quantity of water which will be required, and that which each source will furnish.

As an ordinary rule, it has been found that in cities of this size, sixty gallons per day, for each inhabitant, will be required.

Not that each person will require sixty gallons, for it has been found that a household, averaging seven persons, will require only from seventy to one hundred, or an average of ten or fifteen gallons to each person. But the demand for water for baths, water-closets, and private fountains, for manufactories, watering streets, and extinguishment of fires, and, above all, waste from the street and house service pipes, in the aggregate, amounts to what has been above stated.

In New York, Boston, and some larger cities, it has been found that an average of one hundred gallons per day, per capita, are required.

In smaller cities, where more vigilance against waste of water is exercised, sixty gallons are found to be necessary.

The population of the city in 1870 was as follows:

	Population.	Families.	Dwellings.
Ward 1, ...	4,084	641	482
" 2, ...	2,460	265	262
" 3, ...	4,296	928	786
" 4, ...	4,073	851	660
" 5, ...	3,170	533	337
" 6, ...	3,223		558
" 7, ...	1,662	299	234
" 8, ...	541	108	102
	23,509	3,625	3,421

The population in 1860 was 20,107, which shows an increase of seventeen per cent in the last ten years.

The increase for the preceding ten years was thirty-four per cent.

The polls during the same two periods increased thirty and thirty-eight per cent.

The population of Lowell has increased during the same intervals of time, eleven and sixty-five per cent; Lawrence, seventy and one hundred and thirty per cent; and Fall River, ninety and sixty-five per cent.

The vastly greater demand for manufactured articles; the greater remuneration therefor; the lessened cost of production by impr ved machinery, systematic management, and greater command of capital: these considerations warrant the assumption of a future increase in the population of Manchester of thirty-three and one-third per cent for each ten years, or as follows:

In 1850 the population was			. . . . .	13,932
" 1860 "	"	"	. . . . .	20,107
" 1870 "	"	"	. . . . .	23,509
" 1880, estimated,			. . . .	31,345
" 1890, "			. . . .	41,793
" 1900, "			. . . .	55,724

By the time that the water works could be completed, if they were now commenced, the population would be at least 25,000.

In twenty years, thereafter, it would be doubled, and in forty years, trebled.

Hence, no sources of supply need particular examination which will not—

First, Furnish an abundant supply for a population one-half larger than the present, and

Second, Which does not furnish the means of increasing the supply for a still greater population, either by an extension of the original works, or by supplemental ones.

True economy of construction requires that certain portions of the work should be arranged for a population somewhat larger than the present, say 30,000, while other parts should be adapted to a much larger supply.

The rules for determining this question are as follows:

When the original works can be enlarged, extended, or added to, so as to meet the future requirements without any loss on the first expenditure, or when this loss will not exceed the accumulated interest on the excess of cost on such enlargement.

For instance, the pumping machinery should be arranged to supply the present population during the hours of daylight.

As the demand increases, it may at first be met by working more hours, and, subsequently, by increasing the machinery.

The distributing reservoir, if artificial, should be arranged in two sections, of which only one need at first be constructed.

The canals, conduits, etc., should be made, at first, of capacity adapted to the ultimate supply.

The street pipes need only be laid where the municipal authorities may, from time to time, determine, but all of them should be of size sufficient to deliver the maximum quantity. This applies more particularly to the feeding mains, the great arteries of the system.

THE SOURCES

Which have been examined are:

First, From the Merrimack River, near the State Reform School, by pumping by steam power into a distributing reservoir east of Union Street, at an elevation of 143 feet above the datum line.* The pump main would be 3,500 feet long, and 16 inches in diameter.

For probably two months of the year the river water would be too turbid for use, and the supply for that time could be obtained from Burnham's Pond, or, perhaps, by constructing a filtering bed, either at the river or reservoir.

Second, A gravity supply from Maple Falls, by a brick conduit, three miles long, to Burnham's Pond, at an elevation of 160 feet, and thence by pipes to the city; or to Dorr's Pond, to which an elevation of 110 feet can be given.

Third, A gravity supply from Stevens' Pond, at an elevation of 105 feet, and an increased water shed, by catch-water drains, supplementing this supply, when required, either by a conduit from Maple Falls, or, by pumping with steam power from Lake Massabesic. The pipe to the city would be three miles long and two feet diameter.

Fourth, From Chase's Pond, just below Burnham's Pond, with an elevation of 105 feet, and a very large iron pipe (which would be required to maintain even this low head) to the city distribution.

Fifth, From the Piscataquog, with a reservoir on Rock Raymond, pumping by water power, except in the low stages of water, when steam power must be supplemented, or large storage reservoirs must be provided near the source of the stream.

* NOTE.—The elevations referred to in this report are above the steps in front of the City Hall.

Sixth, From Massabesic Lake, by three methods, namely: by pumping by steam power, in the same manner as suggested for supplementing the Stevens' Pond plan; next, by pumping with power derived from the Lake itself, into a reservoir at Porter's, at 127 feet elevation above the datum, through a force main 9,000 feet long, and — inches diameter; or by constructing an hydraulic canal 7,000 feet long, and pumping by water power through a force main 2,500 feet long, and 16 inches in diameter, into a brick conduit 1,000 feet long, which will discharge into the Porter reservoir.

Many of the details will be similar in each one of these plans.

The distribution will be alike for all of them, except that the largest sized supply mains will be at the north or south end of the city, depending upon the source of supply, and they will gradually diminish in size towards the opposite end of the city.

I have carefully prepared a plan of the sizes of the pipes throughout the entire city (including the outlying wards), so as to distribute the water with nearly the same head, upon each of the pipes now or hereafter required, and also subdivided into nine or more water districts, by lines of water gates, and with hydrants placed at all of the alternate corners of the streets, and many additional ones, where they will be most useful.

I have left with you a copy of the city map, on which the sizes of all these pipes are marked, and which have been carefully determined by precise calculations for each pipe, based upon the demand for water by the actual and prospective population of each of the water districts.

I have been greatly aided in preparing this map by the information which has been freely communicated to me by the Mayor, and by the data which he has furnished me.

At the river, the pipes can readily be carried across at the existing bridges, by being boxed and protected from the frost, or they may be carried under the bed of the river with safety.

In water works which I completed a few years ago, both of these methods were used, and have proved completely successful.

The artificial reservoirs would be substantially alike on all the plans.

They should be made with earthern banks, with puddled walls, and lined on the bottom with puddle, and faced on the inside with brick or stone slope walls, pointed up with hydraulic cement mortar.

In determining the power for the steam pumping engines on the Merrimack plan, I have assumed one and a half millions of gallons to be pumped in ten hours, or three millions in twenty hours, leaving four hours for rest, and, including the loss of power by friction through the force mains, find that it will require one hundred and ninety horse power.

I have also provided for a duplicate non-condensing engine, of one hundred horse power, and, from the actual cost of some similar engines, pumps, boilers, pump wells, houses, etc., find that it will cost $125,000 for this portion of the work.

The reservoir, with a capacity of 20,000,000 gallons, or a fortnight's supply, will cost $68,500, and the force main $21,000.

Burnham's Pond, and a connecting pipe to the distributing reservoir, will cost $85,000.

The distribution, upon the plan of bringing the supply from the south, including the water gates, hydrants, etc., with eighteen miles of pipes, will cost $191,000, but about $12,000 would be saved in the pipes by entering the city from the north.

The whole cost of this plan, including superintendence and contingencies, will be $500,000, and to it should be charged, for the purpose of comparison, $80,000, the interest of which would be required to run and maintain the pumping machinery.

The second plan, from Maple Falls, will require the clearing of Sawyer's Pond for a storage reservoir, and the construction of regulating gates, and the improvement of the dam, which, with a similar dam and gates at Maple Falls, will cost $45,000.

The conduit from thence to Burnham's Pond, including a syphon of 1,400 feet length, of cast iron pipe of two feet diameter, and the necessary gates and fixtures, will cost $86,000.

Burnham's Pond, and the pipe leading to the city distribution, will cost $90,000.

The distribution pipe will cost, as before stated, $178,000.

The whole cost of this plan, including superintendence and contingencies, will be $440,000.

The third plan, from Stevens' Pond, will require the removal of a large amount of muck, peat, and vegetable matter in some places, and the covering of it in others with sand and gravel, which, with the dam at the outlet and the regulating gates, will cost $24,000.

The cast iron pipe from thence to the city will be 15,500 feet long, and two feet diameter, and will cost $116,000.

The distribution pipes, etc., will cost less than on the preceding named plans, namely: $133,000. The whole cost of this plan, including superintendence and contingencies, would be $410,000. But as it would afford an inadequate supply, there should be added to this sum at least $150,000 to render it as effective as the other plans which are hereafter considered in this report.

The Lake Massabesic plan will require a canal 7,000 feet long, with eight feet depth of water, which will cost $50,000.

Water wheels must have one hundred horse power, and, with the flumes, appurtenances, wheel house, etc., will cost $19,000.

The force main, including its water gates, check valves, etc., will cost $20,000; and the reservoir the same as on the Merrimack River plan, viz: $70,000.

The distribution will cost $190,000.

The whole cost of this plan, including superintendence and contingencies. will be $390,000.

For the purpose of comparing this with the other plans, there should be charged $35,000, the interest of which will operate and maintain the works.

In arranging the plans of the distribution, it was assumed that the water should be delivered to the highest compact parts of the city, under not less than fifty feet head above the level of the streets, and it has, therefore, been found necessary to arrange these pipes of increased size, so that the above primary rule should be maintained throughout the city.

The friction of the water passing through the pipes reduces the effective head the further the water is carried; and the larger the pipes the less will be the loss of head by friction.

Hence it will be observed that, upon the maps, the pipes in the more elevated portions of the city have been made of larger size than in the more depressed portions.

Therefore, the greater the head which each of the sources will give, the less will be the size of the pipes required, and they may be correspondingly reduced as this head is increased.

Nevertheless, there will always be great advantage derived from larger sized pipes, because they will maintain the head during conflagrations, at which times the largest demand for water is usually made.

The value of this increased head and supply can only be appreciated by the fire department and those who have carefully observed the increased demand upon such occasions.

As a practical illustration of this idea, I would state that the comparative delivery of water by the same sized pipes, under 49 or 81 feet head, is as 7 to 9, and, therefore, the size of the pipes might be correspondingly reduced.

That is, a pipe of four inches diameter, under 81 feet head, is (about) equal to one of five inches diameter under 49 feet head, and, under similar circumstances, one of nine inches is equal to one of twelve inches diameter.

This ratio applies to the whole system of pipe distribution through the city, and is equal to about twenty per cent when applied to your case, which, on $200,000, would be $40,000, or equal to the cost of extending the smaller sized pipes over eight or ten miles of the streets.

The capacity of the distributing reservoir should be equal to a supply for at least a fortnight, in cases where duplicate pumping machinery is used.

If the use of such duplicate machinery is not practicable, or if it is of a hazardous character, then the reservoir capacity should be extended to from four to six weeks supply.

In comparing the cost of pumping by steam with that by water, it should be remembered that the latter requires no fuel, and less attendance, and is of a less expensive character.

The best informed engineers estimate, in general cases, that water power costs but one-third of that of steam, power.

A reservoir on the Merrimack River or Massabesic plan should contain twenty millions of gallons, and should be arranged to hold fifteen feet depth of water, with an average of four hundred feet square at the bottom, and four hundred and seventy-two feet at the inside top angle of the bank.

The slopes, inside and outside, should be two to one, with a top width of sixteen feet, and should be lined with slope-walls of an average thickness of one and a half feet, underlaid by a lining of gravel of one and a half feet thickness.

Such a reservoir will cost as follows:

ESTIMATE FOR THE RESERVOIR.

40,000 cubic yards of			excavation,	at 30	cents,	$12,000
24,000 "	"	"	puddling,	" 75	"	18,000
7,000 "	"	"	gravel,	" 50	"	3,500
4,500 "	"	"	pavement,	" $4	"	18,000
Land, ...						2,500
2,500 feet of fencing at $1, ...						2,500
Turfing, trimming, etc., ...						2.000
Inlet and outlet at houses, ...						10.000
						$68,500

Say, $70,000.

ESTIMATE FOR THE COST OF THE DISTRIBUTING PIPES, ETC.

The main from the reservoir to street—

12,200 feet of 16-inch pipe, $4,					$48,400
In the city—					
1,300	" "	12-inch	"	2.50	3,250
4,100	" "	10-inch	"	2.25	9,225
14,700	" "	8-inch	"	1.80	26,460
35,200	" "	6-inch	"	1.50	52,800
26,600	" "	4-inch	"	1.10	29,260
18 miles.					$169,795
3-inch pipes not included in the above, say					9,205
					$179,000

WATER GATES.

6 of 16-inch, 96			
1 " 12-inch, 12			
2 " 10-inch, 20	530 in. in diameter, at $8,		$4,240
18" 8-inch, 144			
31" 6-inch, 186			
18" 4 inch, 72			
76 hydrants, at $80,			6,080
Add extra,			680
			$11,000
Total cost of distribution,			$190,000

I have not made out estimates upon the Chase, Dorr, and Stevens' ponds, and the Piscataquog plans, because I have considered them as excluded from consideration, by the circumstances of the case, as herein before mentioned, viz: because of their inadequate area of drainage, which is not sufficient to furnish more than one million of gallons daily; and, in the case of the Piscataquog, because, if reciprocity involves the extra cost of steam pumping for a part of the year, or, what would be equally expensive, the construction of strong reservoirs near its head sources, and, besides this, it is upon the opposite side of the river from the city, and subject to the possible contingency of an interruption of the supply.

RESUME.

To determine the best source of supply, it is necessary to consider:

1st. The comparative quality of the water;

2d. The available quantity;

3d. The cost of construction and maintainance; and

4th. Its effectiveness.

It has been previously stated that the original quality of water from the several sources examined was nearly the same.

The water from the Merrimack River is generally clear, and is at all times free from color. During freshets it is highly charged with loam and sand, and is then unfit for domestic use.

Properly arranged filters, either at the river or at the reservoir, will remove all of the suspended matter, and render it clear, and of good quality; and, as before stated, it is possible to obtain a sufficient quantity, from another source, to last through the turbid season of the river, and, with this provision, or that of the filter, this source of supply may be considered as unobjectionable.

The waters of Sawyer Pond, Stevens Pond, Dorr's, and Piscataquog, are all highly colored.

I do not consider this question of color as objectionable, except to the sight of fastidious persons. The color is imparted from the fallen leaves, evergreen, roots, and aquatic plants, and, though very apparent in many of these waters, does not exist in sufficient quantity to injure it as a potable drink, or for domestic purposes.

Nevertheless, it is offensive to the sensibilities of many persons, and should only be used if no better water is available.

In regard to color, I found that Sawyer's Pond was of the deepest tinge, and the others were in the above named order.

I have omitted Lake Massabesic from the list, because I could not discover the slightest tinge of color in its water, when flowing over the outlet dam, or in the center of the lake,

For the reasons stated, the water of the lake must be of the best quality of any of those which have been examined.

There is an ample supply of water for any possible future use, from either the Merrimack, Maple Falls, Piscataquog, or Lake Massabesic. The latter will also furnish a supply of water, which, with the forty feet of available fall, will give the requisite mechanical power to elevate the water required for consumption by the citizens, into the reservoir.

I have revised my first estimates of the water available from this source both for consumption and for power, and find that they are substantially correct, and therefore restate them. Assuming the rain-fall at Lowell for thirteen years to average the same, or rather to represent that at Manchester, and taking the years of the greatest fluctuations, it will be seen that a storage of five feet depth on the Lake will contain the surplusses of the fall of water in the seasons of the greatest irregularities, and if properly arranged at the outlet will give an average daily flow sufficient to furnish the power to lift five millions of gallons daily into the Porter reservoir.

In this calculation, I have assumed but sixty per cent. of the theoretic power of the water. This estimated power may be increased one-third by more expensive water-wheels. I have also excluded a portion of the power which can be made available by lowering the tail race at the proposed site of the water-wheels.

In my address, I explained the details of this plan.

The Piscataquog will furnish power enough to elevate and distribute the water, except in the dryest seasons, at which time a steam engine would have to be resorted to. The surveys of the area of the water-shed of Ray Brook and Stevens Pond, which have been made at my request, show that neither of these sources can be relied upon to furnish the quantity of water which ought, in your case, to be provided for. By very careful attention, they would furnish for a year or two, a supply which would barely answer the most pressing requirements, but which would be found to be so much less than is now used in other cities as to render it probable that your citizens would soon demand more water than could be obtained from either of these sources, and compel a resort to supplemental works, the cost of which would doubtless exceed that of either of the three plans, which are really the only ones to which you could resort.

These are from the Merrimack, Maple Falls and Lake Massabesic. The question, therefore, is resolved into a choice of one of these.

In Mr. Sawyer's report, there is an excellent discussion of the question of supplying a city by gravity and mechanical power, and I entirely agree with the results of his arguments on this subject.

In ordinary cases a gravity plan is less hazardous than one which is dependent upon the comparatively complicated operations of machinery. In this instance, however, the risk of the dams at Sawyer's, Maple Hill, and Burnhams, and of the long, deep syphon pipe and the other appurtenances connected with this plan, appear to me to be fully equal to that of either the Merrimack or Lake Massebesic plans; and as the advantages of the quality of water and the cost of its introduction is in favor of the two last-mentioned sources, the question seems again to be narrowed down to a comparison of these two.

The Lake plan combines advantages over all of the others, viz:

1. In the quality of its water.

2. In the quantity which can be relied upon, not only for consumption in the city, but also for the necessary power to elevate it into the distributing reservoir.

3. In cost of construction and maintainance, and also in efficiency.

I therefore repeat what I said in my address, that "I recommend that the works should be constructed upon the plan of deriving the supply from Lake Massabesic."

In closing this report, I will add, that I have had occasion to prepare many details of the plans of the several portions of the work, which can easily be transcribed by a draftsman, and will be useful whenever you shall decide upon a commencement of the works. These will be placed at your service if you desire.

I have added hereto a description of the comparative advantages of cement-lined and cast-iron pipes, which will enable you to determine which you will adopt.

Respectfully your obedient servant,

WM. J. MCALPINE.

APPENDIX.

There has been much discussion among engineers in regard to the use of cast-iron pipes as compared with those made of sheet-iron, lined and covered with hydraulic cement mortar.

Against the former it is urged that they are more costly; that they oxydize, especially on the inside, and form tubercles, which materially obstruct the flow of the water and which contaminate it.

Against the cement-lined pipes it is asserted that they do not have sufficient strength to resist the water ram which so frequently occurs, especially when a considerable number of hydrants are simultaneously closed, after the extinguishment of a fire; and lastly, that these pipes are inflexible and break with the slightest unequal settlement of the foundation on which they rest, and the slightest crack in the outer coating of the cement leads to a rapid destruction of the iron, and that they are very difficult to repair.

As a general rule, the cost of cast-iron pipes, for city distribution, has heretofore been about twenty per cent. greater than that of cement-lined pipes. I have recently received a letter containing an offer for cast-iron pipes for the city distribution, which is almost as low as those for cement-lined.

The force mains from the pumps are constantly subjected to the blows from the alternating pumps, and must be of cast iron.

The oxydation of cast-iron has received a good deal of attention among the English engineers, and after careful examination and a long discussion in the London Engineers' Society, the leading engineers expressed the opinion that iron can be selected of such quality as will not materially corrode, even in salt water, for a century.

The examples of the corrosion of iron pipes and the formation of the interior tubercles, are, therefore, doubtless due to the use of a quality of iron not suitable for that purpose.

The extra cost of this suitable iron is only a few dollars (less than five) per ton.

The strength of cement-lined pipes depends almost entirely upon the strength of the sheet-iron riveting. Repeated experiments in hydraulic presses, show that they will, when properly made, and of sufficiently strong, good iron, resist the pressure of more than three hundred feet head of water.

The pipes laid in the streets, however, are often subject to much greater pressure than that due to the statical head of the water.

During a conflagration, a very large quantity of water is drawn from the pipes, producing a very rapid current through all the adjacent ones for a large area. At the termination of the fire, it often happens that the firemen shut off a number of the hydrants nearly or quite simultaneously, the effect of which is, that the whole body of water in all the pipes, for a considerable area, receives the shock or blow, due to the momentum, or weight of the water multiplied by its velocity.

This has been ascertained to be in some cases five times as great as the effect of the statical head, and the effect is communicated to the water in the whole system of pipes. If there be in any part of this system a weak joint or pipe, it bursts at that place.

In my own experience, I have had examples of this effect, and have ascertained that it is not an uncommon one.

After a while, the Fire Department, having experienced the effect of a simultaneous closing of hydrants, meets the difficulty by ordering the hydrants to be closed slowly and one after another.

This is one of the reasons for making the cast-iron pipe of such extra thickness, as compared with the lined wrought-iron pipes, so that they may be able to resist these occasional severe pressures.

The experience of many of the smaller cities has, however, demonstrated that the cement-lined pipes are not more liable to leaks and bursts than those of cast-iron, and, therefore, I do not consider this alleged objection to them as of much account. The cement-lined pipes will, at first, give out to the water a little lime, which will harden it; but in a few months this will cease, and thereafter the water will be conveyed through them without any further effect.

The last objections to these pipes are because they are unyielding, and when they are laid in trenches where the ground gives an unequal support, it will settle more in one place than in another, and this must necessarily break the outer cement envelope of the pipes, and permit the access of moisture and air, which will rapidly corrode the thin sheet-iron and produce a leak or rupture. These pipes should not, therefore, ever be placed or used where there is any danger of this unequal settlement.

In the case of the iron pipes, at each twelve feet there is a lead joint, which will allow the adjacent pipes to settle at their ends an inch or so without producing a leak, and this will generally be sufficient to prevent the breakage of any lengths of cast iron pipes.

I have treated this subject at greater length because, aware of a general impression in favor of the use of cement-lined pipes, I deemed it advisable to fairly state all the advantages and objections of each kind of pipe. With the foregoing statement of advantages and disadvantages of the two kinds of pipe, you will be able to select either.

It is important that the water in the distribution pipes should circulate freely, and that there should be no dead ends. A proper arrangement of the pipes and some blow-off cocks, occasionally, introduced in the lowest places to discharge the stagnant or soiled water, will accomplish these purposes.

It has been frequently asserted in the newspapers, that lead pipe in dwellings is productive of injury to the water by its absorption of the metal. I consider this as a mere popular prejudice, urged upon the public to promote the use of some of the various patented processes of service pipes. The chemists of some of our cities have demonstrated that certain soft waters will decompose lead from service pipes. All of these experiments have been made on water which has been allowed to stand quiescent for many days in lead pipes, and by analysis will, of course, show the presence of lead. Practically, however, no person would use such water, because if the cock is opened ten minutes, it will empty all the water from the lead pipes, and then the supply will be directly from the street mains, which will be perfectly pure and harmless and none of the apprehended dangers of the chemists will occur.

CITY OF MANCHESTER.

In Board of Mayor and Aldermen.

Resolved, If the Board of Common Council concur, that the Joint Special Committee appointed February 7, 1871, by an order of that date, to procure surveys for Water Works, be and they are hereby authorized to make application to the State Legislature at the next session, for such suitable and proper legislation as may be necessary to enable the city to construct adequate Water Works.

June 6, 1871, In Board of Mayor and Aldermen, passed.

JOSEPH E. BENNETT, City Clerk.

June 6, 1871, In Board of Common Council, passed in concurrence.

E. D. HADLEY, Clerk.

A true copy of Record.—Attest:

JOSEPH E. BENNETT, City Clerk.

THE STATE OF NEW HAMPSHIRE.

In the year of our Lord One Thousand eight hundred and seventy-one.

AN ACT

To enable the City of Manchester to establish Water Works.

Be it enacted by the Senate and House of Representatives in General Court convened.

Section 1. The city of Manchester is hereby authorized and empowered to construct, manage and own Water Works for the purpose of introducing an adequate supply of water for extinguishing fires, for the use of the citizens of said city, and for such other purposes as may be required, and for that purpose, may take, purchase and hold real estate not exceeding in value at the time when the same shall be so acquired, the sum of two hundred thousand dollars, and erect, construct and maintain such dams, reservoirs and buildings as may be necessary for such Water Works, and dig ditches and break up ground in the highways and streets of said city; place and maintain pipes therein for conducting water; relay and change the same from time to time, due regard being paid to the safety of the citizens and the security of public travel.

Section 2. Said city shall, before it enters upon the construction of said Water Works, file in the office of the city clerk of said city, a location of the same, with a description, marked by permanent bounds, of the lands and rights of water other than such as may be within the limits of some highway that may be required for said Water Works, and may acquire the title to the same by purchase, when practicable, and such location may be changed, from time to time, and a new location filed in like manner.

SECTION 3. If said city shall not be able to secure on satisfactory terms, the necessary lands and rights of water for said Water Works so located, including the right to lay and maintain pipes where required, the said city may apply to the County Commissioners for the County of Hillsborough, to assess the damages to the owners of such lands or rights of water, and said Commissioners, after notice to the parties interested, and a hearing thereon, if it shall appear that any land, rights of water or rights to lay and maintain pipes are required by said city for said Water Works, shall assess and award damages to the owner of such land or rights adjudged to be required for the purpose of said Water Works; which assessment and award shall be in writing and filed in the office of the City Clerk of said city within ten days after the same is completed, and upon payment or tender to the owner, of the sum so assessed, the rights so taken shall be vested in said city.

SECTION 4. The same right of appeal from such award shall exist as in the case of lands taken for highways by the action of said Commissioners.

SECTION 5. Said city is authorized to contract with individuals and corporations for supplying them with water, and to make such contracts, establish such tolls and charge such rents for the use of water as shall be deemed reasonable; and for the more convenient management of said Works, the same shall be placed under the direction of a Board of seven Water Commissioners, to be appointed by the Mayor and Aldermen of said city, in the month of September in each year, of whom the Mayor for the time being shall be one. Such Commissioners shall hold their offices for six years, and the first Commissioners appointed shall determine, by lot, the term for which they shall hold their office, so that the term of one Commissioner shall become vacant in each year, such term of office to commence with the first Tuesday of January in each year.

SECTION 6. Said city is authorized to levy taxes to defray the expense of such Water Works, and to borrow money therefor, not exceeding in the whole the sum of six hundred thousand dollars, and to issue the notes, bonds or obligations of said city therefor, payable at such time and at such rate of interest as the City Council of said city shall determine, and such notes, bonds and obligations shall be legal and binding on said city.

SECTION 7. Said city is authorized to raise by taxation, and pay in each year, the interest of the notes, bonds or obligations so issued, and such part of the principal as may be determined by the City Council.

SECTION 8. Said city may acquire the rights, powers privileges, franchises and property of any acqueduct corporations located within said city, on such terms as may be agreed upon, and shall thereafter possess the rights, powers, privileges, franchises and property of such corporations in the same manner as if the same had been originally granted to said city.

SECTION 9. This act shall take effect on its passage.

Approved June 30, A. D. 1871.