Cambridge, Massachusetts

City of Cambridge.

# REPORT

OF THE

# SPECIAL COMMITTEE

ON THE

# WATER SUPPLY OF THE CITY.

DECEMBER, 1879.




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# REPORT ON WATER SUPPLY.

*To the City Council of Cambridge:* —

A petition signed by more than 2,500 persons, representing themselves to be citizens of Cambridge, many of whom are well known, was presented to your honorable body, and was in the following words: —

*To the Honorable the City Council of Cambridge:* —

The undersigned, citizens of Cambridge, and many of us water-takers, solicitous for the purity of our water supply, and alarmed by the recent action of the selectmen of Belmont in authorizing the erection of a large slaughter-house upon the borders of Fresh Pond, respectfully and earnestly request you to take immediate steps, under the authority conferred upon you by the legislature, to secure, by purchase or otherwise, sufficient land upon the margin of Fresh Pond to protect our water supply from pollution. We believe the acquisition of this territory a public necessity, and that advantage should be taken of the low price of real estate at the present time.

Upon that petition the following order was adopted Dec. 4, 1878: —

*Ordered*, — That the petition of S. B. Rindge and others, for the purchase of land upon the borders of Fresh Pond, be referred to a special committee, to consist of the present Mayor, President of the Common Council, President of the Water Board, City Solicitor, City Physician, and City Engineer; said committee to have full power to employ experts, and to examine into the whole matter of said petition, with a view to a thorough investigation of the same and the prevention of any pollution of our water supply; said committee to continue until its work is completed and its report made.

The Committee thus appointed has duly considered the matters referred to it, and presents the following

## REPORT.

It appears, by an inspection of the records of the City Council, that, before the petition was referred to us, at the request of the petitioners a public hearing was granted to them Nov. 15, 1878, and that several persons appeared and spoke upon the subject-matter of the petition. The remarks made at that hearing were shortly afterwards published in a pamphlet, and the suggestions therein contained have been carefully considered by us.

It will be observed that the order is very sweeping; and in pursuance thereof we have made as thorough an examination as we could of the whole subject of our water supply.

At the outset we secured the services of Mr. E. S. Chesbrough, of Chicago. This gentleman has been intimately connected with the water supply of Boston from the first, has an extensive and accurate knowledge of this section of this State, and is probably more conversant with the whole subject of the water supply of cities than any other engineer in this country. He met us in consultation, spent a number of days in a personal inspection of the pond, had frequent consultations both here and at Chicago with the City Engineer, and we commend his concise but valuable report to your thoughtful consideration. We also secured the services of Prof. E. S. Wood of this city, an eminent chemist, who was one of the commission of three appointed by the city of Boston to report upon the water supply of that city, which resulted in the selection of the Sudbury River. He has taken a prominent place in most of the sanitary investigations of the last few years, and we submit his report to the people of Cambridge with entire confidence in its high scientific value.

In furtherance of this investigation we have caused a thorough examination to be made, by means of borings, of so much of the territory about Fresh Pond as would affect the character of its water. These borings were made under the immediate supervision of the City Engineer, who has also caused to be prepared the map presented herewith, showing the territory covered by these investigations. He has carefully examined all sources of information known to us, of the amount of water to be obtained

from Fresh Pond, and has presented his conclusions in the subjoined report. He has also prepared a diagram showing the height of water at several points in the course of Alewife Brook, exhibiting clearly, in this way, facts of the utmost sanitary importance.

We have been deeply sensible of the paramount importance of this question; have availed ourselves of all known sources of information; and, although approaching the subject with some differences of opinion, are now unanimous in our conclusions.

We found it convenient to consider the subject under the following heads: —

I. Present water supply, both as to quantity and quality.
II. Sources of pollution, present and future.
III. Remedies.

## I. Present Water Supply, both as to Quantity and Quality.

Fresh Pond has an area of one hundred and eighty-eight (188) acres, and a drainage area, not including the pond itself, of five hundred and sixty-nine (569) acres. It lies partly in Cambridge and partly in the town of Belmont, — about one third of its border being in Cambridge, and the rest in Belmont, — and naturally discharges through Alewife Brook, always a sluggish stream, into Mystic River. In a course of more than two miles the fall is slight, amounting in the first eight thousand (8,000) feet of its course to ten inches only.

Spy Pond in Arlington, Little Pond in Belmont, and Wellington Brook are connected with Fresh Pond by a conduit four thousand and sixty-one (4,061) feet long, which was finished in the spring of 1876, and first used in that year. The natural outlet of Spy and Little Ponds is by Little River, a stream entering Alewife Brook three thousand eight hundred and twenty (3,820) feet from Fresh Pond. Wellington Brook, with its whole course within the limits of Belmont, has a drainage area of two thousand five hundred (2,500) acres, and is connected with the conduit one thousand five hundred and sixty-five (1,565) feet from Little Pond. As might be expected from its large drainage area, Wellington Brook furnishes after heavy rains, or in the time of melting snow, a very large volume of water. In-

asmuch as Spy Pond has never been used in connection with our water supply since the building of the conduit, and as its condition as to purity has not during the same time been satisfactory, and is not, from the peculiar character of the surroundings of the pond, likely to improve in the future, we shall not consider it.

Little Pond, for the reasons set forth in Prof. Wood's report, to which reference is made, cannot be safely reckoned upon. We believe that the reasons which led the Water Board to refrain from using these waters are sound, and that these two ponds are not proper sources of water supply.

While Wellington Brook during the larger part of the year is open to the same objections that apply with so much force to Little Pond, still, at certain seasons of the year, it furnishes a water of apparently unobjectionable character. As this water has not been admitted to the conduit at those seasons of the year when the ground is open, or when its heavily manured surface of cultivated ground is likely to contaminate the waters of the brook, no estimate has been made of its ordinary flow. We have investigated only the character of the water collected during or after heavy storms, or of that furnished by melting snow during winter and early spring, and then only when the brook has been thoroughly washed out by the first flood of water; and, as was to be expected, this water is unobjectionable.

The records of the Water Board, giving the levels of Fresh Pond when Wellington Brook was connected with the conduit, appear to show that the amount thus obtained may reach 20,000,000 gallons daily; and from the records it would seem that this amount has been exceeded on several occasions. The quantity of water obtained in this way would, in practice, be only limited by the capacity to store it. And while it is undoubtedly true that the water of Wellington Brook is unsafe during a large part of the year, we can see no reason for believing that it would be at present unsafe to use the storm waters collected from the surface of frozen ground. The general occupation of the area drained by Wellington Brook will of course in time forbid any use of its waters. It should be remembered in this connection that most of the conclusions adverse to the use of water from cultivated fields come from investigations carried on in England, where the soil is never so locked up by frost that a rain of twenty-four hours' duration would not thoroughly thaw it out and render it improper as a gathering ground for water for domestic use.

The condition of the ground during a January thaw, frozen possibly to a depth of several feet, and covered with melting ice and snow, would enable the drainage area of Wellington Brook to furnish a nearly pure water, and in sufficient quantity to supply the needs of the city. These storm waters have been relied upon during the past unusually dry season to supplement the water of the pond, and would be sufficient in any season if the pond had the necessary storage capacity.

The arrangements for connecting Wellington Brook with the conduit are such that the water of the brook may be admitted or not, as seems at any time best.

The quantity of water that can be furnished daily by Fresh Pond itself has been shown to be 1,750,000 gallons in a dry season, and 2,000,000 in a wet season.

As population increases about the pond, it will become more and more necessary to shut out all surface drainage, and to diminish in consequence the amount of water entering the pond at or immediately below the surface of the ground. It is undoubtedly true that 2,000,000 gallons daily will be the largest quantity of water that the pond alone can ever supply. The average number of gallons pumped daily in the two years of 1877 and 1878 was very nearly 2,500,000 gallons (2,444,461).

It should be remembered, however, that it is only upon the minimum quantity furnished that we can safely rely. All our provision must be made for a season of drought, not for a season of plenty. The minimum quantity of water furnished by a water supply in twenty-four hours, not the maximum quantity, shows the capacity of the supply.

The present quality of the water in Fresh Pond is satisfactory; there is no evidence from a chemical analysis that it has changed in any important respect from the time when it was first examined to determine the fitness of the water for household use.

In order to ascertain, if possible, whether the use of Fresh Pond water had caused any change in the health of the people of Cambridge, or whether any disease generally supposed to be dependent upon use of improper drinking waters had made its appearance in recent years, the two following questions were addressed to the physicians of Cambridge: —

1. Have you observed any facts which lead you to conclude that the use of the Fresh Pond water affects injuriously the health of the inhabitants of Cambridge?

2. If so, will you state what the facts are, and in what way the injury arises?

Twenty-seven answered, "No." One answered, "I have repeatedly noted injurious results from the use of well water in several cases, and on changing to Fresh Pond water the effect has in every case proved beneficial." Two others deemed the water suspicious, but had few facts to offer in support of that suspicion. It was very justly observed, in answer to the first question, by one of the physicians addressed, "It is very difficult to answer this question satisfactorily. It would require that in any given case the water should be used and then omitted several successive times. It would also require that Fresh Pond should remain unchanged or be accounted for during the use and disuse of the water. This last it would be difficult to secure, inasmuch as very few of those who take the water have any other source of supply."

This remark is certainly true; but the difficulty was also considered by us in framing the question. It was thought that the physicians of Cambridge would surely have noticed, in the gradual displacement of other waters by those of Fresh Pond, the appearance of new forms of disease, or the increase of diseases already prevalent. This does not appear to have been the case.

And it is certainly fair to presume that no increase of sickness has attended the yearly increasing use of Fresh Pond water for domestic purposes. The table of waters analyzed from wells supposed to be good, and published by the Board of Health of this city in their report for 1878, shows conclusively that it is very nearly hopeless to seek to obtain, by means of wells within the city, any water equal to that of Fresh Pond.

As the pond derives the principal part of its water from underground sources, a better knowledge of the soil about the pond than any already had was evidently necessary. In order to secure this knowledge, borings were made at various points as marked on the map annexed to this report, specimens of the soil through which the borings were made were taken at intervals of a few feet, and sufficiently accurate information as to the character of the soil was obtained, as shown in the accompanying diagrams.

Borings were made on the line of Alewife Brook, numbered on general map accompanying this report from 1 to 10, to the line of the Fitchburg R. R. The pond on this line has a nearly com-

plete protection from the entrance of water from the marsh by an impervious bed of clay. The deposits of sand and gravel are slight in amount, and not continuous, except in a slight degree in the bed of the stream. Boring No. 1 was carried down to the underlying slate, which was reached at a depth of one hundred and forty-eight (148) feet; the other borings, with but few exceptions, were carried to a depth of about sixty (60) feet. This depth seemed sufficient for our purpose, as the pond has at no point a greater ascertained depth of more than fifty (50) feet. From the crossing of the Fitchburg R. R. another set of borings was made, numbered 11, 12, 13, 14, in the direction of Black's Nook. Here there is a rapid disappearance of the clay and a replacing of the same by gravel and sand. On the line indicated by wells numbered 12, 17, 18, the clay comes again nearer to the surface of the ground, approaching the disposition of soil observed in the first set of borings, and indicating that the danger of contamination to the water of Fresh Pond from the polluted waters of the marsh increases as we approach Black's Nook; but even at boring 17 the clay does not rise sufficiently high to protect under all circumstances.

On the line of borings 13, 15, 16, the clay dam is absent, and the water of the soil, under proper conditions, would meet no obstacle to a direct flow towards Fresh Pond.

The borings on the line of the conduit, numbered 30, 31, 32, 33, show a coarse gravel, extending to a level nearly, if not quite, equal to the bottom of the pond, and this at the portion of the pond at present most exposed to danger of contamination from decomposing animal matter from the hog-slaughtering establishment of Niles Bros., and the highly polluted waters of Alewife Brook flowing in this direction through a channel excavated in connection with the Glacialis, and the necessarily foul muck-heap upon the side of a hill in direct connection with the gravel deposits shown by the last-described line of borings. A very convincing proof of the amount of water furnished to Fresh Pond from this gravel bed is shown by the fact that well No. 14 flows at a height of three inches above the surface of the pond.

The line of borings numbered 20, 21, 22, 23, 24, 25, from Bird's Pond running north into Fresh Pond, gives no evidence of any protection to the pond in this direction by means of clay. The amount of water furnished to the pond from underground sources

on this side is undoubtedly large, as well No. 25 flows at a height of six inches above the surface of the pond. The only district from which the pond appears to have any protection upon this side is that lying to the south of Kirkland and Linden Streets; and this is shown in the diagram of borings numbered 26, 27, 28. How complete this protection may be is, however, a matter of some uncertainty, from the fact that this district may have underground connections with Bird's Pond. The protection is in no case enough to justify us in overlooking the dangers that threaten the pond from the large and growing settlements in this district. Upon the line of borings numbered 20, 21, 22, 23, 24, 25, the height of ground water was taken, and is shown by the dotted line. This is such a line as would be produced by the interstitial friction, and consequent falling off of the water flowing towards the pond through coarse gravel and sand.

From the foregoing it will appear that the pond receives the larger part of its underground water supply from gravel beds extending far beyond the apparent limits of the pond; that through these beds the water can freely circulate; and that the inevitable lowering of the pond establishes currents in the direction of the pond.

Our conclusion is, that we are virtually restricted for our present supply to the waters of Fresh Pond, with the addition, during certain seasons, of those of Wellington Brook, and that these are of good quality.

The admirable diagrams illustrating these borings, and prepared under the personal supervision of the City Engineer, obviate the necessity of more extended remarks upon this head, and we invite you to a careful inspection of them.

## II. Sources of Pollution (Present and Future).

Fresh Pond is exposed to certain dangers to which all ponds in the midst of rapidly growing centres of population are subject; and these dangers are to a great extent inevitable. That our pond must at no very distant day fail to be an acceptable source of supply for this reason is, in our opinion, to be expected. This danger, believed to be inseparable from the covering of the surface of the ground with houses, will be even more menacing to the purity of running streams. The not very thickly settled

banks of Wellington Brook have already cast a well-founded suspicion upon the waters ordinarily contained therein.

But beyond this general danger, to which all water sources are subject, are the peculiar conditions of Fresh Pond. If the objectionable waters only came from the surface of the ground, a marginal sewer would very easily, at a large expense, give us relief and destroy our water supply at one and the same time.

But the existence of beds of coarse gravel upon the north-easterly side of the pond, underlying a part of the great expanse of marsh, introduces a connection between marsh and pond which no system of drains, however perfect, can interrupt. So long as marsh and pond are at the same level, the pond may not suffer; but should, for any reason, the pond again stand at the low level to which it sank in 1875, it can easily be seen that the pond would drain the marsh, and the nature of the matters contained in the waters of the marsh may be seen in the report of Dr. Wood. Instead of waiting through years for the gradual deterioration of the water, we might pass, in the course of a few days even, from a good water to a hopelessly bad one; and if the pond ever did become once fouled, it would be worthless for drinking purposes for ever after.

In wet seasons Alewife Brook overflows its banks, and covers the marsh with polluted waters. In some instances the currents of Little River and Alewife Brook have been reversed, and there has been a direct flow of filthy water into Little and Spy Ponds. Fresh Pond is only protected from the same danger by an elaborate system of artificial barriers; but this does not prevent the deposit, in too close proximity to the pond, of injurious matters contained in the waters of the brook.

The analyses of water taken from the marsh at distances of fifteen feet from the brook show that pollution of the waters in the soil has already advanced to a startling degree.

For an undeterminable amount of time the gravel and sand between the polluted marsh and the pond will be a filter of more or less efficiency; but there is nothing more certain than the proposition that no filter can long be efficient against the very foul waters already contained in the low lands closely adjoining the pond.

The danger from the waters of Cider Mill Pond, in Cushing Street district, is also ever present, in heavy rains escaping into

the pond by a direct channel, and at all times flowing in the same direction by underground watercourses. The danger here is the most serious of all contaminations, — that by human excrement.

Fresh Pond Hotel grounds are dangerous in so far as they are used in defiance of city ordinances; but it has not been ascertained by us that such improper use has been made of them during the present year. The Board of Health, in connection with judicious moderation on the part of the Mayor and Aldermen in licensing the hotel, can probably make the grounds of the hotel as safe, to say the least, as any other part of the surroundings of the pond. Niles Bros.' slaughter-house could only be safe if it were administered with the single object of making it harmless to the pond; and even then it would be subject to accidents by fire, and otherwise capable of doing great harm. This danger is in great measure due to the proximity of buildings to a pervious conduit near the surface of a coarse gravelly soil. The liquid substances not retained by the muck beds necessarily also flow through the lower ground to Wellington Brook, in one direction, and the conduit in the other. There seems to be but one case of the entrance of house-drainage into the pond, through channels distinct from those above mentioned. The dangers from this source, though less in amount, would necessarily be the same in character as those caused by the overflow of Cider Mill Pond, and to be controlled by the same methods.

## III. Remedies.

We are thoroughly convinced that neither any sewage from any municipality, nor any refuse from the slaughter-house, should be allowed to go into Alewife Brook. Our own sewers should be taken from the brook, and the sewage now emptying there should be conducted through our own limits to the Charles River. The City Engineer has made plans and estimates for such a sewer, and we believe it should be at once constructed. It should also be insisted that Niles Bros. should be restrained from conducting any refuse from their establishment into the brook.

As the natural drainage of this territory is towards the Mystic River, the plan of draining the same by a sewer running in that direction has been fully considered by us. Notwithstanding the

manifest advantages of such a sewer, we believe it would be highly impolitic for this city to enter upon the plan. The plan requires legislative sanction, and any application to the legislature would be met by a most determined opposition from several of the municipalities through which the sewer would run. But a still greater objection is that it would involve the city in an unlimited liability for the expense of extending the sewer to deep tidal currents, whenever that should be found necessary, which we believe would be at no distant day.

The matter of remedying the evils threatened by Cider Mill Pond and Richardson's Pond has been the cause of anxious and prolonged investigation and discussion by us; and we are not surprised that the Water Board has frequently and earnestly called the attention of the City Council to this subject. There seems, however, to be but one way to cure the evil, and we have been driven to it by the simple inexorable logic of the subject. That way is to conduct the flow of these ponds by means of a sewer running along the margin of Fresh Pond, and connecting with the sewer already built upon a certain portion of the margin of the pond within the limits of Cambridge, to be conducted from there to the Charles River. This plan requires legislation, as both of the ponds, and much of the land through which the sewer would run, are outside of Cambridge.

The petition referred to in the order under which this committee was appointed asks that another remedy be tried. It requests the City Council "to take immediate steps, under the authority conferred upon you by the legislature, to secure, by purchase or otherwise, sufficient land upon the margin of Fresh Pond to protect our water supply from pollution." The authority directly conferred upon the city by the legislature was to take, by purchase or otherwise, a strip of land not exceeding five rods in width around the pond; and it would perhaps be a fair construction of the petition, when taken in connection with the powers thus directly conferred upon the city, and therein alluded to, to interpret it as simply requesting the city to take land not exceeding the five rods. Our right to take "otherwise" than by purchase is confined to that limit. The consent of the land-owner is necessary if we desire to take more. To the petition thus interpreted our answer is that the taking of such a strip will not accomplish the object set out in the petition. But this was

substantially conceded by one of the petitioners who addressed the Council at the hearing, and the broad proposition was by him enunciated, that "if an exercise of the right of eminent domain granted to Cambridge by the act of 1875 will not secure land enough to protect Fresh Pond from pollution, then" the city should "purchase any additional land that is necessary to that end." In other words, the petitioners request that the city should get by right of eminent domain so far as it can, and where that right stops, then by purchase from the land-owner, upon such terms as can be obtained from them, such land in the vicinity of Fresh Pond as now and hereafter shall keep the water therein suitable for domestic use. And we have considered the petition upon that broad interpretation of it.

Of course, the first thing in the consideration of such a proposition is to ascertain as nearly as possible how much land must be acquired thus to insure the safety of the pond. It is not a question of keeping polluted surface-water from running directly into the pond, but of keeping free from contamination the underground currents. We cannot keep the underground currents from going into the pond. They must be kept pure from polluted matter in solution, because once polluted it is beyond our power to prevent that pollution from reaching the pond. The protection therefore needed is not only to the pond as seen to the eye, but to the underground currents leading to the pond, wherever they may be.

The investigations made by us into the geological features of the land surrounding the pond show conclusively that if the object be to protect these underground currents so as to make it reasonably certain that the water shall, for all time, be suitable for domestic use, it will be necessary to take a strip not only five rods wide, but in some places fifty rods wide, and in some much more; that it will be necessary to take not only land, but many buildings, some of which are quite valuable; and it must be borne in mind that all this property must be taken at the owner's valuation. The underground currents supplying the pond come from a long distance through strata of coarse sand, and it is practically impossible to tell where to stop purchasing.

The cost of the property it would thus be necessary to take would be enormous. It must be remembered, also, that this policy, once entered upon, must be pursued, or at least could

be abandoned only at a great pecuniary sacrifice. Should it at any time in the future be found that, by reason of the inadequacy of the supply, or the quality of the water, it would be unwise further to rely upon Fresh Pond, even as a partial supply, then the city would have upon its hands a large amount of property to sell, and the result would be a great loss.

And this leads us to the consideration of the next point material to this inquiry. What is the value and permanency of the privilege which we are asked to expend so much money upon? Fresh Pond cannot be relied upon as certain for more than 1,750,000 gallons daily.

After the deflection of the waters of the Cushing Street district by means of sewers, and after such other similar operations as may from time to time be found necessary, we think its capacity will not even come up to that. The abandonment of the water from Wellington Brook is only a matter of time, and the time may come in the near future, and we shall then be left to Fresh Pond alone. Even with our present population, this, of itself, is an entirely inadequate supply. Whether we protect the pond or not, it is as clear as the noonday sun that we must soon look elsewhere for a supplemental supply at least. Protection of the pond will not relieve us from the necessity of seeking elsewhere for a supply. Nor do we believe that this necessity places us in such a direful condition as the gloomy forebodings expressed at the hearing, by one of the petitioners, would seem to indicate. The city of Boston has a much larger supply of water than it needs for its own use. It is reasonably certain that the city of Somerville, and that part of Boston formerly constituting the city of Charlestown, both of which localities are now supplied from the Mystic, which is an unsatisfactory source of supply, will be furnished with water from the Sudbury River by a pipe running directly through our own city, and connecting with the Chestnut Hill reservoir.

Of course we could easily make connection with such a pipe, and we have made such inquiries at the most authentic sources of information as entirely to convince us that Boston is able and would be willing to furnish water to this city upon terms so much more reasonable than any hinted at by any of the petitioners as to be scarcely compared with them. The arrangement would be advantageous to both cities.

Nor would such a change of base be attended with any great loss to the city in the abandonment of property purchased and used for our water supply.

From the accounts of the Water Board we ascertained that the total cost of water works to Nov. 30, 1878, was $1,692,000. Of this sum $110,896 had been spent on Fresh Pond and connected sources. Inasmuch as we now recommend to you the positive abandonment of Spy Pond, Little Pond, and filter basin, with so much of conduit as lies between Little Pond and Wellington Brook, the money spent upon these should be deducted, and the money thus spent appears to be $44,000. From the above it is evident that the $66,000 spent upon those sources of supply, which alone, in our opinion, can safely be used, is but a small part of our water debt. From Mr. Chesbrough's plan it will be seen that, in case we seek a new supply, we should still need all our present system from the pumping house down to the consumer.

The scheme of purchasing land is so vague and indefinite in its conception, so impracticable in its execution, so costly in its nature, and so uncertain in its probable result, that we deem it extremely unwise for the city to enter upon it.

While we believe the scheme of purchasing land enough permanently to insure the purity of the water of the pond to be inexpedient and impracticable, we are fully convinced that Cambridge should have the municipal control of the territory immediately surrounding the pond. Annexation of such territory is highly desirable. Only a part of the border of the pond is within the limits of this city. It should all be under our control, and for many reasons.

In a neighborhood so thickly populated there is great need of an active, constant, and vigilant police supervision, to prevent the innumerable acts arising from the habits of careless individuals, which, insignificant as they may seem when considered singly, are in the aggregate likely to pollute the pond. Many of these acts are so temporary in their nature that only by such a supervision as we speak of can they be prevented. This city has, on this account, heretofore petitioned the legislature for the passage of a statute which shall give to Cambridge the right to patrol the borders of the pond by its own police; but the request has been denied upon the ground that it would be a bad and hazardous

precedent to give one municipality police jurisdiction over the territory of another.

It is plain that much of this territory must soon be provided with sewers, and it is equally plain that that provision can with much greater economy and ease be made by Cambridge, by the plan hereinbefore outlined, than by the town of Belmont. Indeed it is difficult to see how that town can provide for such sewers as the purity of the pond requires, without important and complicated legislative action, and without incurring a pecuniary outlay entirely disproportionate to its means and to the benefits likely to arise to the town. Nor, judging by recent experience, can that town be relied upon to attempt the construction of any sewers whatever in the vicinity of the pond, except such as may go into the pond itself. The natural drainage of the territory is of course into the pond and into Alewife Brook; and Belmont, looking solely to what might seem to be for the interest of that town, would not be quick to relieve the pond from that drainage. Belmont's sole interest in the pond is to make it the receptacle of her sewage. It is not right that a water supply so near our limits as Fresh Pond is — a part of its border being actually within our line — should be unnecessarily subjected to the dangers likely to arise from the supervision of a town whose interests in the pond are so inconsistent with the purity of the water.

There is also need of the supervision of that territory by a board of health, whose members shall at once recognize the paramount importance of our interests and, while acting under the most delicate sense of the rights of private individuals, shall be inclined to protect that interest by every proper and legitimate exercise of their powers. We regard this supervision as of the utmost consequence.

The recent erection of a large slaughtering establishment near the pond, and within a few feet of the conduit which connects it with Wellington Brook, furnishes a striking and forcible argument of the importance of annexation.

For two centuries the business of slaughtering animals, in this Commonwealth, has been classed among those noxious and offensive trades which should be carried on, not at the will of any man where and when he might choose, but only in such places and under such restrictions as, in the opinion of certain town or city authorities, would not endanger the public health and com-

fort. Such establishments are tolerated only because they are necessary. The men who conduct them are apt to direct their efforts rather to the pecuniary success of the undertaking than to the preservation of the public interests, and for that as well as other obvious reasons it is of vital consequence that such establishments should be located at such places that, even if the business is negligently carried on, the public will not suffer. Moreover, common humanity would seem to require that no such establishment should be located where it could in the least endanger the water supply of a large city. The slaughtering establishment of Niles Bros., however, is so located, and by the permission of the selectmen of Belmont. The law provides that no such establishment shall be erected in any town without the permission of its selectmen. As soon as reliable information came to the authorities of this city that the erection of such a building was contemplated, notice was given to the selectmen that this city objected to the project, as it was dangerous to its water supply, and requested to be heard. At the hearing the city protested most earnestly against the matter, but permission was given by the selectmen. We are bound to presume that, in granting that permission, the selectmen acted upon their convictions of right, but it needs no remarkable power of vision to see that if the pond had been the water supply of Belmont, that permission would never have been given. What has happened once may happen again, and it is safe to say that, no matter what may be the character of the business, the objection that our water supply may be endangered, whether that objection may be well or ill founded, will have no weight with the selectmen of that town whenever asked to give their official consent. This experience teaches us that our water supply cannot be regarded as reasonably safe when any of its interests are subject to the municipal control of that town. There can be no difference among the citizens of this city upon the desirableness of annexation. Indeed, no one of the petitioners opposed it; while one of them, prominent at the hearing, advised it after the purchase of the land, and seemed to oppose it without purchase chiefly upon the ground that the attempt would be useless. It is said that Belmont will oppose us, and we are advised first to buy the land and then to apply for annexation. But even if purchase were practicable and we should purchase the land, Belmont

would oppose us just as strenuously. Upon the question of whether that town shall lose a part of its territory, the ownership of the land can make no difference in the wishes of the town. Nor do we believe the legislature, in its consideration of this question, will pay much attention to the ownership of the land. So far as we are aware, it has never been considered necessary, nor has it been usual, for the municipality to which territory is to be annexed first to purchase the land. These questions are to be decided upon public considerations. Not the wishes of this city or of that town will be much considered; but the question will be decided upon large, liberal, and enlightened views of what the public interests demand. On that ground, believing we are right, we are willing to stand. It is true that the State Board of Health has certain jurisdiction over slaughter-houses, and application to that board was made several months ago, by this city, to restrain Niles Bros. from the further prosecution of their business, upon which no decision has yet been made; but this jurisdiction begins only after the erection of the buildings, and is by no means so practically efficient as the protection of the pond requires.

It is, in our opinion, a misfortune that the State Board of Health has not such powers as would enable it to deal efficiently with this subject, or, better still, to deal directly with the subject of the proper location of slaughter houses.

In conclusion, then, it is our opinion that it would be unwise for the city to enter upon the scheme of the purchase of land as suggested in the petition. Instead thereof we make the following recommendations: —

1st. That Alewife Brook should, if possible be restored to purity by withdrawing from it the sewage of Cambridge, and the very offensive matter from the hog-slaughtering house of Niles Bros.; that this relief to the brook can be obtained more advantageously to the city by means of a sewer along the right bank of the stream from North Avenue to Concord turnpike, and thence to Charles River, as recommended in a report of the City Engineer.

2d. That a branch drain, connecting with the sewer already described, be constructed to receive the overflow of Richardson's Pond and of Cider Mill Pond.

3d. That the city obtain control, by annexation, of the territory marked out on the accompanying map.

Should the city fail to secure the annexation of this territory, it would then be necessary to secure permission from the legislature to construct the branch drain recommended for the relief of the pollution from Richardson's and Cider Mill ponds, they being in the town of Belmont.

4th. That the waters of Spy Pond, Little Pond and filter basin, and of Wellington Brook, except under the conditions above set forth, be not admitted to Fresh Pond.

SAMUEL L. MONTAGUE.
GEORGE S. SAUNDERS.
GEORGE P. CARTER.
JOHN W. HAMMOND.
HENRY P. WALCOTT.
WILLIAM S. BARBOUR.

CAMBRIDGE, Dec. 15, 1879.

# APPENDIX I.

*To the Committee on Water Supply of the City of Cambridge:—*

Gentlemen, — In compliance with your request that I should examine Fresh Pond and vicinity, together with the waters thereof, and report upon the character and purity — present and future — of the water supplied to the city of Cambridge, I have the honor to present the following

## REPORT:

The attention of the public and of the city government has frequently been called by the Water Board, in their reports for the past few years, to certain sources of contamination existing in the neighborhood of Fresh Pond, and a number of plans have been mentioned to remedy these evils. There is no doubt that such sources of pollution do exist, and that they must be removed, if the citizens of Cambridge are to be supplied with a *good* and *safe* drinking water from Fresh Pond, and the points to which I shall call your attention in the following pages are, —

1. The existing sources of pollution of the water supply of Cambridge.
2. The probable future increase or diminution of the same.
3. Can they be removed or not, and, if they can, by what means.

Before, however, taking up these points in detail, it seems to me advisable to call your attention, as having a direct bearing upon the question before us, to the following

### GENERAL CONSIDERATIONS.

Little need be said concerning the necessity of protecting a water supply from sewage, the danger from which is universally acknowledged. It was formerly considered that a running stream containing sewage purified itself completely in flowing a few miles, but almost all scientists of the present time, who have made a special study of water

supply, agree that such is not the fact, but that the chief difficulty in recognizing the existence of sewage in a running stream a short distance below the entrance of such sewage lies in the fact that it becomes very largely diluted with water.

The use of such diluted sewage — that is, impure drinking-water — does not necessarily produce disease at once, but it is certain that it has a very decided influence upon the system, which shows itself chiefly in rendering the system less able to withstand disease when it does come. This is especially true in the case of epidemics, and has been shown to a marked degree in the cholera epidemics of London. During the epidemic of 1848–49, London was supplied by all of the companies with unfiltered Thames water, some of the companies taking their supply from tide water, where it was liable to be affected by the sewage of London as well as of the towns and cities above on the Thames or Lea. The severity of the epidemic was such that the authorities were satisfied that the impurity of the water supply contributed more or less to it, and therefore a law was passed, requiring the water to be taken from the river above tide water, and to be filtered. At the time of the second visitation of cholera in 1853–54, the required changes had partly been made, and it was found that those portions of the city supplied with the purer water were affected much less severely than other portions supplied with the more impure water.

The evidence which has been given before the various Water and Rivers Pollution Commissions in London shows conclusively that water containing sewage *may* produce typhoid fever and other so-called filth diseases, even when chemical analysis had failed to reveal the existence of contamination, and also in cases in which the water had been filtered.

"Much, indeed, has been said as to the complete self-purification of rivers by a flow of a few dozen miles. No such power exists. The solid parts are deposited, and what remains looks clear and bright, especially when largely diluted. . . . If sewage contains 'germs' of disease, whatever they may be, no agency at present known, except a sufficiently high temperature, will efficiently destroy them. Excessive dilution simply diminishes the chances of danger from any particular tumblerful.

"The most striking case illustrating this law is one reported by Dr. E. D. Mapother of Dublin. Forty cases of typhoid fever occurred in a hospital which received its water supply from a river. The cause was traced to some barracks *twenty-five miles* higher up, from which typhoidal dejections had been emptied, through drains, into the river." [1]

[1] Seventh Annual Report of the State Board of Health of Massachusetts, page 283.

The Rivers Pollution Commission, First Report, River Thames, thus summarizes the results of its thorough investigation into the alleged self-purification of polluted rivers: "Thus, whether we examine the organic pollution of a river at different points of its flow, or the rate of disappearance of the organic matter of sewage when the latter is mixed with water and violently agitated in contact with air, or, finally, the rate at which dissolved oxygen disappears in water polluted with five per cent of sewage, we are led in each case to the inevitable conclusion that the oxidation of organic matter in sewage proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water, and that it is impossible to say how far such water must flow before the sewage matter become thoroughly oxidized. It will be safe to infer, however, from the above results [referring to actual experiments previously detailed], that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation."

Medical and sanitary literature of the present day is filled with cases in which disease has been produced by polluted water, and with cases which show that water which is pure so far as chemical analysis is able to determine, and which is very agreeable to the senses, may contain very injurious substances which nature has not been able to destroy before the water was used for drinking.

Filtration is also frequently incapable of removing sewage from water, as is shown by the contamination of our well waters in thickly settled districts. It is merely a question of time how soon the soil, through which a polluted water percolates, becomes saturated, and ceases to remove the contaminating material. "Loose, porous soil — such as gravel or broken chalk — is not only more liable to drainage contamination, but affords a more imperfect filter than closer soil. Very shallow porous soils are often exceedingly foul from the stagnation and accumulation in them of manurial matters. The dip of the land is also an important element in the study. A cesspool below a well on a hillside may not pollute the water; but if above, the water will be almost sure to suffer. A short time ago we analyzed the water of two wells, one at the bottom and one near the top, of the same hill. The former showed almost exactly three times the amount of contamination of the latter."[1]

"In 'The Report upon the Sanitary Condition of the District of the Combined Sanitary Authorities of Oxfordshire, by Gilbert W. Child, Officer of Health to the above Authorities,' it is stated that, at Charlbury, in consequence of the escape of the contents of a barrel of petroleum or benzoline, which had been buried in an orchard, a circuit of

[1] Lancet, 1872, Vol. II., page 46.

wells, sixty feet below and two hundred and fifty or three hundred yards distant, became so affected that the occupiers of fifteen houses, containing eighty-two inhabitants, were, for ten days, unable to use the water for drinking or cooking. The cattle of one of the proprietors, moreover, refused to drink at the spring where they were accustomed to drink. The hole in which the cask was buried must have been immediately over the head of the spring which supplied the wells. . . . Had this soakage been sewage instead of petroleum, who can doubt that the result might have been wholesale water-poisoning and an outbreak of typhoid fever?"[1]

The experiments of Prof. Wm. Ripley Nichols[2] show that filtration will remove a large amount of organic matter, but a portion, greater or less according to the efficacy of the filter, passes through, and that the filtering material, in order that the filter shall be valuable, must be renewed from time to time according to the amount of pollution in the water to be filtered.

Water passing through the subsoil is thus filtered, and, following the natural drainage of the country, which is toward the valleys, finds its way to the brooks, ponds, and rivers, a part of this water forming the springs with which such ponds or streams are supplied. If the water falls upon, or meets, in the course of its subsoil flow, with soluble compounds, organic or inorganic, vegetable or animal, it dissolves them and is made more or less impure according as the substances dissolved are considered to be impurities or not. If these impurities are met with upon the surface of the land, as in the case of highly manured fields, they may be for a time entirely removed or destroyed by passing through a gravelly subsoil, which acts as a filter, until the gravel becomes partly or entirely saturated, when they may find their way to the ponds and streams. A large portion of the sewage upon the surface of the land may also be washed directly into the water-courses by heavy rains. The danger to sources of water supply from this cause depends naturally upon the amount of cultivated land upon the gathering ground, upon the steepness of the slopes on such gathering ground, and upon the character and quantity of manure placed upon the land.

"Of all forms of filth, the most dangerous, as well as the most offensive and most common, is fecal excrement. Cast off by the human economy as not only incapable of furnishing any support, but utterly unfit to be longer retained in contact with the living body, it is nevertheless stored in the near neighborhood of most dwellings, and of very many wells throughout the Commonwealth. It lies beneath privies, or in the cesspools which receive the wash from water-closets, dissolv-

[1] Lancet, 1874, Vol. I., page 841.

[2] Ninth Annual Report of the State Board of Health of Massachusetts.

ing and oozing more or less rapidly into the surrounding soil, from which it sometimes finds its way into some neighboring well, sometimes rises in gaseous form to poison the air, sometimes lies stored and lurking to infect any dwelling whose cellar may be dug into its ambush-ground with 'mysterious' unwholesomeness. If any portion of that which finds its way into drinking-water came from a person suffering with typhoid fever, cholera, dysentery, or with certain forms of intestinal worms, it sows the specific seeds of those diseases in many new victims till they multiply themselves manifold. Investigations carried to the point of demonstration in England have shown that several severe and extensive epidemics of typhoid fever have originated in milk brought from many miles away in the country, and infected with water into which a most minute amount of typhoid *excreta* had been washed from an adjacent and neglected privy. There is no means known of purifying excrement on a large scale except by the roots of growing vegetation, and it does not become us to be positive that even this method can be depended on to disinfect that which carries the specific poison of cholera or of certain parasites."[1]

No water which has been polluted with sewage containing human excrementitious matter should be allowed to discharge into a source of water supply, since no treatment known at the present day can with certainty entirely remove such pollution, so as to render it safe for drinking. "If this view of the case may seem to be over-cautious, it is to be remembered that the poison, however trifling, is taken daily, and that although, when in robust health, the individual will not suffer from it, it may be sufficient to make itself felt when he is prostrated by sickness, and his powers of resistance to such influences are then proportionally impaired."[2]

That disease may be transmitted by the sewage applied to cultivated land, Liebermeister states, in speaking of the spread of typhoid fever by drinking-water: "Such infection of an aqueduct is most easily effected when excrements from privies containing the typhoid poison are used as manure on the fields from which the aqueduct receives its supply. In this way originated the epidemic in Stuttgart in the year 1872."[3]

Cases might be multiplied, showing the spread of filth diseases through the use of polluted drinking-water, but enough has been said above to demonstrate, —

1st. That diseases may be produced by drinking water contaminated with sewage;

[1] Seventh Annual Report of the State Board of Health of Massachusetts, page 180.
[2] Seventh Annual Report of the State Board of Health of Massachusetts, page 144.
[3] Quoted by J. A. Judson, C. E., Popular Science Monthly, Nov., 1878, page 53.

2d. That water may become contaminated with sewage which has been placed as manure upon cultivated land;

3d. That sewage may be diluted to such an extent that it is not perceptible to the senses, and cannot be detected by chemical means;

4th. That great dilution simply diminishes the *chance* of infection by any given amount of water;

5th. That no means known at the present time will *certainly* remove sewage from water which has once been contaminated with it, and that the only safe way is not to permit sewage to get into a water supply.

### CAMBRIDGE WATER SUPPLY.

It was supposed for a long time that Fresh Pond alone would be capable of supplying the citizens of Cambridge with water for an indefinite period; but experience showed that this was not the case, and that an additional supply was necessary to meet the increasing needs of the city. In the autumn of 1871 the level of Fresh Pond was only four or five inches above low-water mark, and in the winter of 1875 the pond was lowered so much that preparations were made to pump into the pipe. The following record of the height of the pond, and the pumping record, collected from the various reports of the Water Board, shows the amount of the increase in the consumption of water, and the necessity for a source of supply other than Fresh Pond itself.

*Average number of Gallons pumped Daily.*

| | |
|---|---|
| 1865 | 962,127 |
| 1866 | 1,111,339 |
| 1867 | 1,244,180 |
| 1868 | 1,732,759 |
| 1869 | 1,613,050 |
| 1870 | 1,739,869 |
| 1871 | 1,747,704 |
| 1872 | 1,626,006 |
| 1873 | 2,124,884 |
| 1874 | 2,299,146 |
| 1875 | 2,718,484 |
| 1876 | 2,466,167 |
| 1877 | 2,631,732 |
| 1878 | 2,257,190 |

HEIGHT OF FRESH POND BELOW HIGH-WATER MARK.

| | 1871. | 1872. | 1873. | 1874. | 1875. | 1876. | 1877. | 1878. |
|---|---|---|---|---|---|---|---|---|
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches |
| December . . . | 44. | 40.2 | 16. | 36.62 | 69. | 73.75 | 55. | 26.50 |
| January . . . . | 44.6 | 37. | 10. | 21.62 | 78. | 66. | 54. | 24. |
| February . . . | 41.4 | 40. | 12. | 24.37 | 88.62 | 65.50 | 50.50 | 20. |
| March . . . . | 20. | 38. | 7.64 | 29. | 79.12 | 61.37 | 24. | 9. |
| April . . . . . | 20.4 | 26. | 10. | 27.25 | 67. | 49.25 | 8.50 | 8. |
| May . . . . . | 21. | 27. | 17. | 20.88 | 65. | 44.37 | 11.87 | 9. |
| June . . . . . | 29. | 22. | 27. | 23.50 | 50.37 | 48.75 | 21. | 17. |
| July . . . . . | 38.5 | 27. | 46.50 | 33.75 | 68.75 | 59.25 | 32.50 | 27.50 |
| August . . . . | 43. | 18. | 41.50 | 35.37 | 72.62 | 64.37 | 42.25 | 27.37 |
| September . . . | 49. | 9. | 47. | 45.38 | 76.37 | 68.62 | 51.75 | 31.50 |
| October . . . . | 48. | 15. | 50. | 54. | 72. | 77.12 | 54.50 | 37. |
| November . . . | 45. | 10. | 43.50 | 59.62 | 69.50 | 61.37 | 47. | 36. |

The Water Board also state in their report for 1876 (page 15): "There was a general belief, in the early history of our water works, that Fresh Pond would furnish an unlimited supply of water. The great droughts of 1872 and 1873 dispelled this illusion, when, for a considerable time, the amount we pumped out of the pond daily lowered the pond by just about the same amount of water as measured by its area."

Accordingly in 1875 the right was obtained to take water from Little and Spy Ponds and Wellington Brook as the sources for an additional supply, and these were connected with Fresh Pond by a conduit. I will first consider the impurities in Fresh Pond itself, and then in the sources of additional supply. The water of Spy Pond, having been found decidedly objectionable, has never been used, and will not, therefore, be considered in the following pages.

## SOURCES OF POLLUTION.

*Fresh Pond.* — The most important sources of contamination of Fresh Pond itself are situated upon the south-western side of the pond, in what is known as the Strawberry Hill or Cushing Street district.

*Cider Mill Pond* is the worst of these. It is connected with Fresh Pond below by an open ditch and a culvert under Cushing Street, whence it passes into a small bog, where it unites with the water coming from Richardson's Pond (next to be described), and with this flows directly into Fresh Pond; it is also connected with a small pond seven hundred feet above by a ditch, and another culvert under Cushing Street. Cider Mill Pond receives the drainage of quite a large num-

ber of privies, cesspools, and pigstics, some of which drain directly into the pond or ditch, and a large amount of human and animal excrement, together with kitchen slops, are washed with every rain into it; it receives also the drainage from a cemetery. Inquiries which were kindly made for me by the City Engineer show that "the area drained by the 'Cider Mill Pond' and the upper pond east of Cushing Street contains twenty-two dwelling-houses and six barns; there are twenty-nine families, consisting of eighty-nine adults and fifty-nine children. These families keep two horses, ten cows, and twenty-seven pigs. There are twenty-four privies, four of which overflow into the pond and connecting stream, and many of the others are situated on a very steep slope leading to the ponds. A few of the houses may have covered cesspools to receive the house drainage, but in most cases it is discharged directly on to the ground, and a rain must certainly wash it into the ponds."

This pond receives the drainage of about fifty-three acres of territory, collecting and retaining, during dry seasons, all of the drainage and sewage, but after heavy rains it overflows and discharges its accumulated filth through the ditch and culvert directly into Fresh Pond.

In March, 1878, a weir was constructed across the ditch, in order to determine how much of this highly polluted water gains entrance into Fresh Pond, with the following result: —

| 1878. | Gallons. | Rainfall. | |
|---|---|---|---|
| March 8 . . . . | 52,735 | 0.03 inches | |
| „ 16 . . . . | 33,821 | | |
| „ 18 . . . . | 369,100 | 1.37 „ | |
| „ 19 . . . . | 322,957 | 0.19 „ | |
| „ 20 . . . . | 78,203 | | |
| „ 21 . . . . | 50,732 | | |
| „ 22 . . . . | 27,574 | | |
| „ 23 . . . . | 27,574 | | |
| „ 27 . . . . | 17,255 | | |
| „ 29 . . . . | 9,662 | 0.30 „ | |
| April 4 . . . . | 25,527 | | |
| „ 24 . . . . | 6,442 | 0.47 „ | on 23d and 24th |
| „ 26 . . . . | 6,442 | 0.62 „ | |

These figures are interesting, as showing not only the amount of filth which may at times be discharged into Fresh Pond from this source, but also the influence of a heavy rain upon this pond; for on the 17th of March the outlet was nearly dry, when a rainfall of 1.37 inches on the 18th caused an overflow of more than 369,000 gallons. The in-

crease on April 4th was probably caused by melting snow, as there is no record of any rainfall.

The water in Cider Mill Pond is at all seasons very disgusting in appearance, and contains a large amount of organic matter both in suspension and in solution, as may be seen by the analyses in the table.

If an outbreak of typhoid fever should occur in any of these houses, the typhoid excreta might be carried into Fresh Pond directly, in which case it would be impossible to say what effect would be produced in the city. This sewage is, of course, diluted with an exceedingly large amount of water in Fresh Pond, which greatly diminishes the chance of its infecting the water in the pipes, yet such a chance must exist with more than 2,000,000 gallons of water being drawn daily through the pumping conduit; this must create a certain amount of current toward the mouth of the conduit. The history of typhoid fever as caused by infected water shows us that an infinitesimal amount of such excreta may cause a severe outbreak in the district supplied by such water.

The population in this district is steadily increasing, and the contamination from this source is sure to increase rather than diminish, unless some means be taken to divert this sewage. Plans for such a diversion have already been presented by the City Engineer.

*Richardson's Pond* is also a very important source of pollution of Fresh Pond. It receives the drainage from 122½ acres of territory, including a portion of the Hittinger estate, a part of which is highly manured and cultivated. The surface drainage from this district is collected in gutters and brooks which flow through Mr. Hittinger's garden, where it is utilized for washing the vegetables, &c.; thence it flows through a long culvert into what is called Richardson's Pond, which is situated just above the school-house at the junction of Cushing and Grove Streets. The discharge from this pond is through a culvert under Grove Street, through the school-house yard, and under Cushing Street into the low ground below Cushing Street, where it unites with the outlet from Cider Mill Pond, and thence flows directly into Fresh Pond. Upon Mr. Hittinger's estate there is a piggery situated almost directly over the brook, before the latter enters the long culvert. In this piggery are kept three pigs for home use.

During dry seasons the outlet of Richardson's Pond is dry, but in wet seasons a very large amount of water is discharged directly into Fresh Pond. The amount of this surface drainage, which is thus discharged, is shown by the following measurements, which were taken last spring at a weir constructed across the outlet just below Cushing Street, before the water unites with that coming from Cider Mill Pond: —

| 1879. | Gallons. | Rainfall. |
|---|---|---|
| March 11 | 93,839 | |
| „ 13 | 93,839 | |
| „ 15 | 93,839 | 0.14 inches on 14th |
| „ 18 | 60,947 | 0.45 „ |
| „ 20 | 194,385 | 0.03 „ |
| „ 21 | 131,152 | 0.08 „ |
| „ 23 | 1,049,220 | 0.98 „ on 22d and 23d |
| „ 26 | 172,414 | 0.04 „ |
| „ 27 | 151,304 | 1.17 „ |
| „ 28 | 768,375 | 0.03 „ |
| „ 29 | 343,444 | 0.20 „ |
| „ 30 | 715,810 | 0.03 „ |
| „ 31 | 343,444 | 0.64 „ |
| April 1 | 93,839 | |
| „ 2 | 384,928 | |
| „ 3 | 253,112 | 0.22 „ |
| „ 4 | 303,627 | |
| „ 5 | 194,385 | |
| „ 6 | 205,725 | |
| „ 7 | 217,310 | |
| „ 8 | 194,385 | |
| „ 9 | 172,414 | |
| „ 10 | 194,385 | 1.26 „ |
| „ 11 | 786,219 | 0.03 „ |
| „ 12 | 370,977 | |
| „ 13 | 290,723 | |
| „ 14 | 303,627 | |
| „ 15 | 240,965 | 0.32 „ |
| „ 16 | 370,977 | 0.03 „ |
| „ 17 | 265,457 | 0.72 „ |
| „ 18 | 1,572,540 | 0.81 „ |
| „ 19 | 768,375 | 0.07 „ |
| „ 20 | 786,219 | |
| „ 21 | 502,920 | |
| „ 22 | 384,928 | |
| „ 23 | 343,444 | |
| „ 24 | 265,457 | |
| „ 25 | 228,963 | 0.02 „ |
| „ 26 | 217,310 | |
| „ 27 | 183,280 | |
| „ 28 | 151,304 | 0.54 „ |
| „ 29 | 534,024 | 0.96 „ |

| 1879. | | Gallons. | Rainfall. | | |
|---|---|---|---|---|---|
| April | 30 | 1,487,633 | 0.15 | inches | |
| May | 1 | 413,425 | | | |
| „ | 2 | 240,965 | | | |
| „ | 3 | 205,725 | | | |
| „ | 4 | 183,280 | | | |
| „ | 5 | 161,749 | 0.01 | „ | |
| „ | 6 | 141,107 | | | |
| „ | 7 | 111,990 | | | |
| „ | 8 | 93,839 | | | |
| „ | 9 | 76,477 | | | |
| „ | 10 | 60,947 | | | |
| „ | 11 | 53,496 | | | |
| „ | 12 | 46,372 | | | |
| „ | 13 | 39,588 | | | |
| „ | 14 | 33,182 | | | |
| „ | 15 | 27,147 | | | |
| „ | 16 | 21,552 | 0.04 | „ | |
| „ | 17 | 39,588 | 0.19 | „ | |
| „ | 18 | 21,552 | | | |
| „ | 19 | 27,147 | 0.76 | „ | |
| „ | 20 | 93,839 | 0.08 | „ | |
| „ | 21 | 46,372 | 0.12 | „ | |
| „ | 22 | 33,182 | | | |
| „ | 23 | 16,394 | | | |
| „ | 24 | 7,615 | | | |
| June | 4 | 53,496 | 1.35 | „ | on 2d, 3d, and 4th |
| „ | 5 | 11,730 | 0.43 | „ | |
| „ | 6 | 4,148 | 0.10 | „ | |
| „ | 17 | 33,182 | 1.12 | „ | since 14th |
| „ | 18 | dry. | | | |

| | Gallons. |
|---|---|
| Average of 13 days in March | 324,155 |
| „ „ 30 „ „ April | 408,982 |
| „ „ 24 „ „ May | 91,532 |
| „ „ 4 „ „ June | 25,639 |

The rapidity with which a heavy rain influences this source of pollution, and washes the filth into Fresh Pond, may be clearly seen by the above measurements, which were taken by order of the City Engineer. It will also be noticed that, at times, the amount of surface drainage discharged from this source into Fresh Pond may exceed 1,500,000 gallons in a single day. During the dry seasons, the surface-

washings are collected in Richardson's Pond, the water of which is very filthy, especially that which has remained in the pond for some time; this may be seen by the analyses in the table. All of these analyses were of water taken from the outlet during the rainy season, with one exception, viz., the one dated July 8, 1879, at which time the outlet was dry; and the specimen was collected from the pond itself. This analysis shows an exceedingly filthy condition of the water in the pond, which was destined to be washed into Fresh Pond by the next heavy rain. Most of the pollution in this pond must come from highly manured land, and from Mr. Hittinger's piggery, in which there are, however, at the present time (August) but three pigs kept. No night-soil is used upon the Hittinger farm, and none upon the district, so far as I have been able to learn.

It seems to me that water flowing into Fresh Pond at the rate of more than 1,500,000 gallons in a single day at this point, and flowing out through the pumping conduit at a somewhat greater rate, must tend at times to create a slight current in the pond, from the Cushing Street sources of pollution toward the end of the pumping conduit, thereby at certain seasons increasing the chance of polluting the water in the city pipes with any germs of disease which may have been washed into and from Cider Mill Pond from the privies and cesspools.

The future of the district drained by Richardson's Pond presents no more favorable aspect than the present. It is not probable that the number of inhabitants, or the amount of highly cultivated land, will be at all diminished, but they will rather increase; and although there may be no night-soil used upon the land in this district at present, it is no guarantee that there will be none in the future.

The danger to Fresh Pond water from the two sources of pollution mentioned above is very great, and the only safety lies in diverting all of this surface drainage from Fresh Pond by means of a sewer, the proper location of which belongs to the province of the civil engineer.

*Alewife Brook*, with its entering sewers, is another dangerous source of pollution of Fresh Pond. This brook was formerly the outlet of Fresh Pond, but since so large an amount of water has been drawn from the pond for the supply of Cambridge, the level of the pond has much of the time been lower than that of the brook, and the water has tended to flow from the brook to the pond. A gate was, therefore, constructed to prevent this, and later a brick bulkhead was built in the gate-house. In addition to these obstructions to the flow of water between the pond and brook, a sheet-piling dam has been constructed across the brook, so that there is no danger of any *direct* communication between these two bodies of water; but a considerable amount of the

impurities from the brook gets into the pond by percolation through the soil, as shown by the analysis of the water from well No. 29.

At the present time Alewife Brook is simply an open sewer, discharging its filth into the lower Mystic basin, and contaminating the atmosphere throughout its entire length with offensive and deleterious gases, and the sub-soil with its sewage.

The first sewer which discharges its contents into Alewife Brook is the Concord Avenue sewer, which drains 298.21 acres in Cambridge, but at present receives the sewage from only a very few (10) houses, and from the engine-house of the water works, the waste from which (200,000 gallons daily) keeps it well flushed. This sewer empties into Alewife Brook at Concord Avenue, and its sewage is, at present, very dilute in comparison with that of most sewers; but it must, nevertheless, be to a certain extent dangerous, since the sewage is discharged within so short a distance (about 400 feet) from the border of the pond, that some of the filth is liable to soak through the soil into the pond. Moreover, this sub-soil flow toward the pond must be quite rapid at this point, since wells driven at the border of the pond show a pressure of from two to four inches of water above the level of the pond.[1]

The next sewer which drains into Alewife Brook is that from Niles Bros.' slaughter-house, the sewage from which is discharged through a three-inch pipe into the brook, a few rods north of the Fitchburg Railroad track. This contains the blood and offal from the pig-slaughtering establishment, mixed with a little carbolic acid. The brook at this point is exceedingly vile and offensive, and contaminates the sub-soil for some distance, so that the water from a well sunk about fifteen feet from the brook smelled distinctly of the carbolized sewage. The air also for a considerable distance from this point is very offensive, and the filth often flows in both directions, backing up at times as far as Concord Avenue. The peculiar odor was distinctly perceptible at Concord Avenue at the time of my last visit, July 29; that is, the water had backed up as far as the mouth of the Concord Avenue sewer, and there was no perceptible current in the brook.

Lower down, the Spruce Street sewer empties into Alewife Brook, discharging the drainage from 382.92 acres of territory, which is tolerably thickly settled. This sewage is mixed with a large amount of water from the clay-pits, which gives it a whitish appearance, and which probably unites with and neutralizes a certain amount of the sewage.

[1] In well No. 14, at Black's Nook, the water stood three inches higher than the water in the pond. In well No. 16 it stood two inches, and in well No. 18 two and one half inches.

Under the bridge which passes over Alewife Brook on North Avenue empties the North Avenue sewer, which drains 182.64 acres of a very thickly settled district, and discharges very objectionable material into the brook, consisting of not only a large amount of human excreta, but also the refuse from two slaughter-houses, one of which is situated in Cambridge and the other in Somerville. The brook at this point is stained red with blood from these establishments. Probably but very little of this sewage affects the water of Fresh Pond, on account of the distance between the two points, and since the flow of the brook at this point is quite rapid; but it renders the neighborhood offensive from decomposition of the animal matter. Such sewage as this should never be allowed to flow through an *open* sewer.

Between North Avenue and Broadway the brook receives the refuse from the tanneries of William Muller and others. This refuse is conducted from the tanneries through an open ditch. The same objection applies to this sewage as to that from the North Avenue sewer. The filth from these sources may sometimes be seen at the tide-gates on Broadway in considerable quantities, and much complaint has been made by the residents in this vicinity.

The water at the lower end of Alewife Brook is largely diluted with the water of Little River, which is the natural outlet of Little and Spy ponds and Wellington Brook, so that the brook does not appear as foul below the entrance of Little River as in the vicinity of Fresh Pond. An examination of the water near the opening of the various sewers may be found in the table.

During wet seasons Alewife Brook overflows its banks, and the filth is spread for a considerable distance over the meadows, from which the water sooner or later finds its way into Fresh Pond.

The sewage from all of these points is sure to increase rather than diminish, especially that in the Concord Avenue sewer, and must be diverted, in order to prevent dangerous sewage from getting into Fresh Pond, if it is decided to continue the use of Fresh Pond as one of the sources of water supply for the city of Cambridge. All of this sewage may be easily diverted by means of a tight sewer emptying into tide water. Such a sewer has for a long time been recommended by the City Engineer, and should be constructed under any circumstances, even though Fresh Pond were not used as a source of water supply, for other and obvious sanitary reasons.

*Black's Drainage.* — On the western side of Fresh Pond, near the railroad track leading to the ice-houses, is a bog-hole, which receives indirectly the drainage from the late Mr. Black's house and one or two other houses in the vicinity, with their annexed stables, pigsties, hen-

houses, &c. This bog empties directly into Fresh Pond (Black's Nook) through a culvert under the railroad track. This drainage could also be conducted to a sewer connected with the Concord Avenue sewer. An analysis of this water may also be found in the table.

*Fresh Pond Hotel* and the adjoining grounds, which are used so largely for picnic parties, undoubtedly furnish a certain amount of sewage for Fresh Pond. "There is no direct drainage into the pond, either from the grove or from the hotel connected with it; but undoubtedly the pond receives a considerable amount of impurities from the presence on its banks of such large numbers of people."[1] The vault sometimes overflows, in which case the sewage is washed into the pond. This should, of course, be prevented.

### ADDITIONAL WATER SUPPLY.

*Wellington Brook.* — This brook receives a large amount of impurities from the territory draining into it, which is very extensive, its drainage area being about 2,500 acres. It rises between Belmont and North Streets, near their junction with Common Street, about opposite the Cushing estate, flows down toward the Fitchburg railroad track in Waverley, then alongside of the track to the Belmont Station, from which point it crosses the lowlands, passing under Brighton Street, and empties into Little River. A short distance from Brighton Street it crosses the conduit, into which it can be turned or not at pleasure.

Before reaching the Belmont railroad station it receives a large amount of drainage, direct and indirect, from buildings near the bank. Formerly the sewage from the privies and sinks was discharged directly into the brook, the privies in many instances being built over the brook; these were moved back as far as possible, and brick vaults provided for the inhabitants by the Water Board, so that, at the present time, the *privy* drainage in this district is indirect. A considerable amount of house drainage, however, still goes directly into the brook. After leaving the railroad track it enters the lowlands, which are highly cultivated and manured, partly with night-soil. In its flow through these market-gardens it necessarily takes up a large amount of animal matter, especially after a heavy rain. How much of this is human depends largely upon the amount of night-soil used as manure, which varies according to circumstances.

A short distance from Brighton Street it receives the drainage from Richardson's piggery, about which so much has been said in the various Water Board reports. Formerly the drainage from this piggery

[1] Report on the Sanitary Condition of Cambridge, by Edward R. Coggswell, M. D. From the Ninth Annual Report of the State Board of Health of Massachusetts, page 336.

was received into the brook by an open ditch, which has been filled up, and a dike built, so that it is now obliged to flow over the meadow or soak through the soil before entering the brook. "After a heavy rain, however, the water rises high enough to overflow this dike; and for the time at least this attempt to divert the drainage of the piggery is rendered abortive."[1] That portion of the drainage which soaks into the ground must also sooner or later find its way into the brook, since the flow of the subsoil water must be toward the brook, and the earth can only act as a purifier for a short time, when water containing a very large amount of sewage percolates through it.

A more recent source of pollution is Niles Bros.' "muck-heap," upon which all of the "soup" from the slaughter-house is thrown for the purpose of making manure. This muck-heap is situated on the top of a gravel bank, west of the slaughter-house, between it and Wellington Brook. During the warm weather, when the ground is not frozen, the muck will absorb very large quantities of soup, so that if the muck-heap is properly taken care of, there is no danger of pollution of the water of the brook or of the subsoil. In the winter, however, the soup cannot be absorbed, and must flow down the hill-side to Wellington Brook. This matter is, however, under the supervision of the State Board of Health, in whose hands it may safely be left.

*Little Pond.* — Little Pond is connected with Fresh Pond by the conduit; it receives *directly* the drainage of thirty-four acres of highly cultivated land, and is surrounded by market-gardens, upon which a large amount of night-soil is used. A portion of this must be washed into the pond by heavy rains, and another portion must also get into the pond by percolation. During the construction of the filter basin at the side of the pond, it happened that the surface of the pond was lowered a few inches by the pumps, which were used to remove the water from the basin, and it was noticed that, whenever the surface of Little Pond was lowered, the wells in the neighborhood, quite a long distance away, were dried up, thus showing the extent and rapidity of the subsoil flow.

Little Pond is fed not only by the springs supplied with water from the surrounding territory, but by two brooks, which rise upon Arlington Heights; one of these is known by the name of Frost Brook. These brooks supply by far the largest amount of the water of Little Pond, and increase very largely its drainage area. At the source of these brooks the water is very pure, but in its flow through the cultivated land upon the hill-side, and through the market-gardens below Pleasant Street, upon which a large amount of night-soil is used,

[1] Dr. Coggswell's Report, loc. cit. page 341.

it takes up a considerable quantity of organic matter, as may be seen by the analyses of specimens of water taken from Frost Brook in different portions of its course at the same time. A large amount of manure is washed into these brooks from the land by heavy rains, so that at times they are colored dark brown with the coloring matter from the manured land.

The following measurements, which were taken at a weir constructed at the inlet of Little Pond, show the amount of polluted water which is discharged into the pond from these brooks: —

| 1879. | Gallons. | Rainfall. |
|---|---|---|
| April 2 | 3,983,772 | 2.11 inches during past week. |
| „ 9 | 1,573,830 | |
| „ 10 | 1,544,328 | 1.26 „ |
| „ 11 | 3,868,751 | 0.03 „ |
| „ 12 | 2,271,422 | |
| „ 13 | 1,940,983 | |
| „ 14 | 2,101,390 | |
| „ 15 | 2,604,179 | 0.32 „ |
| „ 16 | 2,775,877 | 0.03 „ |
| „ 17 | 2,068,975 | 0.72 „ |
| „ 18 | 4,413,087 | 0.81 „ |
| „ 19 | 3,868,751 | 0.07 „ |
| „ 20 | 3,641,850 | |
| „ 21 | 3,345,390 | |
| „ 22 | 2,950,679 | |
| „ 23 | 2,741,462 | |
| „ 24 | 2,402,815 | |
| „ 25 | 2,336,542 | 0.02 „ |
| „ 26 | 2,238,890 | |
| „ 27 | 2,068,975 | |
| „ 28 | 1,940,983 | 0.54 „ |
| „ 29 | 3,200,535 | 0.96 „ |
| „ 30 | 5,347,585 | 0.15 „ |
| May 1 | 3,200,535 | |
| „ 2 | 2,536,323 | |
| „ 3 | 2,199,667 | |
| „ 4 | 1,972,786 | |
| „ 5 | 1,940,983 | 0.01 „ |
| „ 6 | 1,784,886 | |
| „ 7 | 1,544,328 | |
| „ 8 | 1,428,570 | |
| „ 9 | 1,428,570 | |

| 1879. | | Gallons. | Rainfall. |
|---|---|---|---|
| May | 10 | 1,343,878 | |
| „ | 11 | 1,260,624 | |
| „ | 12 | 1,152,562 | |
| „ | 13 | 1,073,715 | |
| „ | 14 | 777,708 | |
| „ | 15 | 686,155 | |
| „ | 16 | 686,155 | 0.04 inches. |
| „ | 17 | 731,158 | 0.19 „ |
| „ | 18 | 686,155 | |
| „ | 19 | 577,392 | 0.76 „ |
| „ | 20 | 1,288,257 | 0.08 „ |
| „ | 21 | 1,073,715 | 0.12 „ |
| „ | 22 | 1,515,073 | |
| „ | 23 | 1,022,281 | |
| „ | 24 | 896,883 | |
| „ | 25 | 620,137 | |
| „ | 26 | 796,036 | |
| „ | 27 | 620,137 | |
| „ | 28 | 598,660 | 0.02 „ |
| „ | 29 | 535,638 | |
| „ | 30 | 495,048 | |
| „ | 31 | 436,084 | |
| June | 1 | 556,465 | |
| „ | 2 | 361,447 | 0.24 „ |
| „ | 3 | 515,166 | 0.74 „ |
| „ | 4 | 754,380 | 0.37 „ |
| „ | 5 | 796,036 | 0.43 „ |
| „ | 6 | 777,708 | 0.10 „ |
| „ | 7 | 686,155 | 0.03 „ |
| „ | 8 | 495,048 | |
| „ | 9 | 455,440 | 0.04 „ |
| „ | 10 | 495,048 | 0.03 „ |
| „ | 11 | 416,994 | |
| „ | 12 | 379,668 | 0.05 „ |
| „ | 13 | 416,994 | |
| „ | 14 | 308,587 | 0.08 „ |
| „ | 15 | 398,185 | 1.03 „ |
| „ | 16 | 1,047,851 | 0.01 „ |
| „ | 17 | 598,660 | |
| „ | 18 | 416,994 | |
| „ | 19 | 361,447 | |
| „ | 20 | 343,444 | |

| 1879. | | Gallons. | Rainfall. |
|---|---|---|---|
| June | 21 . . . . | 291,577 | |
| „ | 22 . . . . | 274,920 | |
| „ | 23 . . . . | 242,632 | |
| „ | 24 . . . . | 181,163 | |
| „ | 25 . . . . | 181,163 | |
| „ | 26 . . . . | 91,414 | |
| „ | 27 . . . . | 140,758 | |
| „ | 28 . . . . | 91,414 | |
| „ | 29 . . . . | 127,761 | 0.23 inches. |

This water, as a rule, flows directly through Little Pond to its outlet, Little River, which crosses the meadows, unites with Wellington Brook, and empties into Alewife Brook, as mentioned above. But little of the water, fortunately, has been taken into the conduit, an uninterrupted flow from the pond to the conduit being prevented by a gate, which has been open but little since the construction of the conduit. Most of the water passing through the conduit is derived from the filter basin, the water of which, of course, differs from Little Pond water in containing no surface water, but only that which has percolated through the soil. The surroundings of the filter basin are naturally as objectionable as those of the pond, with the single exception that it is not liable to become polluted with surface washings by heavy rains. It is, however, as liable to become contaminated as a surface well dug in the midst of highly manured fields; no sanitarian would think of recommending the use of a well so situated for drinking purposes, especially if a large portion of the manure used upon the fields consisted of night-soil, and, therefore, contained *human* excreta. Upon a single farm in this neighborhood from fifty to sixty loads of night-soil are used annually as manure, and it is probable that a corresponding amount is used upon the others.

The future prospect of this district drained by Little Pond with its entering brooks, and Wellington Brook, which constitute the sources of the additional water supply for the city of Cambridge, is more unfavorable than the present, and with no possibility of being remedied. With the rapidly increasing demand for water, these sources must be drawn upon to a still greater extent than heretofore, unless some other source of supply be obtained in their place. The population in this district is constantly increasing, and the amount of land, which is highly tilled, is also constantly increasing. Even within the last two years a large amount of new land upon the side of the Arlington hills, near the head-waters of Frost Brook, has been broken up for high cultivation. And again, the amount of night-soil used upon the gar-

dens in this district is almost sure to increase; the owner of one of these gardens told me that he used all of the night-soil which he could get, and would gladly use more, but could not obtain it.

As to remedy, it is obviously impossible for the city of Cambridge to control the whole territory drained by Wellington Brook and Little Pond; and if the city could control it, it would be decidedly unwise to interfere with so extensive a business as that of "market-gardening," which is the most important source of pollution of the water in this district. Even if this business were entirely stopped in the district drained by these sources of water supply, all of the land suitable for the erection of dwelling-houses would undoubtedly, in a few years, be densely populated, and thereby not at all improved in character as a gathering-ground for a source of water supply. The only safe remedy is to discontinue altogether the use of Little Pond and Wellington Brook, the waters of which cannot fail to add impurities to Fresh Pond water to an extent and of a character which may prove dangerous to the health of the community.

*The Conduit.* — As has been mentioned above, the conduit extends from Little Pond to Black's Nook. At the Little Pond end there is a gate through which the water from Little Pond may be allowed to flow if necessary. A short distance from Little Pond water from the filter basin is admitted to the conduit, and where the conduit crosses Wellington Brook a gate is constructed, so as to admit the water from the brook.

The water in the conduit is at times exceedingly impure, as may be seen by the analyses in the table. Most of the impurities must come from the filter basin and the surrounding soil, since the conduit is not a tight one, but, on the contrary, permits a large amount of water to leak into it. Gaugings taken by the City Engineer show that this leakage amounts at times to from 600,000 to 800,000 gallons per day between Wellington Brook and Fresh Pond.[1] For a portion of its course the conduit is situated only a few feet below the surface of the ground, so that the water which leaks in is simply the bog-water which covers the meadows, and which always contains a large amount of vegetable matter.

A possible future source of contamination of the water in the conduit is Niles Brothers' slaughter-house, which, although it is constructed so as to be tight, and to prevent, as far as possible, any soakage of animal matter into the ground, acts indirectly as a serious source of pollution by attracting to its neighborhood a number of workmen, for whom buildings have been erected, from which the house drainage is poured on to or into the surrounding earth. In case of certain acci-

[1] See foot-note on page 41.

dents at the slaughter-house a large amount of animal matter might be east upon the ground, from whieh mueh might easily get into the pond or into the eonduit; any aeeident which would cause a leakage from the buildings or from eertain apparatus outside of the buildings, such as the bursting of the pipe whieh conduets the "soup" to the "muck-heap," breaking of the drain-pipe leading to Alewife Brook, cracking of the cemented floors in some of the buildings, negligence of the proper preeautions in the transportation of the pigs, or, lastly, the partial destruetion of the buildings by fire, might result in the contamination of the water in Fresh Pond by animal matter in two ways, either by soaking into the eonduit, which is very near the surfaee of the ground at this point, or by soakage through the subsoil to the pond. Recent investigations made by the City Engineer show that the pressure was such that the subsoil water at Blaek's Nook — that portion of Fresh Pond nearest the slaughter-house — rose from two to four inches above the level of Fresh Pond, so that the flow of the subsoil water in the direction of the pond at this point must be quite rapid. Moreover, the filthy eharaeter of the water in the eonduit, when the gates were elosed at both Little Pond and Wellington Brook, and yet, when a large amount of water was flowing into the pond from the eonduit, whieh water must have eonsisted of the average subsoil water at that time, shows that the upper stratum of gravel, at all events, no longer aets as an effieient filter.[1]

*Fresh Pond Meadows.* — The borings whieh have reeently been made under the supervision of the City Engineer show that there is a very rapid flow of the water under these meadows toward Fresh Pond, and, therefore, that a eonsiderable portion of the supply for the pond comes from the meadows by pereolation through the earth. This shows the neeessity of keeping the surfaee of the meadows as free from pollution as possible.

Of the present sources of contamination some have already been mentioned in the foregoing pages. The most important one is Alewife Brook with its sewers; the filth from this souree is spread over the

[1] Measurements made by Mr. Barbour in July, 1876, showed that the leakage into the conduit between Wellington Brook and the pond was at the rate of 1,071,924 gallons; on Nov. 19, 1878, between Little and Fresh Ponds, it was 1,829,952 gallons after a heavy rain; on Nov. 16, 1878, it was 995,036 gallons; on Dec. 6, 1878, between Little Pond and Wellington Brook, it was 588,586 gallons; on Dec. 16, 1878, between Little Pond and Wellington Brook, it was 520,148 gallons, and for the whole length of the conduit 1,113,294 gallons, making the leakage into the conduit between Wellington Brook and Fresh Pond 593,146 gallons; on Dec, 18, 1878, between Wellington Brook and Fresh Pond, it was 846,377 gallons, and on Dec. 19, it was 858,924 gallons. (Report of Evidence in the case of the City of Cambridge *v.* Niles Brothers, Tenth Annual Report of the State Board of Health of Massachusetts, pp. 130, 131.)

meadows for a considerable distance during wet seasons, and can only be prevented by removing the sewage from the brook. The slaughter-house of Niles Brothers, with its drain-pipe, has also been spoken of. This drain-pipe has already broken several times, when a large quantity of sewage has been poured on to the surface, discoloring the water for a long distance. In addition to these, there are a number of buildings situated on the meadows, from which offensive material is discharged, but there are few or none of these situated near Fresh Pond.

All possible means should be taken to prevent the discharge of noxious material upon this district, especially in the neighborhood of the pond, since the water must find its way very quickly to the pond. The natural meadow water contains a large amount of vegetable matter, which is removed by filtration and storage; but we cannot be certain that the animal matter is so completely removed, especially that which contains human excrement; and such material is poured over the meadows from Alewife Brook and Little River.

## TABLE OF WATER ANALYSES.

### Fresh Pond.

| Date. | Analyst. | Locality. | Free Ammonia. | Albuminoid Ammonia. | Residue. | | | Chlorine. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inorganic. | Organic and Volatile. | Total. | | |
| | | | | | | | | | ° |
| July, 1853 | Mariner. | . . . . . | ..... | ..... | 8.51 | 2.31 | 10.82 | 1.95 | .. |
| Oct. 1872 | Sharples. | . . . . . | ..... | ..... | 16.49 | 5.00 | 21.49 | .... | .. |
| 1873 . . | Horsford. | . . . . . | ..... | ..... | 9.72 | 4.05 | 13.77 | .... | .. |
| 1875. | | | | | | | | | |
| Feb. 22 . | Sharples. | Top . . . . | 0.0170 | 0.0155 | 8.00 | 5.00 | 13.00 | 1.99 | .. |
| " 22 . | " | Bottom . . . | ..... | ..... | 9.00 | 5.00 | 14.00 | .... | .. |
| Mar. 12 . | " | Service . . . | ..... | ..... | 9.00 | 4.00 | 13.00 | .... | .. |
| June 2 . | " | " . . . | 0.0010 | 0.0050 | 11.00 | 3.00 | 14.00 | .... | .. |
| " 16 . | " | " . . . | 0.0010 | 0.0050 | 9.50 | 3.00 | 12.50 | .... | .. |
| 1876. | | | | | | | | | |
| Mar. 13 . | " | " . . . | 0.0048 | 0.0086 | 10.00 | 4.20 | 14.20 | 1.63 | .. |
| Aug. 8 . | " | . . . . . | 0.0010 | 0.0165 | 8.00 | 5.00 | 13.00 | .... | .. |
| Dec. 13 . | " | Top . . . . | 0.0160 | 0.0160 | 10.50 | 3.50 | 14.00 | .... | .. |
| " 16 . | " | Service . . . | 0.0048 | 0.0060 | 9.00 | 3.50 | 12.50 | .... | .. |
| 1877. | | | | | | | | | |
| April 4 . | " | Engine House . | 0.0080 | 0.0096 | 8.00 | 4.00 | 12.00 | .... | .. |
| Sept. 4 . | Nichols. | . . . . . | 0.0061 | 0.0197 | 10.90 | 1.50 | 12.40 | 1.70 | .. |
| " 4 . | " | Service . . . | 0.0051 | 0.0248 | ..... | ..... | ..... | 1.20 | .. |
| Oct. 1 . | Sharples. | . . . . . | 0.0050 | 0.0148 | 10.00 | 3.50 | 13.50 | .... | .. |
| " 1 . | " | Service . . . | 0.0016 | 0.0165 | 10.00 | 4.50 | 14.50 | .... | .. |
| " 1 . | " | Reservoir . . | 0.0050 | 0.0198 | 9.70 | 5.30 | 15.00 | .... | .. |
| " 18 . | Nichols. | Top . . . . | 0.0144 | 0.0234 | 11.05 | 1.10 | 12.15 | 2.10 | .. |
| " 18 . | " | Bottom [1] . . . | 0.2592 | 0.0368 | 13.45 | 1.75 | 15.20 | .... | .. |
| Nov. 14 . | " | Top . . . . | 0.0419 | 0.0179 | 11.90 | 2.40 | 14.30 | 1.81 | .. |
| " 14 . | " | Bottom . . . | 0.0429 | 0.0179 | 11.90 | 1.10 | 13.00 | 1.64 | .. |
| Dec. 12 . | " | " . . . | 0.0267 | 0.0243 | ..... | ..... | ..... | 1.89 | .. |
| " 12 . | " | " . . . | 0.0264 | 0.0248 | ..... | ..... | ..... | 1.87 | .. |
| " 12 . | " | " . . . | 0.0264 | 0.0212 | ..... | ..... | ..... | 1.82 | .. |
| " 12 . | " | " . . . | 0.0264 | 0.0171 | ..... | ..... | ..... | 1.78 | .. |
| " 12 . | " | " . . . | 0.0264 | 0.0177 | ..... | ..... | ..... | 1.84 | .. |
| " 12 . | " | " . . . | 0.0269 | 0.0165 | ..... | ..... | ..... | 1.85 | .. |
| 1878. | | | | | | | | | |
| May 4 . | " | S.W. Buoy [2]. . | 0.0021 | 0.0176 | ..... | ..... | 12.4 | 1.41 | .. |
| " 14 . | " | " " . . | 0.0027 | 0.0149 | ..... | ..... | 13.1 | 1.23 | .. |
| June 4 . | " | " " . . | 0.0045 | 0.0155 | ..... | ..... | 16.1 | 1.41 | .. |
| " 12 . | " | N.E. " . . | 0.0027 | 0.0155 | ..... | ..... | 13.3 | 1.31 | .. |
| " 19 . | " | S.W. " . . | 0.0027 | 0.0129 | ..... | ..... | 13.7 | 1.38 | .. |
| " 25 . | " | N.E. " . . | 0.0035 | 0.0285 | ..... | ..... | 15.6 | 1.47 | .. |
| July 2 . | " | S.W. " . . | 0.0039 | 0.0251 | ..... | ..... | 14.7 | 1.47 | .. |
| " 9 . | " | N.E. " . . | 0.0035 | 0.0184 | ..... | ..... | 13.8 | 1.38 | .. |
| " 16 . | " | S.W. " . . | 0.0029 | 0.0203 | ..... | ..... | 13.2 | 1.30 | .. |
| " 23 . | " | N.E. " . . | 0.0021 | 0.0173 | ..... | ..... | 13.2 | 1.40 | .. |
| Aug. 6 . | " | " " . . | 0.0037 | 0.0197 | ..... | ..... | 11.7 | 1.44 | .. |
| " 13 . | " | S.W. " . . | 0.0045 | 0.0216 | ..... | ..... | 12.0 | 1.37 | .. |
| " 20 . | " | N.E. " . . | 0.0045 | 0.0195 | ..... | ..... | 11.0 | 1.36 | .. |
| " 27 . | " | S.W. " . . | 0.0024 | 0.0202 | ..... | ..... | 11.7 | 1.31 | .. |

[1] "This specimen of water was offensive to the taste and smell when taken from the pond. It probably came from the neighborhood of a mass of decaying matter. The result of six attempts to obtain another similar specimen on Dec. 12, 1877, is seen above."

[2] These samples marked "S. W. Buoy" and "N. E. Buoy" were taken two feet below the surface, at one or the other of two points several hundred feet apart, at the mouth of the bay from which the [pumping] conduit issues.

TABLE OF WATER ANALYSES — *Continued.*

FRESH POND — *Continued.*

| DATE. | ANALYST. | LOCALITY. | Free Ammonia. | Albuminoid Ammonia. | RESIDUE. | | | Chlorine. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inorganic. | Organic and Volatile. | Total. | | |
| 1878. | | | | | | | | | ° |
| Oct. 21 . | Nichols. | N.E. Buoy . . | 0.0181 | 0.0166 | ..:.. | ..... | 13.3 | 1.46 | .. |
| Nov. 7 . | " | S.W. " . . | 0.0309 | 0.0173 | ..... | ..... | 11.5 | 1.22 | .. |
| " 14 . | Sharples. | Engine House . | 0.0224 | 0.0224 | 10.5 | 3.00 | 13.5 | .... | .. |
| Dec. 7 . | Nichols. | N.E. Buoy . . | 0.0296 | 0.0234 | ..... | ..... | 12.6 | 1.30 | .. |
| 1879. | | | | | | | | | |
| Feb. 1 . | ? Sharples. | . . . . . | 0.0128 | 0.0192 | 9.00 | 3.00 | 12.00 | .... | .. |
| " 8 . | Wood. | Black's Nook . | 0.0400 | 0.0290 | 10.50 | 8.00 | 18.50 | 2.35 | 7½ |
| Mar. 19 . | " | Drain from Black's House [1] | 0.0132 | 0.0580 | 1.50 | 3.50 | 5.00 | 0.4 | 1 |
| " 26 . | " | Engine House [2] | 0.0120 | 0.0210 | 6.00 | 7.00 | 13.00 | 1.6 | 6 |
| " 26 . | " | Bar opp. Hittinger's Ice House | 0.0053 | 0.0160 | 5.60 | 5.20 | 10.80 | 1.6 | 6 |
| Aug. 6 . | Sharples. | Near mouth of pump'g conduit | 0.0010 | 0.0150 | 8.00 | 3.50 | 11.50 | .... | .. |
| " 6 . | " | Service . . . | 0.0010 | 0.0070 | 8.00 | 3.00 | 11.00 | .... | .. |

CUSHING STREET DISTRICT.

| DATE. | ANALYST. | LOCALITY. | Free Ammonia. | Albuminoid Ammonia. | RESIDUE. | | | Chlorine. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inorganic. | Organic and Volatile. | Total. | | |
| 1877. | | | | | | | | | ° |
| April 4 . | Sharples. | Cider Mill Pond. | 0.0160 | 0.0190 | 9.50 | 7.50 | 17.00 | .... | .. |
| Dec. 21 . | " | " | 0.0046 | 0.0384 | 6.00 | 10.50 | 16.50 | .... | .. |
| 1878. | | | | | | | | | |
| Mar. 20 . | " | " [3] | 0.0620 | 0.1395 | 14.00 | 8.00 | 22.00 | .... | .. |
| " 20 . | " | " [4] | ..... | ..... | 30.00 | 8.00 | 38.00 | .... | .. |
| Aug. 8 . | " | " | 0.0032 | 0.1440 | 9.00 | 9.00 | 18.00 | .... | .. |
| 1879. | | | | | | | | | |
| Mar. 10 . | Wood. | Cider Mill Pond [5] | 0.0800 | 0.0490 | 2.25 | 3.25 | 5.50 | 1.0 | 1½ |
| April 29 . | " | " | 0.0014 | 0.0500 | 3.00 | 3.50 | 6.50 | 1.5 | 1 |
| July 8 . | " | " [6] | 0.0000 | 0.0610 | 2.25 | 10.00 | 12.25 | 1.6 | 1½ |
| Feb. 13 . | " | Richardson's Pond Outlet . | 0.0160 | 0.0260 | 5.00 | 6.00 | 11.00 | 0.7 | 2½ |
| Mar. 10 . | " | " | 0.0186 | 0.0240 | 5.50 | 6.00 | 11.50 | 0.9 | 3 |
| April 29 . | " | " | 0.0032 | 0.0226 | 7.50 | 7.00 | 14.50 | 1.2 | 3½ |
| May 12 . | " | " | 0.0106 | 0.0172 | 7.00 | 7.50 | 14.50 | 1.2 | 4 |
| July 8 . | " | Richardson's Pond [6] . . . | 0.0532 | 0.0534 | 6.50 | 8.00 | 14.50 | 1.2 | 3½ |
| Feb. 13 . | " | Bridge . . . . | 0.0400 | 0.0260 | 6.00 | 6.00 | 12.00 | 1.30 | 3 |
| April 29 . | " | " . . . . | 0.0040 | 0.0250 | 6.00 | 6.50 | 12.50 | 1.50 | 4 |

[1] A foul oder like that of kitchen slops.

[2] The demijohn had a badly fitting stopper, which may have affected the result of the analysis, especially the free ammonia.

[3] Filtered. [4] Unfiltered. [5] Very foul odor. [6] Outlet dry.

TABLE OF WATER ANALYSES — *Continued.*

WELLINGTON BROOK.

| DATE. | ANALYST. | LOCALITY. | Free Ammonia. | Albuminoid Ammonia. | RESIDUE. | | | Chlorine. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inorganic. | Organic and Volatile. | Total. | | |
| 1875. | | | | | | | | | ° |
| June 16 . | Sharples. | . . . . . | 0.0020 | 0.0090 | 7.50 | 3.00 | 10.50 | .... | .. |
| 1876. | | | | | | | | | |
| Dec. 13 . | " | Above pigsties . | 0.0048 | 0.0064 | 7.50 | 3.50 | 11.00 | .... | .. |
| " 13 . | " | Below " . | 0.0048 | 0.0064 | 7.00 | 3.00 | 10.00 | .... | .. |
| 1877. | | | | | | | | | |
| April 4 . | " | Above Gate House | 0.0064 | 0.0080 | 4.50 | 3.70 | 8.20 | .... | .. |
| Aug. 30 . | Nichols. | . . . . . | 0.0125 | 0.0237 | 8.70 | 3.30 | 12.00 | 1.75 | .. |
| Sept. 7 . | " | . . . . . | 0.0088 | 0.0189 | 9.10 | 3.20 | 12.30 | 1.20 | .. |
| Oct. 1 . | Sharples. | . . . . . | 0.0050 | 0.0066 | 8.70 | 4.00 | 12.70 | .... | .. |
| " 6 . | Nichols. | . . . . . | 0.0280 | 0.0544 | ..... | ..... | 14.90 | 1.10 | .. |
| " 6 . | " | Opp. pigsties . | 0.0272 | 0.0680 | 12.60 | 3.90 | 16.50 | 1.00 | .. |
| " 6 . | " | At conduit . . | 0.0243 | 0.0483 | 13.10 | 4.60 | 17.70 | 1.70 | .. |
| 1879. | | | | | | | | | |
| Mar. 29 . | Wood. | Brighton Street . | 0.0186 | 0.0268 | 5.50 | 5.50 | 11.00 | 1.00 | $2\frac{1}{2}$ |
| July 8 . | " | " | 0.0160 | 0.0200 | 6.00 | 6.00 | 12.00 | 1.10 | $3\frac{1}{2}$ |
| " 8 . | " | Belmont Street . | 0.0620 | 0.0246 | 6.50 | 8.50 | 15.00 | 1.20 | 3 |

LITTLE POND.

| DATE. | ANALYST. | LOCALITY. | Free Ammonia. | Albuminoid Ammonia. | RESIDUE. | | | Chlorine. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inorganic. | Organic and Volatile. | Total. | | |
| 1875. | | | | | | | | | ° |
| June 2 . | Sharples. | Top . . . . . | 0.0016 | 0.0110 | 8.70 | 4.50 | 13.20 | .... | .. |
| 1876. | | | | | | | | | |
| Mar. 13 . | " | Springs . . . | 0.0064 | 0.0064 | 13.20 | 6.80 | 20.00 | 1.92 | .. |
| " 13 . | " | " [1] . . . | 0.0128 | 0.0120 | 13.40 | 6.60 | 20.00 | 2.57 | .. |
| " 13 . | " | " [2] . . . | 0.0088 | 0.0080 | 18.00 | 4.50 | 22.50 | 2.60 | .. |
| Aug. 9 . | " | Filter Basin . . | 0.0254 | 0.0231 | 12.00 | 6.00 | 18.00 | 2.21 | .. |
| Dec. 13 . | " | Top . . . . . | 0.0070 | 0.0120 | 8.00 | 6.00 | 14.00 | .... | .. |
| " 13 . | " | Filter Basin . . | 0.0080 | 0.0054 | 14.00 | 4.50 | 18.50 | 3.09 | .. |
| 1877. | | | | | | | | | |
| Aug. 30 . | Nichols. | . . . . . | 0.0261 | 0.0624 | ..... | ..... | ..... | 3.10 | .. |
| Sept. 7 . | " | . . . . . | 0.1312 | 0.0981 | 13.30 | 5.80 | 19.10 | 2.60 | .. |
| Oct. 1 . | Sharples. | . . . . . | 0.0165 | 0.0165 | 14.20 | 4.50 | 18.70 | .... | .. |
| 1879. | | | | | | | | | |
| Mar. 20 . | Wood. | Top . . . . . | 0.0133 | 0.0900 | 4.25 | 5.25 | 9.50 | 1.20 | $2\frac{1}{2}$ |
| " 26 . | " | " . . . . . | 0.0160 | 0.0320 | 5.50 | 4.75 | 10.25 | 1.20 | $2\frac{1}{2}$ |
| Feb. 1 . | Sharples. | Under ice . . . | 0.0160 | 0.0226 | 7.00 | 4.00 | 11.00 | .... | .. |

[1] Unfiltered. [2] Filtered

## TABLE OF WATER ANALYSES — *Continued.*

### Frost Brook.

| Date. | Analyst. | Locality. | Free Ammonia. | Albuminoid Ammonia. | Residue. | | | Chlorine. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inorganic. | Organic and Volatile. | Total. | | |
| 1879. | | | | | | | | | ° |
| Mar. 29 . | Wood. | Clifton Street . | 0.0080 | 0.0178 | 6.00 | 2.00 | 8.00 | 0.60 | 2 |
| " 29 . | " | Brighton Street | 0.0880 | 0.0228 | 4.50 | 5.50 | 10.00 | 1.00 | 2½ |
| May 12 . | " | Arlington Heights | 0.0052 | 0.0092 | 1.50 | 2.00 | 3.50 | 0.40 | 1 |
| " 12 . | " | Brighton Street | 0.0106 | 0.0126 | 3.50 | 5.00 | 8.50 | 1.00 | 2½ |
| July 8 . | " | Clifton Street . | 0.0106 | 0.0250 | 5.00 | 4.50 | 9.50 | 0.80 | 1½ |
| " 8 . | " | Brighton Street | 0.0106 | 0.0300 | 4.25 | 7.00 | 11.25 | 1.3 | 2½ |

### Conduit Water.

| Date. | Analyst. | Locality. | Free Ammonia. | Albuminoid Ammonia. | Residue. | | | Chlorine. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inorganic. | Organic and Volatile. | Total. | | |
| 1877. | | | | | | | | | ° |
| Oct. 1 . | Sharples. | . . . . . | 0.0040 | 0.0066 | 15.00 | 5.50 | 20.50 | .... | .. |
| Dec. 21 . | " | . . . . . | 0.0010 | 0.0127 | 9.50 | 3.00 | 12.50 | .... | .. |
| 1878. | | | | | | | | | |
| Aug. 29 . | " | Manhole near Black's Gate Ho. | 0.0128 | 0.0128 | 13.00 | 5.00 | 18.00 | .... | .. |
| Nov. 14 . | " | Near Fresh Pond | 0.0128 | 0.0128 | 16.50 | 5.00 | 21.50 | .... | .. |
| Dec. 16 . | " | 3d & 1st Manhole | 0.0062 | 0.0047 | 17.00 | 3.00 | 20.00 | .... | .. |
| 1879. | | | | | | | | | |
| Feb. 27 . | Hills. | 1st Manhole[1] . | 0.0174 | 0.0150 | 10.00 | 7.00 | 17.00 | 3.8 | 8 |
| " 27 . | " | 4th " . . | 0.0186 | 0.0170 | 10.00 | 8.00 | 18.00 | 4.0 | 9 |
| " 27 . | " | 5th " . . | 0.0200 | 0.0100 | 13.00 | 10.00 | 23.00 | 3.8 | 10 |
| " 27 . | " | 7th " . . | 0.0120 | 0.0090 | 11.50 | 7.10 | 18.60 | 4.0 | 10 |
| Mar. 20 . | Wood. | 1st " west of Wellington Br.[2] | 0.0212 | 0.0100 | 11.00 | 7.75 | 18.75 | 2.3 | 9½ |
| " 26 . | " | " " . | 0.0160 | 0.0190 | 10.00 | 7.75 | 17.75 | 1.9 | 8 |

[1] These manholes are numbered from Fresh Pond toward Little Pond.
[2] The demijohn had a badly fitting stopper, which may have affected the result of the analysis, especially the free ammonia.

TABLE OF WATER ANALYSES — *Continued.*

SPY POND.

| DATE. | ANALYST. | LOCALITY. | Free Ammonia. | Albuminoid Ammonia. | RESIDUE. | | | Chlorine. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inorganic. | Organic and Volatile. | Total. | | ° |
| 1870 . . | Horsford. | Outlet . . . . | ..... | ..... | 9.60 | 6.40 | 16.00 | .... | .. |
| 1875. | | | | | | | | | |
| Feb. 22 . | Sharples. | Top . . . . . | 0.0124 | 0.0217 | 12.00 | 5.00 | 17.00 | 2.53 | .. |
| " 22 . | " | Bottom . . . | ..... | ..... | 12.00 | 5.00 | 17.00 | .... | .. |
| June 16 . | " | Top . . . . . | 0.0060 | 0.0090 | 11.70 | 3.00 | 14.70 | .... | .. |
| 1876. | | | | | | | | | |
| Dec. 13 . | " | " . . . . . | 0.0192 | 0.0192 | 9.50 | 4.70 | 14.20 | .... | .. |
| 1877. | | | | | | | | | |
| Aug. 30 . | Nichols. | . . . . . | 0.0040 | 0.0539 | 10.60 | 2.80 | 13.40 | 3.40 | .. |
| Oct. 1 . | Sharples. | . . . . .. | 0 0033 | 0.0231 | 9.50 | 6.00 | 15.50 | .... | .. |
| Feb. 1879 | " | . . . . . | 0.0640 | 0.0128 | 13.00 | 4.00 | 17.00 | .... | .. |

ALEWIFE BROOK.

| DATE. | ANALYST. | LOCALITY. | Free Ammonia. | Albuminoid Ammonia. | RESIDUE. | | | Chlorine. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inorganic. | Organic and Volatile. | Total. | | ° |
| 1875. | | | | | | | | | |
| June 16 . | Sharples. | . . . . . | 0.0050 | 0.0120 | 9.50 | 4.50 | 14.00 | .... | .. |
| 1879. | | | | | | | | | |
| July 29 . | Wood. | Spruce St. Sewer | 0.4800 | 0.0580 | 15.75 | 15.75 | 31.50 | 5.50 | $12\frac{1}{2}$ |
| " 29 . | " | North Av. " | 0.2880 | 0.0560 | 7.75 | 12.75 | 20.50 | 5.10 | 9 |
| " 28 . | " | Concord Av. " | 0.2160 | 0.0290 | 9.75 | 5.50 | 15.25 | 3.75 | $7\frac{1}{2}$ |
| " 28 . | " | Niles Bros.' " | 1.1520 | 0.0650 | 27.75 | 19.50 | 47.25 | 19.50 | $11\frac{1}{2}$ |

## TABLE OF WATER ANALYSES — *Continued.*

### Wells on Meadows.[1]

| Date. | Analyst. | Locality. | Free Ammonia. | Albuminoid Ammonia. | Residue. | | | Chlorine. | Hardness. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inorganic. | Organic and Volatile. | Total. | | |
| 1879. | | | | | | | | | |
| July 28 . | Wood. | Well No. 14[2] . . | ..... | ..... | ..... | ..... | ..... | 2.60 | ... |
| " 29 . | " | " " 14 . . | ..... | ..... | ..... | ..... | ..... | 2.75 | ... |
| " 28 . | " | " " 10[3] . . | ..... | ..... | 27.75 | 30.00 | 57.75 | 8.25 | ... |
| " 29 . | " | " " 17[4] . . | ..... | ..... | 30.50 | 9.50 | 40.00 | 8.25 | ... |
| Aug. 6 . | " | " " 14 . . | 0.0021 | 0.0046 | 20.00 | 14.75 | 34.75 | 2.70 | 16½ |
| " 6 . | " | " " 19[5] . . | 0.0074 | 0.0036 | 23.75 | 5.75 | 29.50 | 6.30 | 12 |
| " 15 . | " | " " 11[6] . . | 0.1440 | 0.0420 | 37.25 | 17.75 | 55.00 | 18.50 | 20 |
| " 15 . | " | " " 29[7] . . | 0.3840 | 0.1400 | 13.00 | 13.00 | 26.00 | 2.90 | 14 |

[1] Borings recently made under the supervision of the City Engineer.
[2] On the edge of Fresh Pond, at Black's Nook. The water in this well stood three inches above the level of Fresh Pond.
[3] At the side of Alewife Brook between North Avenue and Broadway. This was a deep well from below a very thick stratum of clay. A large amount of gas was discharged with the water.
[4] On the meadows, about 50 feet north of Concord Avenue.
[5] On the edge of Fresh Pond, near Tudor's ice-house.
[6] Fifteen feet from Alewife Brook and from the mouth of the sewer of Niles Bros.' slaughter-house.
[7] Between Concord Avenue and Fresh Pond, 15 feet from Alewife Brook, and about 350 feet from the pond.

## FRESH POND.

### Frankland and Armstrong Method.

By Prof. Wm. Ripley Nichols.

| Date. | Approximate depth. | Organic Carbon. | Organic Nitrogen. | Ratio $\frac{\text{Carbon}}{\text{Nitrogen}}$. |
|---|---|---|---|---|
| 1879. | | | | |
| January 22 . . | 20 feet[1] . . . . . | 0.174 | 0.048 | 3.6 |
| " 22 . . | 35 " . . . . . | 0.136 | 0.049 | 2.8 |
| April 14 . . . | 2 " [2] . . . . . | 0.775 | 0.131 | 6.2 |
| " 14 . . . | 20 " . . . . . | 0.915 | 0.146 | 6.3 |
| " 14 . . . | 35 " . . . . . | 0.828 | 0.146 | 5.7 |
| May 13 . . . | 2 " . . . . . | 0.308 | 0.045 | 6.9 |
| " 13 . . . | 20 " . . . . . | 0.304 | 0.045 | 6.8 |
| " 13 . . . | 35 " . . . . . | 0.258 | 0.038 | 6.8 |
| June 12 . . . | 2 " . . . . . | 0.275 | 0.053 | 5.2 |
| " 12 . . . | 20 " . . . . . | 0.289 | 0.064 | 4.5 |
| " 12 . . . | 35 " . . . . . | 0.325 | 0.047 | 6.9 |
| | Average . . . | 0.417 | 0.074 | 5.6 |

[1] "Taken through the ice." [2] "Just after the ice had broken up."

I have collected in the above table all of the analyses of Fresh Pond waters which I have been able to find in the various reports upon the Cambridge water, and also some analyses performed by the Frankland and Armstrong method of water-analysis, which were kindly furnished me by Prof. Wm. Ripley Nichols of the Massachusetts Institute of Technology. The average composition of the Cochituate water, as determined by Prof. Nichols from January to June, 1879, was

| Organic Carbon. | Organic Nitrogen. | Ratio $\frac{\text{Carbon}}{\text{Nitrogen}}$. |
|---|---|---|
| 0.408. | 0.052. | 7.9. |

The following figures, taken from the 6th Report of the Rivers Pollution Commission, 1874, show the average composition of waters with which Fresh Pond may properly be compared.

| | Organic Carbon. | Organic Nitrogen. | Ratio $\frac{\text{Carbon}}{\text{Nitrogen}}$. |
|---|---|---|---|
| Average unpolluted upland surface water . . . . | 0.322 | 0.032 | 10.1 |
| The Teign, above Old Wheal, Exmouth, Sept. 26, 1873[1] | 0.582 | 0.058 | 10. |
| Loch Katrine, Aug. 3, 1870[2] . . . . . | 0.185 | 0 022 | 8.4 |
| The Thames, at Thames Ditton, Jan. 31, 1873[3] . . | 0.325 | 0.076 | 4.3 |

[1] "A peaty water, which contains more vegetable matter than is admissible for drinking."
[2] "A very good water."
[3] "Surface water from cultivated land." "Certain amount of animal pollution. Nitrates and nitrites present from use of manures. Most efficient filtration needful."

The ratio of the carbon to the nitrogen is considered very important, as showing the nature of the organic matter, whether of vegetable or animal origin. As a rule, especially in surface waters, if the organic matter is of vegetable origin, this ratio is high, but if of animal origin, the ratio is low; so that, as a rule, in the same class of waters, the higher this ratio the better the water. In this respect the analyses of Prof. Nichols show the water of Fresh Pond to be at times somewhat inferior in quality to that of Cochituate, and a comparison of his analyses with those quoted from the Rivers Pollution Commission Report show it to be inferior to the "average unpolluted upland surface water," and to resemble more nearly the water of "the Thames at Thames Ditton," which is "surface water from cultivated land," and contains a "certain amount of animal pollution," from the use of manure upon the surrounding gathering-ground.

By the Wanklyn and Chapman method of water-analysis which is almost universally used in this country, and to a very large extent also in England, organic contamination is shown in surface waters chiefly

by an excess of the free and albuminoid ammonia and chlorine, — an increase of the free ammonia and chlorine together indicating especially animal pollution, and the albuminoid ammonia alone vegetable contamination. Fresh Pond water contains a larger amount of chlorine and is much harder than other surface waters in this vicinity which are used as sources of water supply; these properties it undoubtedly derives from the neighboring ground, which has, in former times, been saturated with sea-water. So far as the chlorine is concerned, therefore, we must not take into consideration its absolute amount, but only its increase over and above the average amount. Unfortunately there are not as many determinations of the chlorine in Fresh Pond water as of the free and albuminoid ammonia, but at times the chlorine is considerably increased, together with the ammonia; as, for instance, on Oct. 18, and Nov. 14, 1877, when all of these substances were increased more than usual.

It is, however, impossible to state with certainty whether the excess of chlorine found at certain times was due to the addition of a large amount of animal matter or to an increased flow of water from the subsoil, as, for instance, from the conduit. The analyses of the water derived from some of the recent borings near the pond, as well as those of the water which has leaked into the conduit from the surrounding earth, show that a considerable amount of water drawn from these sources would increase the chlorine in the pond. At the same time, the introduction into Fresh Pond of from one to three million gallons daily of water coming from highly cultivated land (from the Cushing Street district and the new conduit) would tend also to increase the ammonia.

The large increase in the amount of ammonia in the autumn may be explained in many ways. A portion may be due to decaying vegetation, but not the whole; since we do not observe so large an increase in other ponds which are subjected to the same conditions as Fresh Pond, so far as decaying vegetation is concerned. It may also be partly explained by the surface washings from the cultivated land, caused by the heavy rains in the fall and spring, at which seasons the manure is applied to the land.

The organic matter which is introduced into Fresh Pond through the various sources of pollution mentioned above partly disappears by decomposition, the volatile products of such decomposition escaping into the air, and the insoluble products being deposited as a sediment, and is partly disguised by being diluted with the purer water from the springs, which has been filtered through a long distance of gravel and sand; a portion, also, disappears in its passage through the distributing pipes; a portion, however, escapes decomposition and may be de-

tected in the water drawn from the service pipes, sometimes in too large an amount, as, for instance, on Sept. 4, 1877.

At the present time (Aug., 1879), the water is in excellent condition, as shown by the latest analyses (Aug. 6). This is, in my opinion, largely due to the fact that the pond has received no water directly from any of those sources of pollution which yield an abundant supply. The outlets of Cider Mill and Richardson's ponds have been dry since about the 1st of July, and the gate at the mouth of the conduit has been closed during the entire summer.

All of the analyses of water from the Cushing Street district show great pollution. In these waters the amount of chlorine is important, since they are surface waters, and, if unpolluted, would not contain more than 0.3 or 0.5 parts in 100,000. They contain less chlorine than Fresh Pond, and the excess above 0.5 parts in 100,000 comes undoubtedly from sewage.

The analyses of Wellington Brook water simply confirm, what a careful inspection of the district would lead us to expect, viz., that at times, especially in the autumn, the water is very much polluted. This is shown particularly by the analyses of Prof. Nichols on Oct. 6, 1877. The last analysis, on July 8, 1879, was taken from the spring at the side of the engine-house on Belmont Street. This spring forms the source of Wellington Brook, and is surrounded by highly-cultivated farms, from which it receives its supply; it was surrounded by a covered wooden casing, and is undoubtedly considered by the inhabitants in the neighborhood as a spring of excellent drinking-water. It was, however, at that time highly polluted; further down it became diluted with a purer water, probably from the Waverley Hills, so that at Brighton Street it was less impure than at its source.

The analyses of Little Pond water show that, at times, it is liable to be very impure. This is shown especially by the analyses of the water in August and September.

The three sets of analyses of the water of Frost Brook are extremely interesting, as showing the influence of cultivated land upon a surface water. In only one of these, that of May 12, was the upper specimen taken from a point above all cultivated land; between this point and where the brook crosses Clifton Street it flows through ordinary farming-land, but between Clifton and Brighton Streets it flows through the highly manured market-gardens. The effect of these gardens in the early spring, when they are heavily manured, is well shown by the analyses of March 29, when the free ammonia was increased eleven times; at this time 1.67 inches of rain had fallen during the previous week, so that there must have been considerable surface washing into the brook.

The recent analyses of Alewife Brook water were made partly to determine the influence of the various sewers upon the brook. The impurities found at the mouth of the Concord Avenue sewer were, in part, undoubtedly due to the sewage from Niles Bros.' slaughter-house, the peculiar odor of which was plainly perceptible at Concord Avenue. Moreover, the Concord Avenue sewer receives the drainage from only ten houses, and is flushed daily by about 200,000 gallons of water from the air-pump at the engine-house of the water works. The water taken from the mouth of the Spruce Street sewer was unmixed with brook water; but that marked "North Avenue sewer" was taken below the bridge, and was, therefore, diluted with the brook water.

The "organic and volatile" residue from the water of the wells driven upon the borders of the pond and upon the meadows consisted chiefly of volatile inorganic matter; the residue did not char perceptibly upon being ignited, with the exception of that of wells No. 11 and 29, both of which show organic contamination from Alewife Brook. The water of well No. 11 was largely polluted with sewage from Niles Bros.' slaughter-house, although taken from the subsoil fifteen feet from the brook; that the sewage came from the slaughter-house was very evident from the peculiar odor.

The water from well No. 29 was taken from just above the clay, and its analysis shows that it must have been polluted by sewage from the brook. This well is located about 350 feet from the border of the pond.

## Conclusions.

The careful survey of Fresh Pond and vicinity, and the study of the history of the Cambridge water supply, in regard to which I have endeavored to give the principal facts in the foregoing pages, have led me to the following conclusions.

1st. That Fresh Pond alone cannot be relied upon to furnish a sufficient supply of water for the city of Cambridge.

2d. That there are certain sources of contamination, which are liable to pollute the water of Fresh Pond to an extent dangerous to the health of the community, and which must be removed in order to preserve the purity of Fresh Pond water.

3d. That the principal sources of pollution of Fresh Pond itself can be diverted. The sewage discharging into the pond at Cushing Street, and that into Alewife Brook and Black's Nook, can be conducted away from the pond by means of sewers.

4th. That, in order to still further preserve the purity of Fresh Pond, the city authorities should exercise constant supervision over Fresh Pond Hotel and its adjoining grounds, and the Fresh Pond meadows,

and prevent, upon this territory, the carrying on of any business or the erection of any buildings, the refuse from which would tend to injure in any way a source of water supply. And if the city has not this power vested in its Board of Health, or other board, it should obtain it, if possible, by legislative enactment.

5th. That the water of Little Pond and Wellington Brook is, at times, polluted to so great an extent, and with material of so dangerous a character, that these waters are totally unfit to be used as sources of water supply; and since this pollution is of such a nature as to render it impossible to prevent it from entering these waters, their use should be discontinued, and they should be prevented from entering Fresh Pond.

6th. That some other additional supply should be obtained.

7th. That if the above-mentioned sources of pollution of Fresh Pond be removed, the purity of its water may be sufficiently preserved, so as to render it suitable to be used as a source of water supply for an indefinite period, and also as a storage reservoir, if necessary, for any other additional supply.

Very respectfully your obedient servant,

EDWARD S. WOOD, M.D.

CAMBRIDGE, August 25, 1879.

# APPENDIX II.

OFFICE OF THE CITY ENGINEER,
CAMBRIDGE, Aug. 16, 1879.

*To the Committee on Water Supply of the City of Cambridge:* —

GENTLEMEN, — Having spent much time in carefully studying the condition and prospects of your water supply as placed before me by you and your City Engineer, — including his more recent unpublished investigations, — and in personal examinations, I beg leave to submit the following report: —

The questions at issue are clearly set forth in the published investigations of the city authorities and of individual citizens who evidently have devoted much time and thought to the subject, and may be thus stated: —

*First.* The present condition of the supply as to purity.

*Second.* The sufficiency of that supply, not only for the present, but for the probable future.

*Third.* The existing sources of impurity.

*Fourth.* The possible and probable increase of impurity from such, and perhaps from other sources.

*Fifth.* The means of removing or mitigating the present sources of impurity.

*Sixth.* The means of preventing future sources of impurity from polluting the water; or,

*Seventh.* In case future pollution of the water supply cannot be prevented, where else could the city obtain a satisfactory supply?

*First.* The present condition of the supply as to purity appears to have been proved satisfactory by the investigations referred to. The appearance of the water, the analyses of the chemists, and the sanitary condition of the city, are proofs of this. This statement applies only to the supply which comes directly from Fresh Pond.

*Second.* For a sufficient supply it has been unnecessary heretofore to draw from any other sources than Fresh Pond, except a limited amount through the conduits from Wellington Brook and Little and Spy

ponds. Nothing directly is known to have been drawn from Spy Pond, and very rarely any thing from Wellington Brook or Little Pond. The supply received into Fresh Pond through the lower conduit has been mostly from percolation into it.

The probable growth of the city will make it necessary, before long, to obtain a larger supply than the sources now utilized afford. The conduits above mentioned have been so arranged that any portion of their capacity may be used in feeding Fresh Pond whenever needed. The entire drainage area tributary to Fresh, Spy, and Little ponds and to Wellington Brook is supposed to be about 5.2 square miles, or sufficient in quantity for a number of years to come. Examinations show already, however, that the waters of Spy and Little ponds and Wellington Brook are decidedly inferior to that of Fresh Pond, for which reason they have been carefully excluded from the direct supply to the city. Unless those sources can be made and kept pure, the inadequacy of Fresh Pond as a satisfactory supply for probable future wants is evident.

*Third.* The existing sources of impurity that have attracted attention are Cushing Street district; Fresh Pond Hotel grounds; Niles Bros.' slaughter-house; piggeries, water-closets, and barn-yards drained into Wellington and other brooks; drainage from market-farms highly manured with night-soil; Alewife Brook; and shallow places along a portion of the shore and in some of the coves of Fresh Pond, All these have not produced as yet, according to the information before me, an appreciably deleterious effect upon the supply from Fresh Pond, except at rare intervals; but they cannot fail to do so unless remedied. Even a strong suspicion of the pollution of a water supply is greatly to be deprecated, and should by all available means be avoided.

*Fourth.* The future increase of impurities cannot be foretold with certainty. If Boston should continue to be the metropolis of New England, which is exceedingly probable, its increase must overflow into the suburban districts, and bring with it the habits of life and industrial pursuits that tend inevitably to pollute the soil and consequently the water it bears. This pollution may be greater or less according to population and industries; but to some extent it is sure to come, though the wisest sanitary measures now known may be adopted to prevent it.

*Fifth.* Various expedients have been suggested for removing or mitigating present sources of impurity. Among these are an intercepting sewer entirely around Fresh Pond, another along the right bank of Alewife Brook between Fresh Pond and Mystic River, or, in place of the latter, one on the same side of Alewife Brook, entirely within the limits of Cambridge, having its outlet into Charles River.

The intercepting sewer around Fresh Pond could undoubtedly be

made to receive and carry off into another intercepting sewer, discharging into Mystic or Charles River, the surface drainage now considered objectionable. Such a sewer, to be effectual, would necessarily be very expensive.

Without constructing an intercepting sewer around Fresh Pond, Cushing Street district drainage could be kept out by comparatively inexpensive means, — a small pipe along the margin of the pond to an existing sewer at Lexington Avenue, or by a still less costly plan not yet fully developed, both suggested by the City Engineer.

Fresh Pond Hotel grounds could be purchased and sold again, if thought advisable, under conditions that would prevent them from becoming a source of pollution.

The slaughter-house of Niles Bros. might not be of serious injury if always managed with sufficient skill and faithfulness; but the existence of such an establishment in such a position is very unfortunate, considering how liable it is to be managed in the interests of the owners far more than in those of the city. So vital a matter as the water supply of a city should not be contingent upon the possible mismanagement of such an establishment.

Existing piggeries, water-closets, and barn-yards could be made useful in fertilizing the soil, instead of emptying their contents directly into streams that can be received into the conduits.

Alewife Brook should at once be restored to purity by keeping out of it the drainage it now receives, not only from city sewers but from Niles Bros.' slaughter-house. I can think of no more effectual or economical plan for this than the intercepting sewer already proposed by the City Engineer. This involves the necessity of an outlet through other territory than that of Cambridge, if the discharge should be into Mystic River. An outlet into Charles River, though more expensive, would require no additional jurisdiction, and would accommodate the future sewerage of that district, — a decided advantage.

The degree of objection to the shallow places in some portions of Fresh Pond must depend greatly upon the level at which it may be necessary to maintain the pond. The expense of dredging to make such places deep enough to remove all real or supposed objections to them would undoubtedly be very heavy.

*Sixth.* The means necessary to prevent future pollution of Fresh Pond include, besides those already mentioned for remedying existing evils, either the ownership of a large extent of territory, or such jurisdiction over it as would give practically the same control. To purchase a considerable quantity of land would be very expensive; yet without the control this, or annexation, would give over the shores of the pond and adjacent lands, it would be impossible to prevent pollu-

tion of this source of supply. Recent borings clearly indicate percolation towards the pond from a considerable distance.

*Seventh.* While a careful consideration of the foregoing statements leaves a reasonable assurance that the present condition of the water supply is wholesome, a serious doubt arises as to the practicability and cost of keeping it so. The increase of population and industries within the next few years may be such as to affect this supply very injuriously, in spite of all legislation and engineering expedients to the contrary. In such a case, what could the city do to obtain a satisfactory supply?

Among the sources suggested for that purpose the two most favorably known are the Shawsheen River and the Chestnut Hill reservoir. What it would cost to construct the necessary works, including land and water rights, does not appear to be known in relation to the Shawsheen River project, but there is every reason to believe the cost would be within the ability of the city to provide for.

The height of Chestnut Hill reservoir is all that could be desired to deliver a sufficient supply into the Cambridge reservoir. For increasing the pressure, at certain hours of the day, all over the city as now done, the existing pumping works, with probably another force main between them and the reservoir, would be ample. The probable cost of the necessary pipes and other works, for delivering 5,000,000 gallons daily, would not exceed $150,000. The cost of the water would of course depend upon an arrangement with the city of Boston. Such an arrangement could no doubt be made mutually advantageous, Boston having an abundant supply, not only for the present but the future.

My examination of this subject leads me to the following

CONCLUSIONS.

*First.* There is satisfactory evidence to show that, up to the present time, the supply from Fresh Pond has been sufficiently pure.

*Second.* Comparatively cheap expedients may be adopted to maintain its present purity under existing conditions in regard to population and industries.

*Third.* That to provide against future probabilities it will be necessary to take constantly into Fresh Pond sources of supply now admitted to but a limited extent because not sufficiently pure; or,

*Fourth.* It will, as I believe, be found best ultimately to abandon the attempt to make and keep all the present available sources of supply pure, on account of great expense and impracticability; and for an additional supply to take a part of the Shawsheen River; or go to the city of Boston.

Respectfully submitted,

E. S. CHESBROUGH.

# APPENDIX III.

*Gentlemen of the Water Supply Committee: —*

The nature of the question submitted to me, namely: What quantity of water can be depended upon from Fresh Pond and that portion of the conduit connecting Fresh and Little Ponds, which lies between Fresh Pond and Wellington Brook? limits the examination to those times in which Fresh Pond has been used, or drawn upon, without being supplemented from any other source.

The first information bearing upon this matter, seems to be the measurements of the discharge of water from Fresh Pond made by Mr. F. W. Bardwell for the Water Works Company in 1855, and continued for a few weeks only; the result of his examination, for this time, showed an average discharge of 1,725,000 gallons daily. In March, 1856, his observations were again commenced, and continued for a period of one year with, as a result, an average daily discharge of 2,125,000 gallons. These measurements were made before pumping had been carried on to any great extent, and would seem to show the capacity of Fresh Pond, as it existed in rather a wet year, previous to the construction of the water works.

In the same year Mr. W. S. Whitwell also made an examination, based upon the water-shed draining into Fresh Pond, which was found to be 1,200 acres. After deducting the area of the pond, and basing his calculation on four-tenths of the rainfall reaching the pond, he gives as his result a daily average of 1,634,256 gallons.

From the records of the Water Company, and from those kept by the city since the purchase, we find that when the amount of water drawn from the pond has not exceeded the quantities as determined previous to pumping, the pond is spoken of as unaffected, and has kept about its average level; but when these quantities have been exceeded, the level has fallen, and has only been restored by being supplemented by water drawn from other sources.

In the year 1865, when the works were purchased by the city, the daily record shows pumping at the rate of 1,461,048 gallons; the rain-

fall for the year was 43.59 inches. The superintendent in his report speaks of the season as being remarkably dry, and the water being very freely used in consequence for watering gardens, &c., but no mention is made of any lack of supply from the pond; there are no records of the variation in the pond level.

In the year 1868 we find the quantity of water pumped had reached a daily average of 1,732,755 gallons, and this remark is made. The rapid increase of water taken, and consequent consumption of water, admonish us that early measures should be taken to secure the water of Spy Pond, as provided for in the charter establishing the Cambridge Water Works. The question is then asked, What is the capacity of Fresh Pond? The answer given is, We can only say that we have been unable to produce any perceptible reduction with the greatest draught of water made by our pumps. Rainfall for the year, 39.89 inches.

In 1870 the average daily quantity of water pumped was 1,739,869 gallons; the rainfall was 41.53 inches. The drought was called extreme during the summer, and the pond was supplemented via Alewife Brook, a dam having been placed at the culverts under the Lexington Branch Railroad. As no record was kept showing the variation of the water in the pond, or the quantity drawn through the brook, this year will give no additional light as to the capacity, but will show that it was deemed necessary to supplement the supply from Fresh Pond.

The same conditions were found in the year 1871. The rainfall was 40.56 inches, the number of gallons pumped 1,747,704, and the pond gained 4½ inches, which, if added to the amount pumped, would have made a daily average of 1,809,347 gallons, but the pond was supplemented as before.

In 1872 the average number of gallons pumped was 1,626,006, the rainfall was 51.98 inches, and the pond gained during the year 35 inches, which, at 5,000,000 gallons per inch, would equal 175,000,000 gallons, — a daily average gain of 479,452; and would give, if added to the amount actually pumped, a daily average supply of 2,105,458 gallons.

In 1873 the pumping had increased to a daily average of 2,124,884 gallons; the rainfall was 46.10 inches. At the close of the year the pond showed a loss of 35½ inches, and clearly shows that the capacity of the pond had been exceeded by nearly a half a million gallons per day.

In 1874 the daily pumping averaged 2,299,146 gallons; the rainfall was 41.87 inches. At the end of the year the pond showed a loss of 16.12 inches below the point reached at the close of 1873.

In 1875 the daily average pumping was 2,718,484 gallons; the rainfall was 51.46 inches, — the pond showing, at the close of the year, only

one half an inch loss below the point reached at the close of 1874. It appears, however, that some water was drawn from Wellington Brook and Little Pond through the new conduit constructed this year. Fresh Pond reached at this time (1875) the lowest point of which we have any record, and was 7 feet $4\frac{5}{8}$ inches below high-water mark, as determined by the commissioner in 1870 and 1871.

The surface drainage area of Fresh Pond has been so reduced by the construction of roads and sewers as to yield (on the same basis as by earlier determinations, *i. e.*, $\frac{4}{10}$ of the rainfall reaching the pond) about 772,000 gallons daily, with a rainfall of 45.6 inches. Experiments made during the last two years, on the northerly side of the pond, near the conduit, show conclusively that the ground water at this point rises and falls with the pond, maintaining an almost constant difference in level, the ground water always being from 3 to 5 inches the highest. Gaugings of the conduit between Wellington Brook and Fresh Pond have always shown a very considerable yield of water, at times exceeding 500,000 gallons in 24 hours. Borings recently made on the southwesterly side of the pond also indicate a very considerable ground-flow from the direction of Bird's Pond; also from the westerly side, where springs are known to exist. The yield from ground-flow will probably exceed 1,000,000 gallons daily. It would seem that in former years too much credit has been given as to the quantity of water received from the drainage area (called 1,200 acres), and too little to the underground flow, or springs. It is quite possible that the conduit does not furnish any new supply, but merely acts as a collecting gallery, and delivers the water more quickly into the pond than by its natural flow. The porous nature of the soil shown by the recent tests, and a series of wells sunk on the borders of the pond, in which the water rises several inches above the pond level, certainly show that the tendency of the ground water is in that direction.

## CONCLUSIONS.

Some of the conclusions which may be drawn from the foregoing pages are:—

*First.* That the measurements made about the time the works were started, in 1855–56, show that the pond did at this time yield a daily average supply of 2,125,000 gallons, as shown by Mr. Bardwell's measurements, and 1,634,256 by Mr. Whitwell's.

*Second.* From the pumping records, and the rise and fall of the pond level, we find that for a term of years, when the pond has not been supplemented from any other source, there has been pumped a quantity of water varying from 1,461,048 to a little over 2,000,000 gallons in 24 hours, without serious loss to the pond; but when this quantity

(2,000,000 gallons) has been exceeded, there has been a constant lowering of its surface without recovery. When the consumption had reached 2,700,000 gallons the pond became reduced more than 7 feet below high-water mark, and was evidently drawn upon much beyond its capacity.

*Third.* That the present drainage area and the ground-water will probably furnish (including the conduit to Wellington Brook), in a year of average rainfall, about 1,750,000 gallons daily, and in a wet year possibly 2,000,000 gallons. The pond would probably not yield as much in a very dry year or a succession of dry years. The accompanying diagrams show the rainfall, pond levels, and pumping records.

Respectfully submitted,

W. S. Barbour.

Cambridgeport, October 13, 1879.

Note. — The figures relating to rainfall and pumping, in the foregoing report, are mainly taken from the reports of the Cambridge Water Board; while the rainfall shown in the diagram was made from records kept at Harvard College Observatory, — the averages being for different months than those from the Water Board reports. The pumping averages, as shown on the diagram, are also for different months, — those in the report being from December to December; those in the diagram being from January to January.

Plate I

# CAMBRIDGE WATER WORKS

PLAN OF

## FRESH POND AND SURROUNDINGS

*TO ACCOMPANY REPORT OF*

## WATER SUPPLY COMMITTEE

1879

Cambridge Dec. 1 1874

Hiram F. Barbour
City Engineer

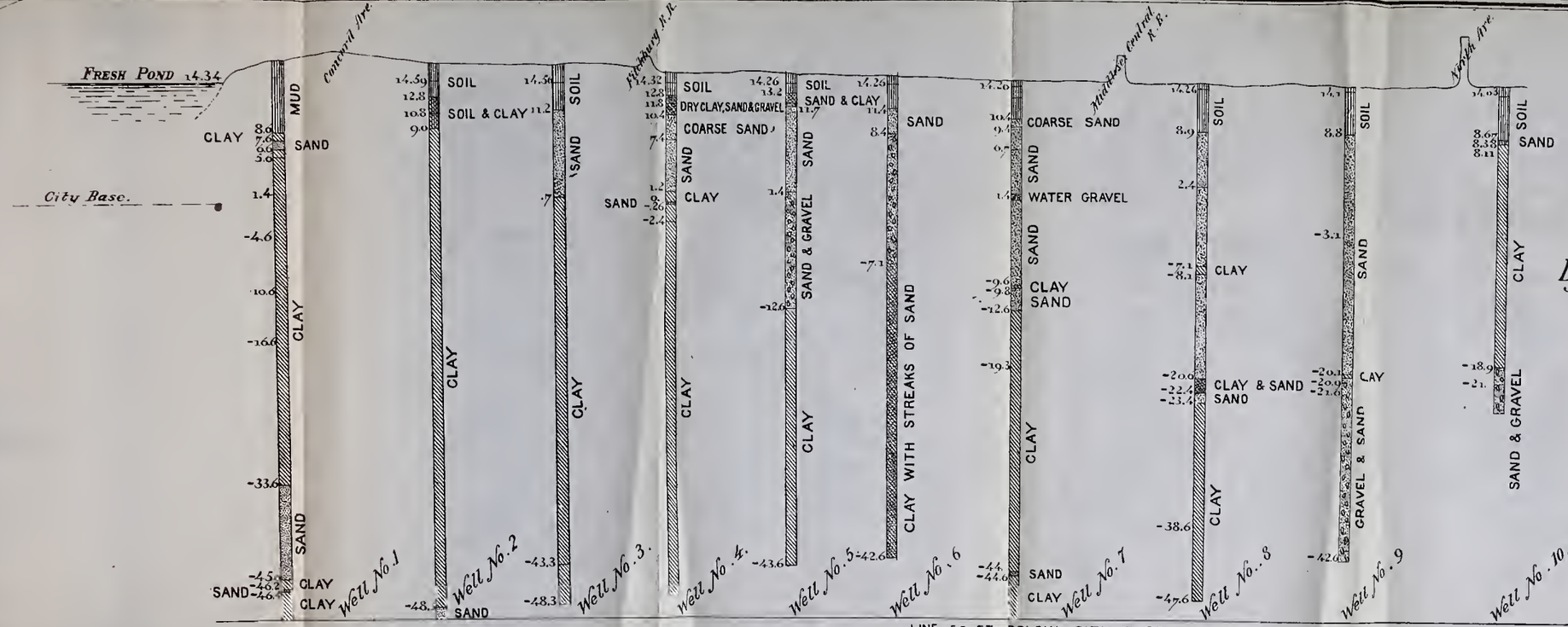
BUFFORD'S RHEOTYPE PROCESS.

5-0.7 Acres, proposed annexation from Belmont
6/4 + 1 " " " Arlington
Borings shown thus 6

WASHINGTON ST
BRIGHTON ST
CROSS ST
HILLS ROAD
LAKE ST
CEMETERY ST
CONCORD TURNPIKE
ARLINGTON AVE
MIDDLESEX TURNPIKE
PROPOSED LINE OF ANNEXATION
WELLINGTON BROOK
LITTLE POND
SPY POND
FRESH POND
BIRDS POND
STRAWBERRY HILL OR CUTTINGS ST. DISTRICT
CITY OF CAMBRIDGE GRAVEL PIT
GLACIALIS OR ARTIFICIAL ICE POND
FRESH POND DRIVE
RICHARDSON POND
CROUT ST
THIRKLAND ST
AUBURN ST
MT AUBURN ST
BELMONT ST
AUBURN AVE
CAMBRIDGE
ARLINGTON
BELMONT


COLLEGE OF SURGEONS
LIBRARY

Plate II




# Cambridge Water Works

## Diagram showing Borings made near Fresh Pond.

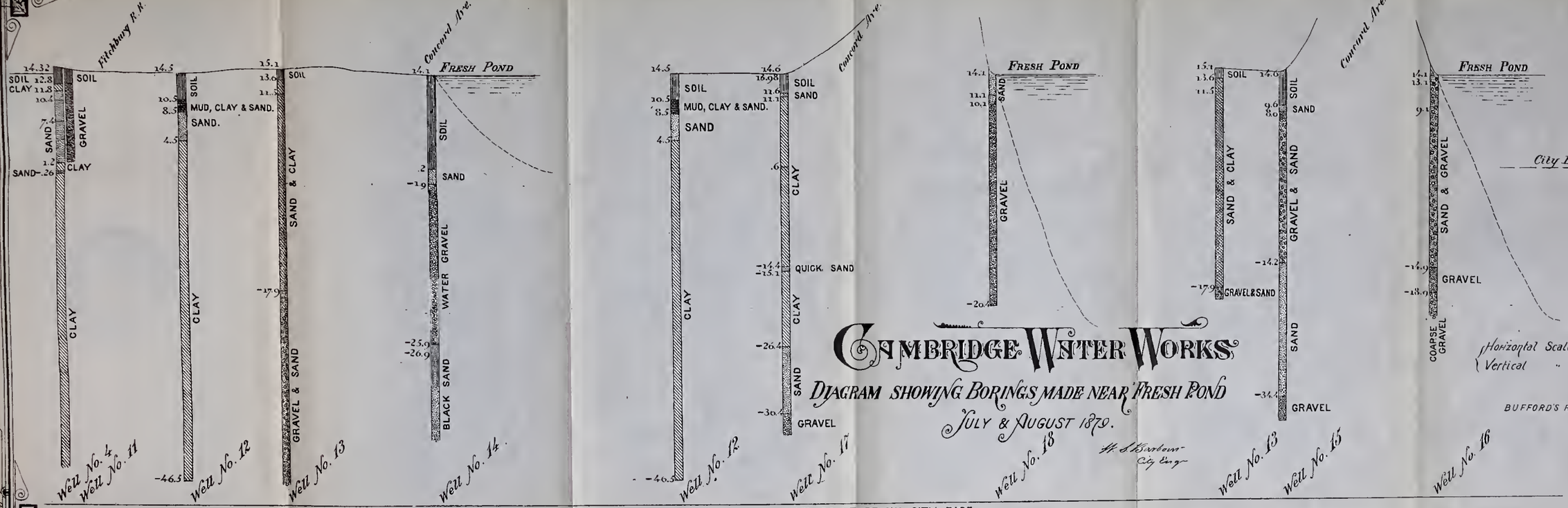
July & August 1879.

W. S. Barbour, City Engr.

Horizontal Scale 400 ft. to an inch.
Vertical " 10 " " " "

BUFFORD'S RHEOTYPE PROCESS

Plate III




# CAMBRIDGE WATER WORKS

## DIAGRAM SHOWING BORINGS MADE NEAR FRESH POND

JULY & AUGUST 1879.

H. S. Barbour
City Engr

Horizontal Scale 400 ft. to an inch
Vertical " 10 " " " "

BUFFORD'S RHEOTYPE PROCESS

Plate IV.

# CAMBRIDGE WATER WORKS

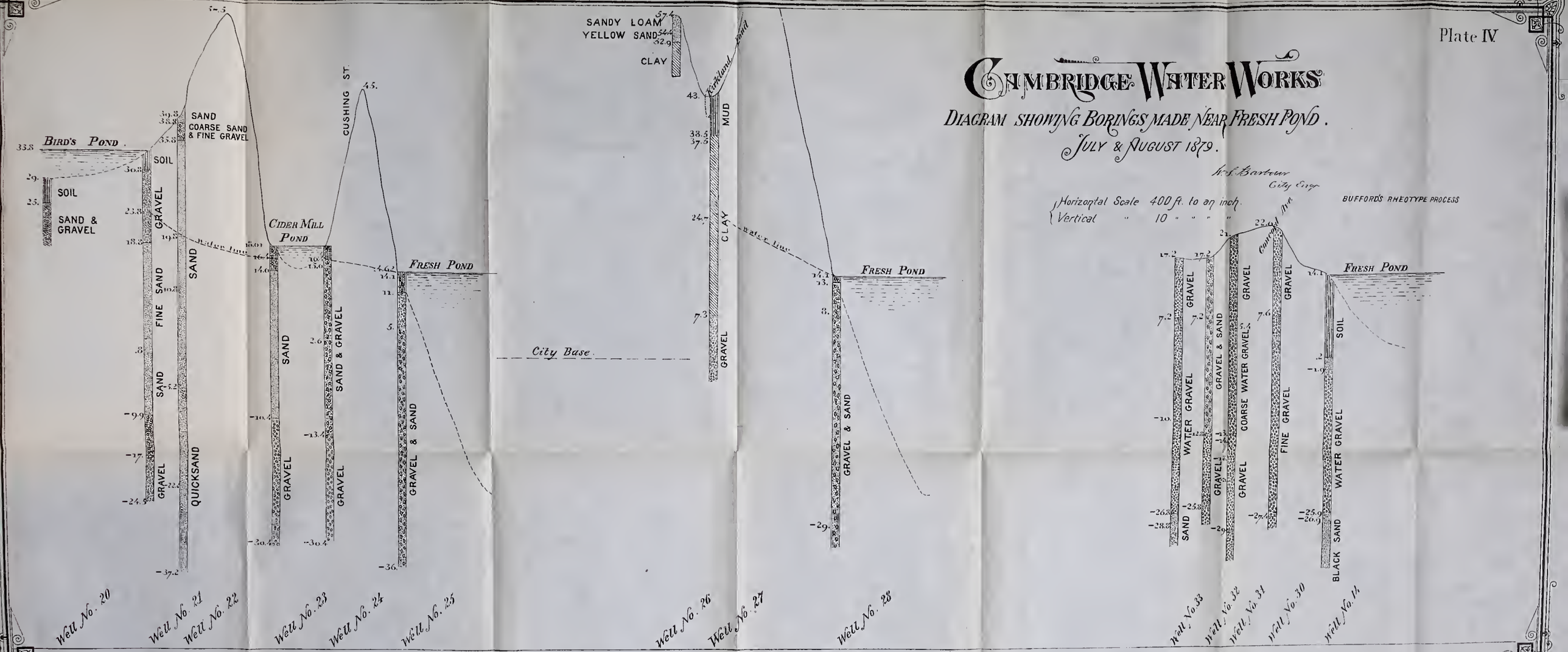
## DIAGRAM SHOWING BORINGS MADE NEAR FRESH POND.

### JULY & AUGUST 1879.

Wm. F. Barbour
City Engr

Horizontal Scale 400 ft. to an inch.
Vertical " 10 " " "

BUFFORD'S RHEOTYPE PROCESS




LINE 50 FT BELOW CITY BASE

Plate V

# Cambridge Water Works

*Diagram showing Monthly Average Pumping, Rise and Fall of Fresh Pond, and Rainfall, from 1871 to 1879.*

*H. F. Bardwell*
*City Engr.*

Average Daily Pumpage

Yearly Average 2,324,641 gal.

2,782,761 gal.

2,641,823 gal.

2,561,904 gal.

2,260,135 gal.

2,401,215 gal.

1685 Height of water April 21, 1870.

Average Monthly Elevation Fresh Pond

Monthly Rainfall

Yearly Rainfall 1871 40.30

1872 38.53

1873 46.81

1874 38.53

1875 51.00

1876 47.65

1877 44.68

1878 44.53

1879

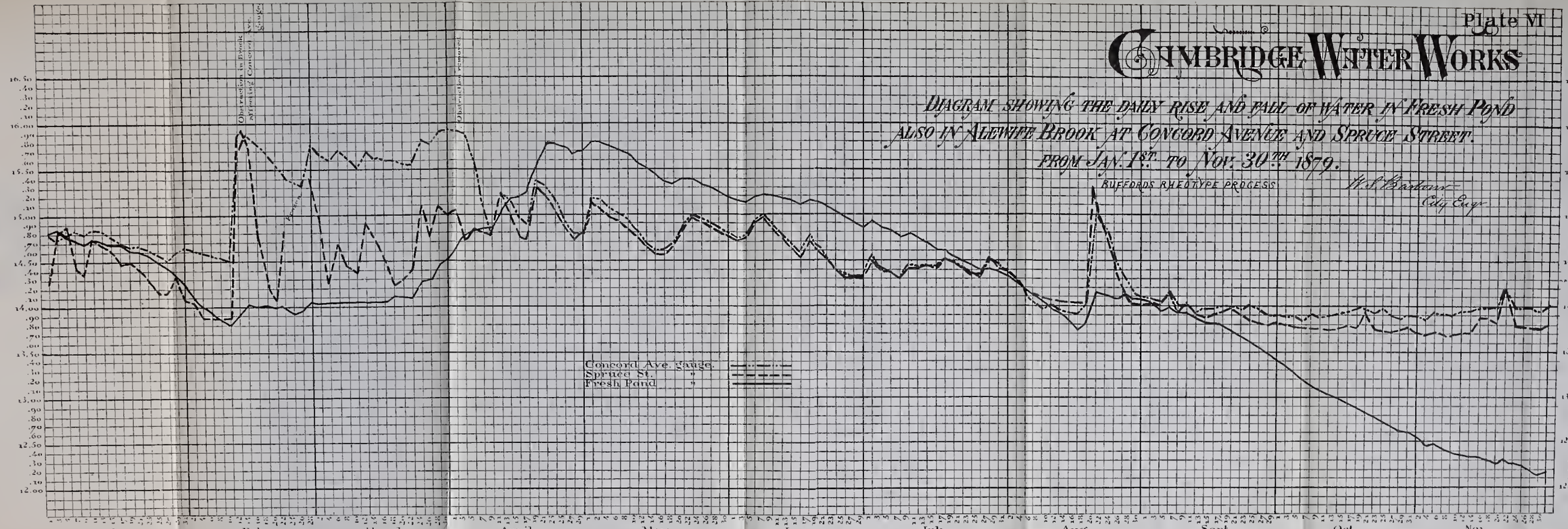
Plate VI

# Cambridge Water Works

*Diagram showing the daily rise and fall of water in Fresh Pond also in Alewife Brook at Concord Avenue and Spruce Street. From Jan. 1st. to Nov. 30th 1879.*

Buffords Rheotype Process

H. F. Bardwell City Engr




1879


LIBRARY