and as far as it relates to the character of the water must be exceedingly satisfactory and encouraging to all.

*Gentlemen:* I have thus briefly laid before you the wants and condition of the city. Let us now vigorously and perseveringly enter upon our several trusts. If our duties are collective they are none the less binding, and we have each one taken a solemn oath to a faithful performance of the obligations now resting upon us. You shall have my earnest co-operation in whatever seems calculated to advance the interests of the city or the welfare of its inhabitants.

WM. S. STEVENS.

# REPORT OF THE SURVEY

—OF—

# WILLAND POND.

# ENGINEERS' REPORT.

*To Hon. William S. Stevens, Mayor of the City of Dover, N. H.:—*

At your request we have examined Willand Pond with reference to the feasibility of supplying the City of Dover with water therefrom, and submit the following as the result of our investigation:

In such examinations the question that first arises is usually that of

THE QUANTITY REQUIRED.

This is commonly answered by allowing about fifty or sixty gallons per day to each inhabitant. It has been found, indeed, that an ordinary household of seven persons is abundantly supplied by from seventy to one hundred gallons per day. But the amount consumed in stables, manufactories, private fountains and gardens, together with that for extinguishing fires, watering streets, the erection of buildings, and above all, the waste, has been found so great as to

require the larger quantity above mentioned. The Water Board of Boston have recently published a notice warning the inhabitants of that City against waste of the Cochituate water, and stating that the consumption was at the rate of seventy gallons per day for each person. At times the consumption has risen to one hundred gallons in Boston and New York. But it is found that small towns require a smaller quantity *per capita* than larger ones, and it is probable that sixty gallons per day will be found sufficient for Dover.

The smaller quantity of fifty gallons may be sufficient for a few years to come, but the experience of other places has been that the consumption increases faster than the population, and it is therefore better to estimate on the larger quantity.

| | | |
|---|---|---|
| The population of Dover was in | 1850, | 8186 |
| " " | 1860, | 8502 |
| " " | 1870, | 9212 |

Showing an increase of eight per cent. in the last ten years, and of four per cent. in the preceding ten. If the ratio of increase for the present decade should be ten per cent. the population of 1880 will be about ten thousand.

But as a considerable number of the inhabitants will reside in those sections of the City which are beyond the reach of water-works, it is probable that a supply for 10,000 persons will be sufficient for fifteen or twenty years to come.

It therefore appears that we should look for a source capable of supplying 600,000 gallons per day.

The examination of Willand Pond has been made with reference to the following particulars, viz.: Location, Elevation, Quality, Quantity, and Cost of Introduction.



## LOCATION.

The Pond lies principally in the Town of Somersworth. Its distance from the City Hall in Dover, as measured on a line following the highway to a point near the house of Mr. George Hussey, and thence through his land to the Pond, is 12,932 feet. This route is pretty direct, and it may perhaps be found on further investigation to be the best line for a main pipe. But by deviating from it somewhat, the line may be made straighter, and, of course, shorter. This will be seen by reference to the accompanying plan.

The land surrounding the Pond is principally a sandy or gravelly plain. It is infertile and of little value for agriculture. It is so far distant from your own City, and from other large towns, and from railroads, that it is not likely to be occupied by any considerable population or by any manufacturing establishments, which would defile the Pond to any appreciable extent. The location is excellent.

## ELEVATION.

The height of the surface of the Pond, as it stood Oct. 17th, above some of the prominent points in the City was as follows:

| | |
|---|---|
| Low tide in the Cochecho at the Print Works, | 191.58 feet. |
| Lower step at front door of City Hall, | 146.17 " |
| " " American House, | 118.41 " |
| Summit in Franklin St., near Dr. Horne's house, | 105.03 " |
| Lower step at front gate of Mayor Stevens' house, | 70.35 " |
| Grade at corner of Locust and Silver streets, | 93.54 " |
| First floor Belknap School House, | 68.25 " |
| " R. Cristy's house, | 57.16 " |
| Threshold of tool house at Pine Hill Cemetery, | 40.02 " |
| Reservoir of Cochecho Aqueduct Co. near Gage Hill, | 41.03 " |

It will be seen that with this Pond for a reservoir, the head of water in the lower and more compact and valuable parts of the City, will be all that can be desired for the pur-

pose of extinguishing fires. Indeed, in all places where the head exceeds eighty feet, very valuable and efficient hydrant streams could be brought upon a fire. But in the higher portions of the City, the head, though of some value, would not be sufficient to enable you to dispense with steam fire engines. In those places the principal value of the aqueduct, in its relation to the fire department, would be in the convenient and abundant supply of water for the steamers. But streams suitable for private uses, such as watering lawns and gardens, washing carriages, sidewalks and windows, could be obtained throughout the City.

The highest point of land on Garrison Hill is 105 feet higher than Willand Pond, and a reservoir might be made there which would give about 100 feet of additional head throughout the City. But even this head, undesirable as it would be for the ordinary service, would not enable you to dispense with a steam fire department, for there will always be a large amount of property in the outskirts of the City beyond the reach of a hose and hydrant service, and, of course, without any adequate protection except from steamers.

Such a reservoir, with the necessary pumping machinery, would add largely to the first cost of the works, and the annual expense of running the pumps would be some $2800. By making the works more complicated the liability to accidents and interruptions would be much increased.

For these reasons it does not seem advisable to adopt this plan.

### QUALITY.

The question as to the quality of the water, so far as it belongs to the domain of the chemist, has been ably and satisfactorily answered by Dr. John Bell. So far as it belongs to the engineer, it may be stated that the Pond seems to receive its supply principally from filtration through the sand composing the plain in which it lies. Its beach (with the exception of some four or six rods at one point,) is composed of small pebbles, or clean sand. Its waters are singularly clear, transparent and inviting to the eye. They are very free from aquatic vegetation, and, as has been before remarked, they are not likely to be contaminated by high cultivation, by manufacturing establishments, or by a dense population in the vicinity.



There can be no reasonable objection to this water on the score of quality.

### QUANTITY.

Willand Pond has an area at low water of 83 5-8 acres, or about 86 acres at high water. It has no visible inlet worthy of consideration, and at ordinary stages it has no visible outlet. The ordinary annual high water mark was about two feet above its surface at the time the survey was made. It appears that when the Pond reaches this hight, the surplus water, if any there be, runs off through a piece of low, wet, bushy ground, (called a heath) of some ten or fifteen acres in extent, which lies on the northern border of the Pond, the water finally escaping through a slight artificial channel or ditch into a brook which is tributary to the Salmon Falls River.

On all other sides the Pond is bounded by a dry gravelly plain, which is from twelve to seventeen feet above low water, and which extends from a quarter to a half-mile from the Pond. This plain is bounded in most directions by lower plains and valleys having a retentive clayey soil, which,

being lower than the surface of the Pond, contribute nothing to its waters.

On the contrary, there are several large springs on the borders of the lower plains which are supplied from the body of sand constituting the plain above, and probably in some instances from the Pond itself. On the side next the City the springs are about forty-one feet lower than the Pond, and are of such size that they supply the water for the Cochecho Aqueduct Co. It is probable that these springs are subterranean outlets for the water of the Pond. And undoubtedly these and all the others drain some portions of the sandy plain surrounding the Pond.

All the water in or upon the earth above the level of the sea, comes in the first instance from the rain and snow which falls upon the surface. A portion of this water is evaporated, another portion is absorbed by the earth to re-appear in the form of springs, and a third portion runs off on the surface forming rivulets, brooks, and rivers. Many experiments and observations have been made as to the quantity that can be collected on a given area and on different kinds of soil. It is therefore customary for engineers, when examining any given source of supply, to rely very much on the area of the water-shed

But in this case there are no superficial streams and few or no "gullies" which convey the water of the great rains to the Pond, or, indeed, in any other direction. A very large proportion of the water falling upon the plain is absorbed by the sand, and, passing downward through the coarse material, it is arrested by the impervious stratum beneath, and flows off laterally, in some localities toward the Pond, in others toward the marginal springs, according as the descent may be this way or that.



How extensive the area is which furnishes water to the Pond we have no reliable means of determining, because the water-courses and divides are hidden beneath the surface. It may be stated in a general way that the wells sunk into this plain indicate that the water-table rises toward the north and west, and falls toward the south and east. The heath before spoken of as lying at the north end of the Pond seems to be but an uncovered portion of this stratum.

As all the water which finds its way into the Pond escapes from it again by evaporation, overflow and percolation, it follows that if we abstract any water through other channels it must have one or more of the following results, viz. :—

1. Occasion a greater influx of water to the Pond.
2. Diminish the quantity escaping by overflow and percolation, or—
3. Reduce the quantity remaining in the Pond.

We cannot presume to any considerable extent on the first of these alternatives.

If the third is realized the Pond will soon fail as a source of supply.

Our chief reliance must therefore be on the second. If, as there is good reason to believe, the Pond lies in a basin or hollow in the impervious stratum, and percolation takes place to any considerable extent only when the water overflows its brim, then by drawing off a certain quantity of water for the use of the City we should only be taking that which would otherwise escape by percolation and overflow.

Of course the Pond might be expected to fall lower during the drier half of the year than it now does. In ordinary cases, where the water-shed is only sufficient to supply the annual quantity required, a storage capacity equal to about

three months' consumption is necessary. Two feet in depth on the surface of the Pond gives this amount of storage. If the quantity of water that may be drawn from this Pond without permanently diminishing the quantity remaining is just equal to the consumption, and if it is supplied to the Pond in a manner as irregular as is usual with other ponds, we may expect the surface to fluctuate two feet more than it now does. It will be drawn down so much lower in autumn, and filled up to its present high-water mark in the spring.

The circumstances in this case are such that the ordinary methods of ascertaining the capacity of the Pond as a source of supply cannot be used. The water-shed cannot be measured, nor can the streams be gauged. There is some reason to think that the water-shed does not exceed four hundred or four hundred and fifty acres.

Experience has shown that there are some years in which only one-third of the water precipitated on a given area of the average character of New England soils can be collected and stored in reservoirs. This would require about one square mile to furnish the quantity we seek. But the soil of the area in question is not of the average character of New England soils. It is all flat, sandy and highly absorbent, and the proportion of water that can be collected from it is quite uncertain.

The theory, held by some, that the Pond is supplied by deep springs having a distant source, is not probable. It is true that in some parts of the world copious springs, and even rivers, do flow for great distances under ground. But this can occur only where the rocky strata lie in a position almost perfectly horizontal. In such cases the springs are few, but of great volume. In New Hampshire the underground water-table, like the surface of the earth, is full of



hills and valleys. As a consequence, the subterranean water, like that on the surface, is collected into numerous rills and veins which soon find some valley or low place where they burst out to the surface. Our springs are numerous, and of course small.

Water under ground, like that on the surface, is subject to the law of gravitation It moves only in obedience to that law; that is, it moves from a higher to a lower place. In plain words, it can only run down hill. It is not probable that there is any subterranean conduit or natural aqueduct conveying water to this Pond from any higher source which, in this case, must be miles away, and beyond ranges of hills and intervening valleys. It is far more likely that the supply comes from the rain which falls directly into the Pond, and on the land in the immediate vicinity.

The few observations that have been made on the fluctuations of the Pond indicate that it receives its water occasionally and fitfully, not regularly and constantly as it would from a deep-seated fountain.

These observations have been as follows:

From Oct. 17th to Nov. 3d the hight remained unchanged.
From Nov. 3d to the 10th it fell 2 1-8 inches.
From the 10th to the 24th of the same month it rose 6 3-4 inches.
From the last date to Dec. 23d it rose 3 1-4 inches.

There may have been some intermediate fluctuations which have escaped observation. But the net result is that the Pond is but 7 7-8 inches higher than it was two months ago. This quantity of water is not quite sufficient for one month's consumption.

It will be seen that there are good reasons to doubt the capacity of the Pond as a source of supply. It would not be advisable for the City to construct works for bringing

water from this source without more definite information in this respect than can be obtained by surveying. And yet it is possible that the Pond would, on trial, be found sufficient. If it is so, its advantages over any other source are so obvious that they need not be recounted here. It is therefore desirable to acertain the fact.

Much may be learned by observing closely the manner in which the Pond rises and falls during the present winter and the coming spring. In connection with this, observations should be made on the rain-fall by means of a gauge located in the vicinity. It is possible that the matter can be definitely determined in this way. At any rate it will show whether there is encouragement to proceed to make a more expensive and certain test.

This test may be made in the following manner: By cutting a ditch about 3100 feet in length, through the heath to the northward, the Pond may be drawn down some three feet below the ordinary low-water mark. This will probably be as low as it will ever be necessary to draw it. If the Pond will furnish a supply it will do so without fluctuating three feet more than it now does. With such a ditch the power of the Pond to furnish 80,000 cubic feet per day can be fully tested.

If it stands the test you can then proceed to build Works with confidence. If it fails, its insufficiency will be demonstrated, and the attention of the community will turn to some other source.

A route for such a ditch has been surveyed and laid down on the plan presented herewith. Such a ditch, with a bottom width of four feet and side slopes of one-half to one, will require about 3000 yards of earth excavation.



This experiment would require time and would probably delay the construction of Water Works by one year, but it would be better to make it than to build upon such possibilities of failure.

In the mean time it would be well to make further investigations as to the facilities for supplementing the supply from the Pond by recourse to some other source. There may be no water which can be turned in by gravitation, but it may be found advisable to use the Pond for a reservoir, availing yourselves of the natural supply, whatever that may be, and supplementing it with such a quantity as may be found necessary by pumping from some source nearer the City, either directly into the distribution pipes, or into a rising main leading directly to the Pond, as may on investigation be found best. The Pond offers you a reservoir already built. It is well located and of sufficient hight. It is large, clean and safe, and it will afford some water. These considerations point to the propriety of the investigations here suggested.

## ESTIMATE OF COST.

In the following estimate we have assumed that the wrought iron and cement pipe will be used. The sizes and location of the pipes are given on the accompanying plan:

| | | | | | |
|---|---|---|---|---|---|
| Land Damages, | | | | | $1,000 |
| Gate House at Pond and appurtenances, | | | | | 2,500 |
| 12,500 lineal feet | 14 | inch | pipe at | 2.40, | 30,000 |
| 2,200 | " 10 | " | | 1.45, | 3,190 |
| 11,875 | " 8 | " | | 1.20, | 14,250 |
| 38,825 | " 6 | " | | .85, | 33,001 |
| 4,785 | " 4 | " | | .60, | 2,871 |
| 23,231 cubic yards earth in deep cut near Pond at 50 cents, | | | | | 11,616 |
| 68,785 lineal feet trenching and back filling at 30c, | | | | | 20.635 |
| Extra for crossing river at two places, | | | | | 1,500 |
| 100 Hydrants at 70 dollars, | | | | | 7,000 |

| | | |
|---|---|---|
| Gates—4, 14 inch make 56 inches,<br>4, 10 inch make 40 inches,<br>7, 8 inch make 56 inches.<br>31, 6 inch make 186 inches,<br>1, 4 inch make 4 inches, | 342 inches in diameter at $8 | 2,736 |
| Contingences and general expenses 15 per cent., say | | 19,701 |
| | | $150,000 |

All of which is respectfully submitted,

JAMES A. WESTON,
JOSEPH B. SAWYER, } Civil Engineers.

Manchester, Dec. 28, 1871.

## Analysis of the Water.

*To the Mayor of the City of Dover:*

SIR—I find the following to be the contents of a gallon of the Willand Pond water:

| | |
|---|---|
| Total of Impurities, | 4.62 grains |
| Of this, Organic matter, | 1.03 " |
| Inorganic matter, | 3.59 " |
| Of the Inorganic matter, | |
| Iron, | .11 " |
| Lime, | 1.20 " |
| Soda, | .23 " |
| Sulphuric Acid, | 1.39 " |
| Chlorine, | .46 " |
| Silica, | .20 " |

Besides a general analysis I have experimented on the effects of the water upon soap and lead—its relation to these being by far more important than to any other substances.

A solution of soap in the water was perfectly clear,—showing that, notwithstanding the considerable quantity of Sulphate of Lime present, it was not sufficient to make the water *hard*.

A piece of bright lead pipe exposed, at the same time to this water and the air, showed, in a short time, that so considerable a quantity of lead was dissolved in and diffused

through the water, as to make it dangerous to use. The same experiment, tried a second time upon the same piece of lead, showed a very much less action. After remaining in the water a week, the latter being changed several times, the lead had nearly ceased to be acted upon; a white, varnish-like coating being formed upon its surface, which protects it from further corrosion. After it has been exposed to the action of the water for several weeks, there is no doubt but the very delicate tests we have for lead would show that it had entirely ceased to contaminate the water. As lead pipes *will* be used, I would advise that this water (and indeed all water) flowing through *new* pipes be not used for culinary or drinking purposes. But after two or three months it may be used without danger. Even then, however, lead is so subtile a poison, water, that has stood in contact with it over night ought to be allowed to run off before drawing for use.

On the whole, the Willand Pond water may be considered as very pure; it would be difficult to find a purer unless distilled. This is shown by a comparison with that supplied to other cities, as follows:

| | | | | | |
|---|---|---|---|---|---|
| Boston, | 3.11 | grains of | impurities | to the | gallon of water. |
| Philadelphia, | 3.50 | " | " | " | " |
| Brooklyn, | 3.92 | " | " | " | " |
| New York, | 4.78 | " | " | " | " |
| Chicago, | 6.68 | " | " | " | " |
| Albany, | 10.78 | " | " | " | " |
| London, | 16.38 | " | " | " | " |

Ordinary well-water in this region contains from 20 to 60 grains of impurities to the gallon.

From this it will be seen that the Willand Pond water —so admirably situated in its position with reference to the City—is every way desirable, so far as its purity is concerned.



Probably the water, if taken during colder weather, would show a still less amount of impurities, particularly of organic matter.

Very Respectfully,

Your ob't servant,

JOHN BELL.

Dover, N. H., Nov. 22, 1871.