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Official Document.

REPORT

OF

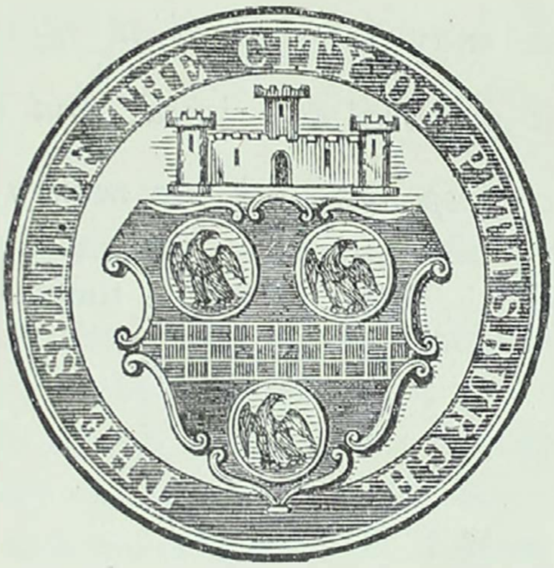
W. Milnor Roberts,

ON

THE NEW WATER WORKS

OF THE

City of



Pittsburgh.

In Councils March 30, 1874. *Accepted, and* 500 *copies ordered to be printed in pamphlet form.*

E. S. MORROW,
GEO. BOOTH,
Clerks of Councils.

PITTSBURGH:
PRINTED BY STEVENSON & FOSTER, CORNER WOOD STREET AND THIRD AVENUE.
1874.

Resolved, *That the Finance Committee are hereby instructed and empowered to employ a competent Engineer, Assistant, and such clerical force as may be required to measure and estimate all work done, and material furnished, and report to Councils, whether the same corresponds with the money expended.*

In Councils December 8th, 1873. Read three times, and passed.

REPORT

ON THE

New Water Works.

To the Finance Committee of Councils of the City of Pittsburgh :

GENTLEMEN : Immediately after my appointment to the duty of examining and reporting upon the situation of the work upon the new Water-works of the city of Pittsburgh, I entered upon the necessary investigations by forming a temporary engineering party for measuring and calculating, placing it under the direction of Mr. T. P. Roberts, to whom, after having visited the three reservoir sites, &c., I gave the requisite instructions as to the method of measuring them.

The weather, during much of the month of January, was not favorable for out-door operations in such exposed situations ; but during the intervals, when no work could be done in the field, the time was employed in making the numerous calculations.

In the course of my investigations I visited the foundations of the engine-house above Negley's run, the quarries, eighteen miles above the engine-house, the reservoirs, the streets in which new pipe had been laid, and where they were still laying the 36-inch main on Butler street; I also examined all the old and new engines now used for pumping at the old Water-works, at the works on the hill, those in Allegheny and Birmingham, as well as the old lower and upper reservoirs, in the city, and the reservoirs in Allegheny and Birmingham.

At different times I visited the foundry of Wm. Smith, contractor for furnishing pipes, and the works of Mr. Hartupee, who is building the pumping engines.

Every facility was extended to me by Mr. Kennedy, Chief Engineer in charge of the new reservoirs, Mr. Lowry, Mechanical Engineer, who designed and is in charge of the new engines, engine-house, &c., and their assistants; also by Mr. Atkinson, Superintendent of the old Water-works, and others connected with the different departments of the works.

It will be recollected that, five or six years ago, in the summer or fall of 1868, I made examinations, at the request of Councils, preparatory to the undertaking of these new Water-works, and in December, of that year, presented a "preliminary report" on the subject, which was printed. Although I then suggested that much more extensive and detailed surveys should be instituted prior to determining the precise plans, I made some general recommendations, which seemed warranted from the examinations, namely:

First. That the Allegheny river was the proper source of supply.

Second. That the water should not be taken from the river below Negley's run; but might be taken out either near that point or several miles above.

Third. That the place on the river, for the erection of the pumping works, need not be at any point far above Negley's run; but might be farther down, much nearer to the old Water-works. The water to be conveyed through a brick conduit from the place where it should be taken from the river to the said pumping works, wherever they might be located.

Fourth. That there might be, at different elevations, two reservoirs; one about 250 feet, and the other about 500 feet above the river; the lower one, for the older parts of the city, including also most of Allegheny, Birmingham, &c.; and the upper one, for the newer and higher portions of the city of Pittsburgh; much the larger portion of the service being needed from the lower of the two proposed reservoirs, including most of the manufactories.

Fifth. That the pumping engines, in the first instance, should be arranged for a supply of 30,000,000 gallons daily; the engine-house to be planned so that additional engines could be put up when the future growth of the city should demand a greater daily quantity. (The city of Philadelphia, the year before, in 1867, had used only 29,771,018 gallons.*)

Sixth. That much more extensive and accurate surveys and examinations should be made before finally determining the main points of such an important undertaking—especially the *reservoir sites*, and the *place for the pumping works.*

Several years after the above mentioned report was presented, Councils engaged the services of two able and thoroughly experienced hydraulic engineers, Messrs. E. S. Chesbrough and Moses Lane, who, after very extensive and complete surveys and investigations, submitted their report in March, 1871. The chief recommendations of their report are:

First. That the pumping works should be located about eight hundred feet above Negley's run, and that the water should be taken out of the river about three miles above, and conveyed through a brick conduit to the pumping works, though the conduit might be dispensed with in the beginning. The conduit was designated wholly for the purpose of securing purer water, water free from the impurities of the oil refineries, &c., along the river.

Second. That the reservoir system should be arranged with three lifts; the first at an elevation of 228 feet, the second, 356 feet, and the third, or Herron's Hill reservoir, 550 feet above the Allegheny river. This was the conclusion of those gentlemen, after having made very careful surveys and levelings, and after obtaining, as their map shows, the complete contour lines of the irregular topography of the city.

Third. That the lowest reservoir should be located at Brilliant Hill; the second, or middle reservoir, at Hiland Avenue Hill, and the third, or highest reservoir, at Herron's Hill.

Fourth. That all the water for the city should be pumped from the river into the Brilliant Hill reservoir, through two lines of 36-inch force mains, each 2,325 feet in length, one from each of the two pumping engines; the extreme lift at this pumping station being 228 feet. The reservoir to have two compartments, to contain about 50,000,000 gallons, with a surface of eight (8) acres, and depth of twenty (20) feet.

The Brilliant Hill reservoir was to supply all the lower plane of the city, through a 36-inch main. The daily quantity assumed to be supplied from this low service reservoir, was 16,000,000 gallons over an area of five and one-sixth square miles.

Fifth. That the Hiland avenue reservoir, elevated at 128 feet above the Brilliant Hill reservoir, was to supply that portion of the city above the plane of 120 feet and below 250 feet, called the "middle level." The

*The city of Philadelphia now uses 37,000,000 gallons daily—1872.

water to be pumped through one 24-inch main from the Brilliant Hill reservoir, into the Hiland avenue reservoir. The flow line of the Hiland avenue reservoir being 128 feet above the Brilliant Hill reservoir, and 356 feet above low water at Negley's Run Water-works. This reservoir to be built in two compartments, to contain, when full, 104,000,000 gallons; the area of the water surface being seventeen and two-third acres, with a depth of twenty (20) feet. The daily quantity assumed to be supplied from this middle-service reservoir, was 3,500,000 gallons, over an area of eight and six-tenth square miles.

Sixth. That the Herron's Hill, or high-service reservoir, be 194 feet above the Hiland avenue reservoir, or 550 feet above low water at Negley's Run Water-works, with but one compartment; to contain 10,000,000 gallons, having a water surface of two acres, and a depth of twenty feet. The pumping main for this to be 4,900 feet long, and twelve inches in diameter. The quantity of water required to be supplied within ten years from this high-service reservoir, was assumed to be 500,000 gallons per twenty-four hours, over an area of $7\frac{6}{10}$ square miles. The total assumed for the three reservoirs, for the entire city, was 20,000,000 daily (not including Allegheny or Birmingham, &c.), covering an area of $20\frac{8}{10}$ square miles.

Seventh. That, in the first instance, there might be two pumping engines, each capable of throwing 12,000,000 gallons, or together, 24,000,000 gallons into the Brilliant Hill reservoir from the river; and two smaller engines to pump from Brilliant Hill reservoir to Hiland avenue reservoir. It was proposed to have a water-pressure engine to pump to the Herron's Hill, or high-service reservoir, from a point at the junction of Neville street and Ellsworth avenue. It was then understood that the Water Committee proposed to lay the whole length of Penn avenue with a twenty-inch main, which would serve as a distributing main, and also as a connecting main, between the middle level district and the low service district.* The large quantity of water (over 100,000,000 gallons), which the middle level, or Hiland avenue reservoir, will contain, will thus always be at command on the low-service distribution, in case of any temporary stoppage or disabling of the pumping station.

Eighth. That the proposed method of constructing the reservoirs was with earth embankments built four feet higher than the water, twenty feet wide at the top, with outside slopes $1\frac{3}{4}$ to 1, and inside slopes $1\frac{1}{2}$ to 1. The bottom of the reservoir and the inner slopes to be lined with clay puddle, the bottom to be covered with concrete, five inches thick. The inner slopes to have a coating of broken stone, six inches thick, and upon this to be laid a wall of masonry, one foot thick, with hydraulic cement mortar.

* This twenty-inch main was laid.

Ninth. That the estimated cost of the works, on the plan recommended, including about fourteen miles of pipe (chiefly twenty to thirty-six inch diameter), was $2,039,498, exclusive of the brick conduit above Negley's run, which they had indicated as contingent.

This comprises the gist of the plans devised and recommended by Messrs. Chesbrough and Lane, as set forth in their report, and adopted by the Board of Examiners in March, 1871. The *Board*, at that time, also recommended the addition of a small reservoir on Craft's Hill.

Having familiarized myself with these adopted plans, the next step was to determine the primary points, which the Finance Committee, without any special detailed instructions, desired me to investigate. The matters to be investigated appeared to be:

First. The safety and propriety of the location of the new Water-works near Negley's run, and the adequacy of the present foundation, the sufficiency of which had been questioned, and their cost, &c.

Second. The plan of the pumping engines now being built by contract for the river works, and their condition, their sufficiency, cost of building, and running, &c.; together with the particular manner of raising the water from the river to the reservoirs, and the size and number of force mains to be laid, their cost, &c.

Third. The reservoirs at Brilliant Hill, Hiland avenue, and Herron's Hill. Their location, plan, present condition, cost, and future service.

Fourth. The pipes. The contract, and its present state of advancement; the manufacture, inspection, testing, delivery, and acceptance; and the manner and cost of laying, &c.

Measurements have been made by my assistants, acting under my immediate direction and supervision, of such portions as admitted of measurement, embracing all the work at the three reservoirs.

The results of these measurements, which will appear in their proper place, combined with my personal observations, added to a great deal of information cheerfully given by the heads of the different departments, and their assistants, constitute the basis of this report. It is due to the committee of Councils, as well as myself, to say, that the subject is somewhat more complicated than I had supposed when entering upon the duty assigned to me, involving more or less uncertainty; which uncertainty can only be completely removed by the final action of the ultimate authority in the premises.

LOCATION, ADEQUACY, SAFETY, &c., OF THE PRESENT FOUNDATIONS.

FOUNDATIONS OF ENGINE-HOUSE.

The contract was made in April, 1873, with Mr. John Douglass, for excavating the pit and laying the foundations and walls of the engine-house and boilers; the work to be commenced on or before the 25th of April, to be completed on or before the 1st of October, 1873.

On the 23d of September, 1873, the pit having then been but partially excavated, and the work not advancing as rapidly as the Board of Water Commissioners deemed necessary, the contract was declared forfeited, and the management of the work was placed in the hands of Mr. Lowry, the Mechanical Engineer, to be carried on by day's work; and it has ever since that date been so carried on.

At the date of September 23d, the work done by the contractor, according to the measurements made by Mr. Wm. G. Roe, under the directions of Mr. Lowry, was as follows:

Excavation for foundation	3,359.9	cubic	yards.
" on side hill	1,613.5	"	"
" on top	1,095.9	"	"
Total	6,069.3	"	"

The amount that has been paid to Mr. Douglass, as I am informed, partly upon an appraisement, covering work at Clinton quarry, and Shade's quarry, is $23,981.47.

I have not felt called upon to institute any examination into the merits of the contractor's case.

The excavation of the pit, the pumping, the making of the coffer dam, and maintaining it against the river floods, and the quarrying, dressing, delivering, and laying of the stone, have since been done by day's work.

About sixteen hundred perches, (twenty-five cubic feet each), have been laid in the foundations, chiefly in double course of paving, each course 2½ feet deep. About one-fourth of this is in the foundation piers, four in number, which are to support the heavy pumps. These piers are founded 5½ feet below the level of the residue of the walls; the lowest part of the foundations, at the bottom of the piers, being 19 feet 3 inches below the level of low water of the river.

The total expenditure by the city since taking the work out of the hands of the contractor, on the 23d of September, to January 1st, 1874, is	$ 81,424 96
Amount paid to contractor	6,153 92
By award	17,827 55
Total	$105,406 43

The above sum of $81,424.96 includes cost of boarding houses, tools, sidings, steam pump, cement, freight, fuel, rip-rapping, and cost at Shade's quarry, Coll's quarry and Clinton quarry, &c., as well as the excavation of the pit, and pumping, and masonry.

There are some features in connection with these foundations which may not perhaps be generally understood.

Their adequacy being questioned, of course, one of the first duties was to ascertain what kind of a natural foundation had been found, and what method had been adopted in building upon it the masonry, on which the integrity of the future structure, and the perfect working of the pumping machinery must depend. A failure, it was justly considered, from any cause, in the foundations, might entail terrible disaster to the works, and irreparable injury to the city.

The foundation stones of the masonry do not rest upon rock; although the pit, under the four piers, was excavated to the depth of 19 feet 3 inches below low water of the river at that point, through material of tolerably homogeneous character, consisting of a mixture of shaly or flattened gravel and earth.

The foundation stones of the piers, it is said, are of good size, laid directly on the bottom of the pit, in hydraulic cement mortar. Two courses of heavy stone paving, each 2½ feet thick, are laid over the residue of the pit; the bottom of the four piers being 5½ feet lower than the bottom of said paving; the top of the piers, which will support the pumps, stand at the height of 12 feet above the lowest part of the excavated pits. These four foundation walls extend across the pit, each 14 feet wide, 30 feet long, and 12 feet in depth.

The main walls, as planned, will be built upon, and extend 43 feet above the stone paving, making the total height of the foundation masonry of the engines 55 feet, measured from the lowest part of the pit.

The stones used in construction, so far as they can now be seen in the work, and those delivered on the ground, are large, well shaped, and of good quality of durable sandstone. There are some large, good shaped stone delivered, and laid, of a different material, which would not stand exposure to the frost, but which, when laid and covered from the frost, either by water or earth, will be permanent. I heard no question as to the strength of the stone. The strength of the stone, for the purpose designed, is ample.

Some of the stones, that the masons were laying in the bottom at the time of my first visit, were set on their edge, instead of being laid upon their natural beds ; but I understand these to be chiefly *paving*, and not for the support of a great weight of material and machinery. For paving, such a method of laying is deemed allowable, although it might be quite objectionable in regular masonry designed to resist a heavy verticle crushing force.

Several efforts were made, at different times, to have the water pumped out of the foundation pit, in order to afford a better opportunity for a more thorough examination, but without success. The river rose several times, and interfered, and upon the last trial, recently, the pipes burst. The foundation is referred to more particularly in another part of my report.

LOCATION OF THE WATER WORKS.

So far as the location is concerned, provided it had been previously decided to put the works above and not far from Negley's run, I might have recommended a point five or six hundred feet nearer to the run ; partly on account of shortening the length of the force mains, and thus reducing materially that heavy item of cost. The works are placed directly opposite an ancient hill-slip ; although the main body of this slip has apparently stood so long in its present position, that, probably, after the completion of the foundation walls and engine-house, they would not be moved by any future action of the slip.

The only danger, if any, is during the progress of the works, while the foot-hill is partially cut away by the excavation of the pit, and before the masonry is built up to resist, by its weight, the pressure, in case of any tendency to slip at the foot. I refer to it, not for the purpose of exciting any anxiety on this point, but simply to present the facts.

A reduction in the length of the force mains on two lines of 50-inch pipe, 1,200 feet long, in case 50-inch pipes are to be used, would have made a saving of about $80,000 in first cost,* on the two lines of force mains of same length, 1,200 feet, 36 inches diameter, as originally proposed by Messrs. Chesbrough and Lane, the saving would have been about $35,000 in first cost.

In connection with this matter of location—at this particular spot, it seems to have been largely determined by the availability, in point of cost,

*It should be recollected that these are the heavy pipes, receiving the greatest pressure ; namely, the full head of the reservoir.

&c., of the *site;* valuable oil works having possession of the water front just below, and between the present site and Negley's run.

It may be remarked upon this point of the *location* of the pumping works: that, although the water could have been taken from the river at some (indefinite) point above Negley's run, yet a location for the pumping works, and also for the reservoirs, was practicable farther down the river, requiring only the extension of the brick conduit.

How far the work already done, at the site chosen, should affect any future action, may be a matter for ultimate consideration.

Second. As to the excavation of the pit and the starting of the foundations.

The pit having been excavated to the depth of 13 feet 9 inches, and under the piers to 19 feet 3 inches below low water at that place, it was for the engineer in charge, if it were left to him, to say, whether it was low enough, in view of the masonry plans; and also to say, what should be done in securing the foundations. There were three elements to be considered: the risk of extraordinary pressure from the hill, in case it should slip at the foot; the risk of scour from the action of the river, in floods; and the risk of irregular settling of the walls, in case the material on which they were to be built was soft, or of irregular hardness. I consider the risk to the foundations from scour of the river to be nothing, at this point, and there does not appear to have been any great risk from the slipping of the hill.

The fact that there is no danger of a scour at the foundation from the river, to the depth at which the masonry is founded, shows that the pit is deep enough, so far as any scouring action of the river can affect it.

The main question remains; whether the bottom of the pit is low enough, and sufficiently hard and homogeneous to build the masonry upon without any artificial security, either in piling, or of timber and plank. I have no hesitation in saying that, so far as I have been able to judge, from examining the material taken out, and from partial sounding of the bottom, and from the statements of the engineer, Mr. Lowry, and of his superintendent of masonry, Mr. Hinchcliffe, as to the character of the excavation, I would have advised, either some piling, or a timber and plank foundation, as an additional safeguard; mainly for the purpose of preventing any chance of injury from irregular settling of the walls, by distributing the weight equably, upon such timber foundation, over the harder and softer material. Being always under water, the timber foundations would have been as permament as the stone resting on it; it would also aid in making the bottom water-tight.

While it is entirely proper for me to say what I might have recommended under the circumstances, as I now understand them, it does not follow, and it should not be inferred, that the foundations, as built, may not be good and sufficient. I cannot, in strictness, claim that any of my own examinations have shown evidences of great risk of irregular settling of the present masonry; and this is the only risk of consequence to which it would seem to be exposed; unless the hill should move, at the foot, and displace the foundations before the heavy walls should be entirely laid up. It is proper to state also, that even if the walls now rested on a timber foundation, this latter circumstance, of itself, would not prevent the hill from slipping and pressing the masonry, although it would distribute the strain better.

It is important to bear in mind, that it is impossible, now, owing to the masonry built, to make a very thorough examination of the character of the entire bottom of the pit. Any soundings or excavations that are made now, can only be around the outside of the foundation walls as laid, and not *under them.* It will be readily seen that my own position is, therefore, somewhat peculiar. I am called upon to decide as to the safety, in my judgment, of the foundation, as laid, of this important structure.

The fact that its safety has been seriously doubted by some, might or might not be important. It should not operate upon me, if I can clearly satisfy my own mind and the minds of others of its stability.

It is possible, I think, to do away with the risk of any hurtful, irregular settling of the walls, if there is now a risk of any, by bringing to bear experience obtained in founding a cut-stone lock *entirely on quick-sand*, on the Erie Extension Canal, near Greenville; which treacherous material had previously baffled the contractors at two sites, near to each other. The plan was very simple; it was to drive squared timber piles, close to each other, entirely around the outside of the timber and plank foundation; thus forming a tight box, and preventing the escape or movement of the quicksand. Twenty-five years afterward I saw that lock, still standing, perfect, without a crack in the walls.

I mention this as a precedent for what may now be suggested; namely, the driving of such piles all around the outside of the foundation walls as they are now built, forming, as nearly as may be, a box. If the material proves to be so hard that iron-shod piles will not drive far, so much the better. It might even be unnecessary to drive them on the hill side of the masonry at all.

The driving of these piles would settle the question in my mind as to the sufficiency of the foundation.

Even if the Water Committee should deem it unnecessary to apply such additional test or security, I could scarcely be expected, under the circumstances, to take the responsibility of expressing the opinion that the foundation is absolutely unsafe; neither could I take the responsibility of guaranteeing its safety. The cost of such piling may be three to four thousand dollars.

The only other adequate means that anyone would now have of ascertaining exactly the character of the foundation under the walls, would be by taking them up. There are about 1,600 perches laid. It might cost about eight thousand dollars or more, in all, and two months' time to take up and relay the stone; whereas the box-piling need not necessarily delay the work, or only in a very trifling degree. If, however, on taking up the masonry, it should then be deemed advisable to introduce timber and plank foundations under the walls, that would add several thousand dollars more, and cause more delay.

It is important to have the work so built that, at small expense for pumping, the water can be kept out of the pumping pits, for purposes of repairs. In times of high water in the river, at which times, possibly, access to the bottom of the pit might be desirable, the head of water seeking to force itself up through the bottom masonry at such times, may be 33 feet or more, or about one ton upward pressure per square foot. This pressure may come immediately under the upper course of the stone paving, which is 2½ feet thick, said to be laid with wedge-shaped joints, to prevent the stones from being separately forced up. In regard to this, and if there should remain any doubt as to the adequacy of the present arrangement of this upper course of stone paving, the close sheet-piling, as suggested, all around the outside of the masonry, would help to remedy the leakage from the river to such an extent as to make the leakage from the river a matter of less importance.

While, therefore, it need not be claimed that the present arrangement of the paving is inadequate for the perfect support of the engines and pumps, it is certain that the tight sheet-piling all around the masonry may cut off a large portion of the leakage from the river, that might otherwise force itself through and press under the paving, which, if it did not disturb the masonry, might, at times, cause considerable extra pumping.

Incidently, there may arise some question as to the size and proper first cost of the proposed engine-house that may be really necessary, depending upon the general plan that may be finally adopted; whether two pairs of very heavy engines, as planned by Mr. Lowry, or one pair of heavy engines and a lighter one, &c.

Not only the engine-house, but the size, cost and arrangement of the force mains, should depend upon the size of engines to be worked, and upon the height to which the water is to be raised. Therefore, until the main points are settled, it is unnecessary, in this place, to discuss the detail plans.

PLAN OF PUMPING ENGINES, FORCE MAINS, &c.

Upon inquiring of Mr. Kennedy, Chief Engineer of the reservoirs, as to the method of supplying and drawing water from the two reservoirs, namely: Brilliant Hill and Hiland avenue reservoirs, which are only about one thousand feet apart, he informed me that it was not yet precisely determined, and that the force mains from the engine-house at the river to the reservoirs were not under his jurisdiction, although he had, by authority, changed the dimensions of the influent pipe in the masonry from thirty-six (36) inches to fifty (50) inches, which he understood to correspond to the size of the force mains adopted by Mr. Lowry, the Mechanical Engineer, who had charge of the engines, &c.

On further inquiry, Mr. Lowry informed me that each of the two pairs of engines had been planned of sufficient power to raise all the water, at one lift, from the river to the Hiland Avenue reservoir, 356 feet vertical height, through about 3,500 feet length of force main, 50 inches in interior diameter. In answer to my inquiries respecting the mode adopted for supplying the lower or Brilliant Hill reservoir, which is 228 feet vertical height above the river, he informed me that it was yet undecided, or held in abeyance; that there were some elements of uncertainty surrounding the question.

Mr. Lowry stated that the plan which he preferred, under the circumstances which had been fixed, was to pump all the water directly to the Hiland avenue, or middle reservoir; and that he had calculated the engines accordingly; each engine being capable, according to his calculations, of throwing 40,000,000 gallons per twenty-four hours, 356 feet high; but that, if he had had the arranging of the reservoirs originally, he would have preferred having only two lifts, of about 250 feet each; but that the Hiland avenue reservoir being established, at the elevation of 356 feet, he had advocated the plan of pumping directly to it, in preference to pumping into the Brilliant Hill reservoir and afterward pumping from that into the Hiland avenue reservoir.

Meanwhile, it appears that, although the engines were thus planned, and contracted for, and although the influent masonry in the Hiland avenue reservoir was built around the 50-inch pipe and thus adapted to such direct pumping from the river, the work at the Brilliant Hill reservoir has gone on just as if the original plan, recommended by Messrs. Chesbrough and Lane and the original Board of Examiners, had not been changed or modified.

Mr. Lowry suggested, or rather indicated, to me, in answer to my inquiry, that the Brilliant Hill reservoir could be supplied by a side pipe branching from the said 50-inch force main, or that it might be dispensed with altogether.

So that it now becomes a question for consideration; what is the most advisable course to pursue? Whether,

First. To carry out the plan originally adopted by the Water Commissioners; namely, to pump from the river into Brilliant Hill reservoir, and thence into Hiland avenue reservoir, or,

Second. To pump directly from the river into the Hiland avenue reservoir, with side pipe into the Brilliant Hill reservoir? Or,

Third. To dispense with the Brilliant Hill reservoir, and pump entirely into the Hiland avenue reservoir?

Before considering either of these three methods, it is, however, important to note the present condition of things.

WORK DONE ON ENGINES.

The two pairs of large pumping engines, planned by Mr. Lowry, have been under contract, the first pair since August 19th, 1872, and the second pair since September 1st, 1873, and they are now daily progressing; one being about half done, and the other about one-fourth finished. The contract price for these two engines is, I learn, $423,000 and $375,000, respectively; for the two, $798,000. No provision or no contract has yet been made for a pumping engine to pump from Brilliant Hill reservoir to Hiland avenue reservoir.

Only sixteen (16) sections (of 12 feet lengths), of the 50-inch pipe, for the force main, making 192 feet in length, have yet been manufactured. This size of pipe is not specified in the pipe contract with Wm. Smith, the largest therein specified being 36 inches.

WORK DONE ON RESERVOIRS.

The Brilliant Hill reservoir is about four-tenths done; and according to the contract prices and estimate of the Chief Engineer, it will cost about $230,000 in all, when finished; and it will take about $130,000 yet to complete it.

If it be now attempted to carry out the first plan of pumping into the Brilliant Hill reservoir, and thence into the Hiland avenue reservoir, it is met with the fact that the four large engines now in the course of construction, are very much larger, very much more powerful, and very much more costly than would be necessary to pump only to the height of 228 feet, since they are planned to pump 356 feet high. The two pairs of engines are not only planned large enough and powerful enough to pump to the height of 356 feet, but to pump the immense quantity of 80,000,000 gallons per twenty-four hours, to that height. Of course, then, they are vastly more capacious than the engines to which the Engineers of the Water Commissioners referred, and upon which they estimated the cost in their report of March, 1871, which were set down at $150,000 each, or $300,000 for the two engines. Adding $70,000 for the two pumping engines at Brilliant Hill, made $370,000 for the engines deemed by them necessary to pump 24,000,000 gallons daily to the two reservoirs at Brilliant Hill and Hiland avenue.

Messrs. Chesbrough and Lane, in 1871, estimated the price of pipe castings at $55 per ton of 2,000 lbs.; and the special castings at $65 per ton of 2,000 lbs.; but the contract price for those which have been delivered, and of those now being made and delivered, is, for pipe castings, from $83 to $83.50, and for special castings, $110 per ton of 2,000 lbs.

Now, in case 50-inch mains be adopted in lieu of 36-inch mains, what is to be the price per ton of the 50-inch mains? Until this is determined, there is, of course, an element of uncertainty as to the cost of the proposed force mains between the engine-house at the river and the reservoirs. Allowing that there should be in the two 50-inch mains (the two being say, 7,000 feet long), say 4,000 tons, the difference between $83 and $55 per ton would amount to $112,000. The total cost, for the two mains, at $83 per ton, would be $332,000 for the pipes alone.

No accurate comparison, therefore, is practicable until something is definitely settled as to the weight and the price of these 50-inch mains, and whether single or double.

This rough, approximate estimate of the cost of the pipe alone, at $83 per ton, gives about $47 per foot, lineal. The estimate, at the same price per ton, of the cost of the pipe alone of 36-inch force mains, at $83 per ton, is about $22 per foot, lineal. The cost of laying the 50-inch mains, including excavations, lead for joints, &c., would, of course, be considerable; so that the cost of the 50-inch force main would be more than double the cost per foot, lineal, of the 36-inch force main.

It will depend upon circumstances, therefore, what the cost of the 50-inch mains will be. If 36-inch mains were to be used, perhaps they would have to be furnished under the present contract with Wm. Smith, at $83 per ton.

With pipe at the same price per ton, the cost of the 50-inch mains will be more than double that of 36-inch mains per foot; but if one 50-inch main be substituted for two 36-inch mains, then the difference in the first cost will not be a vital matter, though still in favor of the two 36-inch mains.

If the large engines be employed, the size of the force mains is still an open question. The area of the two 36-inch pipes is a trifle more than the area of one 50-inch pipe. Area of two 36-inch mains, 2,034¾ square inches. Area of one 50-inch main, 1,962½ square inches.

Practically, the quantity of water to be forced through these, respectively, need not be regarded as materially different.

On account of safety and economy, it may be better to force through two 36-inch mains, rather than one 50-inch main.

My inquiries respecting the manner in which the change of plan occurred from that originally proposed by the Water Commissioners, to what now appears to be the plan, have not led to a very clear understanding of the case. I am, therefore, somewhat at a loss to know whether to regard the Brilliant Hill reservoir as a portion of the present plan of supplying a large part of the city with water, or whether to consider it as having been practically abandoned, notwithstanding the continued prosecution of the work. The work is still progressing, and no order has been given for the suspension, or stoppage, yet there does not seem to be any definite provision made for supplying it with water from the Allegheny River Water-works; although, in answer to a question, Mr. Lowry, as already mentioned, intimated that it could be supplied by a side pipe from the large force main designed for the Hiland avenue reservoir; but if I understood him correctly, he seemed to view the Brilliant Hill reservoir as unnecessary; since, as he claimed, it is practicable, by a system of valves in the city pipes, to relieve the pressure on the pipes in the lower part of the city; and he thinks it would be more economical, now, to pump all the water directly to the Hiland avenue reservoir. At the same time, Mr. Lowry stated that, although he was in favor of having only two lifts, instead of three, to Herron's Hill reservoir, from the river, yet if he had had the location to make originally, he would have put the first reservoir at an elevation of about 250 to 280 feet, and not to what it is now in the Hiland avenue reservoir, namely, 356 feet. Still, according to Mr. Lowry's judgment, based on his calculations, he thinks it will be cheaper and better to pump directly to the Hiland avenue reservoir, without first pumping into the Brilliant Hill reservoir, the engines being powerful enough to do it.

From this statement of the condition of affairs, it will be seen, that a very unusual problem is now presented for consideration; containing also some elements of uncertainty.

Here are the elements:

First. Four immense pumping engines are contracted for, and far advanced, and the work upon them is rapidly progressing. Each pair of these engines is deemed by Mr. Lowry capable of elevating 40,000,000 gallons per 24 hours to the Hiland avenue reservoir, or 80,000,000 in all, which is more than four times the quantity at present needed.

Second. The masonry is built around the influent pipes in the Hiland avenue reservoir, and arranged with 50-inch pipe. There are, beside, 16 sections, or about 192 feet in length, of 50-inch pipe manufactured. (This quantity is less than 3 per cent. of the total length that would be required for a double line of 50-inch force mains.)

Third. The Brilliant Hill reservoir is about four-tenths done. Say, in round numbers, $100,000 expended.

Fourth. The effluent or supply pipes from Hiland avenue reservoir, 30 inches in diameter, are already laid along Hiland avenue to East Liberty, a distance of 7,705 feet, (nearly a mile and a half.)

Fifth. The engine foundations are planned to suit these heavy engines, and about 1,600 perches of masonry have been laid in the foundations. This may be utilized.

Sixth. No work has been done along the proposed route of the force mains, between the engine-house and either reservoir.

Seventh. Meanwhile the 36-inch main, as planned by Messrs. Chesbrough and Lane, is being laid along Butler street.

The problem is, to decide what, under all the circumstances, is the best for the interest of the city to do.

The city cannot get back to the original status of two years ago, and select what might, upon the most careful investigation, appear to be the best general plan, and then carry it out; because one part of the works is progressing in view of one plan, and another part of the works is progressing in view of another plan; each having a separate engineer.

The Brilliant Hill reservoir, it seems, was originally planned to be the first or lower reservoir, into which, with two engines at the river of power sufficient to pump together 24,000,000 gallons daily, all the water for the three reservoirs was to be first pumped. This method would obviously need engines of much less power than if they should be required to pump all the water at one operation 128 feet higher. It would require about five-eighths of the power; but the four engines, of great power, are now provided for by contract, and they are capable, according to the calculations of Mr. Lowry, of supplying, even to the higher or Hiland avenue reservoir, over *four times* the amount now needed by the city, being sufficiently powerful to supply a population of a million with the high average of 80 gallons each day. Of course, then, these engines are very much more powerful than is necessary for the present population, or for double of the present population, or than will probably be necessary during the present century. Ordinarily, a population of 500,000, using 60 gallons per head per day, would consume 30,000,000 gallons daily, and a population of 250,000, 15,000,000 gallons daily. A present arrangement, for the daily supply of 30,000,000 gallons, would, therefore, seem to be sufficient for many years; if proper provision should be made for increasing the power, when needed, by simply adding more engines and additional force mains, at some future period.

For convenience of reference, I will introduce, in this place, some calculations of the probable cost to the city of Pittsburgh, upon five different schemes, made out in view of the peculiar circumstances just described; which may afford a better understanding of the case.

They are all based on the lowest cost of steam power water-works, selected from the records of a number of different cities.

First. As proposed by Messrs. Chesbrough and Lane; pumping to Brilliant Hill reservoir, and thence to Hiland avenue reservoir.

Second. As proposed by Mr. Lowry; all the water to be pumped into Hiland avenue reservoir, Brilliant Hill reservoir to be abandoned.

Third. Abandoning one pair Lowry engines; pumping with remaining pair into Brilliant Hill reservoir, and putting up an engine at Brilliant Hill to pump into Hiland avenue reservoir, assuming that $50,000 can be saved in foundations and engine-house by abandoning one pair of engines.

Fourth. Abandoning one pair Lowry engines; abandoning Brilliant Hill reservoir, and pumping all the water into Hiland avenue reservoir.

Fifth. Completing both Lowry engines, and both reservoirs, and pumping 16,000,000 gallons daily into Brilliant Hill reservoir, and 4,000,000 gallons daily into Hiland avenue reservoir direct.

MEMORANDA

OF

Estimated Cost of Supplying the City of Pittsburgh with Water,

BY FIVE DIFFERENT SCHEMES.

The cost of pumping has been assumed at six cents per million gallons, raised one foot, (which is about the lowest cost on record), for pumping from the river; and seven cents per million gallons, raised one foot, when pumping from Brilliant Hill to Hiland avenue reservoir.

One-fifth of the total supply to be required on the upper and middle levels, say 4,000,000 out of the 20,000,000 gallons.

SCHEME I.

AS PROPOSED BY MESSRS. CHESBROUGH AND LANE.

ASSUMED COST OF WORKS.

Engine-house and pump-well at river........$	150,000 00
Two pumping engines, capacity twenty-four millions........	300,000 00
Two 36-inch force mains........	120,000 00
Engine-house at Brilliant Hill........	35,000 00
Engines at Brilliant Hill........	70,000 00
Twenty-four-inch force main........	14,000 00
Brilliant Hill reservoir........	230,000 00
Hiland avenue reservoir........	320,000 00
	$1,239,000 00

Annual Cost of Supplying twenty million gallons daily, of which four millions being raised to Hiland Avenue Reservoir:

Interest on cost of engine foundations, force mains, &c., at 7 per cent........	$ 22,330 00
Interest and depreciation on cost of engines, at 10 per cent........	37,000 00
Cost of pumping twenty million gallons daily 228 feet, 6c. per million gallons, one foot........	99,864 00
Cost of pumping four million gallons daily 128 feet, 7c. per million gallons, one foot........	13,082 00
Annual cost of pumping twenty millions daily........	$172,276 00
Interest on cost of reservoirs, at 7 per cent........	38,500 00
Annual cost of supplying twenty million gallons daily........	$210,776 00

Cost per day, $577.47 ; cost per million gallons, $28.86. Annual cost of supplying thirty million gallons daily, including interest and depreciation on cost of additional engines and force mains, ($150,000, at 10 per cent., $15,000 ; and $100,000, at 7 per cent., $7,000.) Annual cost of supplying thirty million gallons daily, $289,189. Cost per day, $792.47. Cost per million gallons, $26.41.

SCHEME II.

AS PROPOSED BY MR. LOWRY.

All the Water to be Pumped into Hiland Avenue Reservoir. Brilliant Hill Reservoir to be abandoned.

ASSUMED COST OF WORKS.

Engine-house and foundations, &c., say	$ 250,000 00
Two double engines, capacity eighty-two millions	800,000 00
Two sets boilers	50,000 00
One force main, fifty inches	200,000 00
Hiland avenue reservoir	320,000 00
Loss by abandoning Brilliant Hill reservoir.†	100,000 00
	$1,720,000 00

† This item uncertain.

Annual Cost of Supplying twenty million gallons daily, all being Pumped to Hiland Avenue Reservoir:

Interest on cost of engine foundations, force mains, &c., at 7 per cent	$ 31,500 00
Interest and depreciation on cost of engines and boilers, at 10 per cent	85,000 00
Cost of pumping twenty million gallons daily 356 feet, 6c. per million gallons, one foot	155,928 00
Annual cost of pumping twenty million gallons daily	$272,428 00
Interest on cost of Hiland avenue reservoir, at 7 per cent	22,400 00
" " loss on Brilliant Hill " " " †	7,000 00
Annual cost of supplying twenty million gallons daily	$301,828 00

† This item uncertain.

Cost per day, $826.92 ; cost per million gallons, $41.34. Annual cost of supplying thirty million gallons daily, $379,792.00. Cost per day, $1,040.52. Cost per million gallons, $34.68.

SCHEME III.

Abandoning one pair Lowry Engines, Pumping with remaining pair into Brilliant Hill Reservoir, and putting up an Engine at Brilliant Hill to Pump into Hiland Avenue Reservoir, assuming $50,000 can be saved on Foundations and Engine-house, by abandoning one pair of Engines.

ASSUMED COST OF WORKS.

Engine-house and foundations at river, say	$ 200,000 00
One pair Lowry engines	423,550 00
One set boilers	25,000 00
Loss by abandoning one pair of engines†	100,000 00
Force main to Brilliant Hill reservoir	120,000 00
Engine-house at Brilliant Hill	35,000 00
Engine at " "	70,000 00
Force main, 24-inch, to Hiland avenue reservoir	14,000 00
Brilliant Hill reservoir	230,000 00
Hiland avenue reservoir	320,000 00
	$1,537,550 00

† This item uncertain.

Annual Cost of Supplying twenty million gallons daily—four million at Hiland Avenue:

Interest on cost of engine-house, force main, loss on second pair of engines, at 7 per cent	$ 31,850 00
Interest and depreciation on cost of engines and boilers, at 10 per cent.	51,855 00
Cost of pumping twenty million gallons daily 228 feet, at 6c. per million gallons, one foot	99,864 00
Cost of pumping four million gallons daily 128 feet, at 7c. per million gallons, one foot	13,081 00
Cost of pumping twenty million gallons daily to appropriate height	$196,650 00
Interest on cost of reservoirs, at 7 per cent	38,500 00
Annual cost of supplying twenty million gallons daily	$235,150 00

Cost per day, $646.93. Cost per million gallons, $32.34. Annual cost of supplying thirty million gallons daily, $292,122.00. Cost per day, $800.03. Cost per million gallons, $26.67.

SCHEME IV.

Abandoning one Pair Lowry Engines; abandoning Brilliant Hill Reservoir, and Pumping all the Water into Hiland Avenue Reservoir.

ASSUMED COST OF WORKS.

Engine-house and foundations	$ 200,000 00
One pair Lowry engines	423,550 00
One set boilers	25,000 00
Loss on abandoned engine†	100,000 00
One force main (fifty inches) to Hiland avenue reservoir	200,000 00
Hiland avenue reservoir	320,000 00
Loss on Brilliant Hill reservoir	100,000 00
	$1,368,550 00

† This item uncertain.

Annual Cost of Supplying twenty million gallons daily, Pumped to Hiland Avenue Reservoir:

Interest on cost of engine-house, force main and abandoned engine, at 7 per cent	$ 35,000 00
Interest and depreciation on engine and boilers, at 10 per cent	44,855 00
Annual cost of pumping twenty million gallons daily 356 feet, at 6c. per million gallons, one foot	155,928 00
Annual cost of pumping twenty million gallons daily	$ 235,783 00
Interest on cost of Hiland avenue reservoir, at 7 per cent	22,400 00
Loss on Brilliant Hill reservoir, at 7 per cent†	7,000 00
Annual cost of supplying twenty million gallons daily	$ 265,183 00

† This item uncertain.

Cost per day, $726.53. Cost per million gallons, $36.32. Annual cost of supplying thirty million gallons daily, $343,147. Cost per day, $940.13. Cost per million gallons, $31.33.

SCHEME V.

Completing both Engines and both Reservoirs, and Pumping 16,000,000 gallons daily into Brilliant Hill Reservoir, and 4,000,000 gallons daily into Hiland Avenue Reservoir direct.

ASSUMED COST OF WORKS.

Engines and foundations at river	$ 250,000 00
Two pairs Lowry engines, capacity eighty-two millions	800,000 00
Two sets boilers	50,000 00
Force main to Hiland avenue reservoir	200,000 00
Force main to Brilliant Hill reservoir	120,000 00
Cost of Brilliant Hill reservoir	230,000 00
Cost of Hiland avenue reservoir	320,000 00
	$1,970,000 00

Annual cost of Supplying twenty million gallons daily; four millions being raised to Hiland Avenue Reservoir direct from river:

Interest on cost of engine-house, force main, &c., at 7 per cent	$ 39,900 00
Interest and depreciation on cost of engines and boilers, at 10 per cent	85,000 00
Cost of pumping sixteen million gallons daily 228 feet, at 6c. per million gallons, one foot	79,891 00
Cost of pumping four million gallons daily 356 feet, at 6c. per million gallons, one foot	31,185 00
	$235,976 00
Interest on cost of reservoirs, at 7 per cent	38,500 00
Annual cost of supplying twenty million gallons daily	$274,476 00

Cost per day, $751.99. Cost per million gallons, $37.60. Annual cost of supplying thirty million gallons daily, $330,014. Cost per day, $904.15. Cost per million gallons, $30.14.

SUMMARY OF RESULTS.

Cost of supplying *twenty million* gallons per day, at appropriate levels:

Number of Scheme	I.	II.	III.	IV.	V.
Cost per day	$577 47	$826 92	$646 93	$726 53	$751 99
Cost per million gallons	28 86	41 34	32 34	36 32	37 60

Cost of supplying *thirty million* gallons per day, at appropriate levels:

Number of Scheme	I.	II.	III.	IV.	V.
Cost per day	$792 47	$1,040 52	$800 03	$940 13	$904 15
Cost per million gallons	26 41	34 68	26 67	31 33	30 14

Scheme I, as originally proposed by Messrs. Chesbrough and Lane, is the cheapest in first cost, and *in working*, so long as the needed quantity is under 30,000,000 gallons daily. When 30,000,000 gallons are needed, then the cost by Scheme III is nearly the same as by Scheme I. Scheme III is "abandoning one pair of Lowry engines, pumping with remaining pair into Brilliant Hill reservoir, and putting up an engine at Brilliant Hill reservoir, to pump into Hiland avenue reservoir."

The quantities of water required at first, in the three different levels of the city, as originally planned by Messrs. Chesbrough and Lane, were approximately estimated as follows:

DAILY SUPPLY.

	Gallons.
High level, from Herron's Hill	500,000
Middle level, from Hiland avenue reservoir	3,500,000
Lower level, from Brilliant Hill reservoir	16,000,000
Aggregate	20,000,000

(At present about 15,000,000 gallons in all are supplied.)

If it be arranged to pump all the water directly from the river to the Hiland avenue reservoir, it is obvious that about four-fifths of the total supply would be pumped 128 feet higher than necessary; and that it would make an extraordinary pressure in the pipes upon a very large portion of the city service, which the pipes certainly cannot stand, unless, as indicated by Mr. Lowry, special arrangements be made, with peculiar valves, to cut off the extra pressure. The pressure now comes from a reservoir 162 feet above the river, at the old Water-works; whereas, if admitted from the Hiland avenue reservoir, which is 356 feet above the river, opposite Negley's run, the pressure would be from a head about 366 feet higher than the river at the old Water-works, or 204 feet greater head than that now on the pipes; † being 126 per cent. more pressure.

If, however, it be arranged by means of a side pipe from the 50-inch force main, already described, to supply the Brilliant Hill reservoir, and to draw the 16,000,000 gallons of water therefrom, the above difficulty of the extra pressure upon the low-service pipes would be avoided; but in that case, it may be asked, what need of a 50-inch main, where a 36-inch main, at much less cost, would be ample? And what need of such large engines, when much smaller, and much cheaper, engines would answer?

Again, if it be concluded to dispense with the Brilliant Hill reservoir, and to force all the water to the Hiland avenue reservoir, and then, by means of the peculiar special valves mentioned, to relieve the lower portion of the city service pipes from the extra pressure, what need of such large engines, with 50-inch mains, when smaller engines, with 36-inch mains, would deliver the required supply at less cost?

Not that the smaller engines, with two 36-inch mains, would deliver as much as the larger engines, with two 50-inch mains, but that much smaller and cheaper engines would deliver all that is likely to be required for many years.

Allowing that the four large engines, now under contract, will each throw 20,000,000 gallons, or 80,000,000 gallons for the two, daily, to the height of 356 feet, it is certain that no such quantity as 80,000,000, or 40,000,000, or even 30,000,000 is needed at present.

The city should not, of course, confine its views wholly to the present needs of Pittsburgh; in a comprehensive study of the subject, it is but reasonable to consider the possible entire consumption of the city proper, Allegheny, Manchester, South Pittsburgh, Birmingham, &c., as it may be ten or fifteen years hence. Putting it for the present supply for all these, at 24,000,000 gallons per day, ample present provision would seem to have been made by adopting engines of sufficient capacity to throw each 12,000,000 gallons, with room in the building for the erection of a third engine; the combined service of the three being 36,000,000 gallons daily.

It has been estimated that, on the completion of the larger engines, the entire consumption might, *possibly*, amount to 20,000,000 gallons per day in the city of Pittsburgh. This would require one pair of the large

† The city of Pittsburgh now has a very good system; the whole supply is pumped to the lower reservoir, 162 feet high, whence the bulk of the city's supply is drawn; while about 3,000,000 gallons are pumped 236 feet higher, to the second reservoir, for the supply of parts of the city above 162 feet and below 398 feet. Now, suppose it should be proposed to pump the whole 14,000,000 gallons daily, to this higher reservoir, and dispense with the lower reservoir, who would advocate the change? Yet the principle involved is the same as the case under consideration.

engines contracted for, to pump twelve out of twenty-four hours, or just half the time. Mr. Lowry, the Mechanical Engineer in charge, has intimated that only one of the large 50-inch force mains should be laid now. One pair of the large engines would, of course, remain idle all the time (excepting in case of accident to the running engines, when that pair could be set to work); but it should be noted, that in case of an accident to the proposed single 50-inch force main, *the entire supply of the city reservoirs would be cut off till it could be repaired.* This is a practical and, I think, a vital objection to any plan depending *wholly* upon a *single force main* for the supply of such a city as Pittsburgh.

Mr. Lowry's estimate of the daily cost of running one of the large engines, is about as follows (which is, I apprehend, too low):

First cost of buildings and engines, &c., with one force main......$1,175,000 00

Interest per day, at 7 per cent....................................	$225 00
Working expense per day..................	188 46
	$413 46

This is exclusive of the cost of repairs, and wear and tear, and ultimate renewal of engines, which, if allowed, would add to the cost.

The cost calculated in the usual manner, as shown in Scheme II, is $826.92 per day.

If the work to be done amounts to but 20,000,000 gallons per day, this would represent the cost of 1,000,000 gallons, raised 356 feet, at $41.34, or for 1,000,000 gallons raised one foot high, $11\frac{6}{10}$ cents.

This is about the average cost of raising water, per foot of height, at most of the water-works in the United States, excepting in the cities of Pittsburgh, Allegheny and Wheeling, where it is only about six cents.

Mr. Lowry, however, makes his calculations refer to 40,000,000 gallons per day, which would, of course, greatly reduce the cost per million gallons thrown to the reservoirs; but it would still be not materially less than six cents per 1,000,000 gallons raised one foot high.

His estimate is, also, that it would cost about one-fourth less for fuel, if four-fifths of the 40,000,000, or only 32,000,000 gallons be raised to the Brilliant Hill reservoir, and the other 8,000,000 to the Hiland avenue reservoir; but these quantities will not be required for many years, even for over half a million persons.

These calculations tend to confirm the impression that, in view of all the circumstances, the engines contracted for are planned unnecessarily large for the duty they will be called upon to perform; and, since it must be presumed that their weight and cost are proportioned to the duty demanded in the contract, they must be unnecessarily costly, both in first cost, and in the future daily expenses of running. That is, smaller and cheaper engines would do the work needed, at less cost.

It may be granted that, with a very early requirement of 40,000,000 gallons per day, and, within a reasonable future thereafter, of 80,000,000 gallons per day, engines of this large class might *possibly* have been advisable in the first instance; but these do not appear to have been the requirements that were to be considered.

When a community is called upon to invest $800,000, or more, in the building of two pairs of steam engines, to do the present work that experienced engineers had shown could be done by two engines costing $300,000 and two costing $70,000, in all $370,000, or less than half, there should be a sufficient reason assigned for the change.

The difference in first cost is, counting everything, over a half million of dollars; the annual interest of $500,000, at 7 per cent., is $35,000; while it is very clear that the large, heavy, powerful engines cannot be run and perform the comparatively moderate duty of 20,000,000 or 24,000,000 gallons per day, as economically as the lighter and cheaper engines properly proportioned to that duty. True, at some distant future period, when such large engines might be called upon to work up to or near their capacity, they might possibly do the work then more economically than it could be done by additional lighter engines; but, meanwhile, how stands the investment of the money of the citizens?

Suppose that the city had put up the $370,000 engines, and made a sinking fund of $500,000 to be put at 7 per cent. compound interest, and only to be used hereafter when needed in the construction of large engines. Suppose it possible that, fifteen years hence, the city should need such large engines, how would their fund stand? The sum compounded in hand would be over $1,300,000; sufficient to put up *two pairs* of such large engines, and still leaving the original fund of $500,000 in hand; but *two pairs* could not possibly be needed so soon; for one pair would *add* 40,000,000 gallons per day capacity to the works, according to its calculated performance.

Although it seems to be too late for the city to avail itself of a clear choice in the matter of engines, it is only by some such presentation that the case can be fairly understood.

The city is committed to the contract for the two pairs of large engines; the work upon them is going on, and possibly the real problem may now be, how can this work be made most available, so as to perform such service as the city really requires, in the most economical manner.

Shall the works be arranged with, or without, the Brilliant Hill reservoir? Shall they be arranged with one 50-inch force main, or with two

36-inch force mains, or with two 50-inch force mains? Shall both pairs of the large engines, or only one pair of these large engines, be set up? It is uncertain whether it is a part of my present duty to attempt, at this time, a complete answer to these questions. The foregoing statement of facts, with the views which have naturally accompanied them, may possibly be all that the Committee would expect from me, at this time, on this branch of my investigations; especially as it is unknown what arrangements could be made with contractors, in case any should be desired.

It may be regarded as exceedingly unfortunate for the city, that two distinct systems, or parts of a system, which do not match each other, should be in progress at the same time. This, certainly, should be soon remedied; the decision respecting the particular manner in which it is to be remedied, constitutes, in my judgment, by far the most important point in connection with the new Water-works.

In the concluding part of this report, this may be referred to, with such recommendations as may seem, under all the circumstances, to be reasonable. There has been no intention in any of these remarks to pass an opinion adverse to the merits *of the plan of engines designed by Mr. Lowry.* That is a matter by itself. If properly proportioned, in all their parts, to the work required of them, I think they should do good service; but I cannot recommend the adoption of a system of pumping all the water to the height of 356 feet, when there is no necessity for it, and when the objections to it are so manifest.

RESPECTING THE MODE OF ARRANGING THE PUMPING WORKS, FORCE MAINS, &c.

Until the general plan upon which the system of the pumping works and the reservoirs is to be constructed shall be finally settled, it would seem unnecessary to devote much time to the study of such details as may or may not be dispensed with, obviously depending largely upon such decision. How far present plans may be regarded as unalterably determined, or how far such as admit of modification may be modified by future action of the proper authorities, are at present unknown to me.

There are, however, some principal features regarding these matters, to which it may be proper to refer. In my original preliminary report of 1868, based on partial surveys and examinations of the question of water supply, I stated my impression, that, from the examinations then made, it appeared that a system of two lifts, with two reservoirs, one at the height of about 250 feet, and the other about 500 feet above the river, would probably meet the wants of the city, looking also to the supply of Allegheny, Manchester, Birmingham, South Pittsburgh, &c.; although I then distinctly pointed out the necessity of much more extensive and careful surveys before determining that important point.

The later and much more elaborate surveys and examinations, made by Messrs. Chesbrough and Lane, show more clearly how the city is arranged by nature, and by the improvements, more or less adapted to the natural capabilities of the ground, into several different levels, in connection with water supply; and the lowest or Brilliant Hill reservoir, 228 feet high, as proposed by them, is quite high enough to command all the old portions of the city, including the manufactories, the reservoirs in Allegheny and Birmingham, and the old lower reservoir in the city. It would have been disadvantageous to have established the lowest reservoir materially higher, since there was to be another, at a greater elevation, to supply the middle level, and another, still higher, for the most elevated portions. Even now, the Brilliant Hill reservoir is about 66 feet higher than the old city reservoir, but in view of the additional length of mains through which the water must flow, this presents no material objection. The old city reservoir can be kept in service, fed from the Brilliant Hill reservoir, for aiding in supplying all such parts of the old city as can be most conveniently supplied therefrom, the main connections can be so arranged that, where desired, the supply can also be direct from Brilliant Hill reservoir.

The Hiland avenue reservoir was established at the elevation of 356 feet, as best adapted for the supply of a large area of the city designated as the middle level, requiring at present, and for many years to come, only a small proportion of the total quantity to be forced up. This commands East Liberty, and a total area of $8\frac{6}{10}$ square miles. It was assumed that, for the present, about one-fifth only of the supply would be required on the middle and high levels.

The Herron Hill reservoir was established at the elevation of 550 feet, or 194 feet higher than the Hiland avenue reservoir, to supply the most elevated portions of the city, at present very sparsely settled, and which will not be densely populated for many years. It would have been a wasteful plan to have discarded the Hiland avenue reservoir, and pumped all the water for the middle level to the height of the highest reservoir, when not more than about one-eighth of the quantity thrown into the middle reservoir would be needed in the highest reservoir.

The present system of the three reservoirs, at the three different elevations, therefore, seems well adapted to the circumstances of the city, both now, and in the future. The upper old city reservoir, if it be deemed desirable, can also be connected with the Herron Hill reservoir, and made available to aid, hereafter, in supplying such portions of the city as it already supplies. The difference of head between these two reservoirs, is about 150 feet. Such an arrangement may prove advantageous for those streets which are too high for the Hiland avenue reservoir, and not high enough to require the full head from the highest reservoir.

In the arrangement of the elevations of the three new reservoirs, the entire city will have a good system. In regard to their respective capacities for storing water, they were, in each case, made as large as the topography of the ground permitted at those elevations, and, in emergencies, the water stored in the higher reservoirs can be made available through the lower reservoirs also. Of course, had the topography of the ground allowed, the engineers would have planned the larger reservoir for the level requiring the larger supply; but reservoirs must necessarily be adapted to the topography. †

Assuming that the reservoirs may be retained where they are now located, (in whatever particular shape they may be finished,) the same general arrangement of the pumping machinery at the river will be required.

Owing to the deep, flat valley of Negley's run, between the present location of the pumping works and the reservoirs, together with the position of the Allegheny Valley Railroad and the Brilliant Oil Works, the situation is not favorable for the location and laying of the force mains up the hill. Negley's run must be crossed underneath, or by an embankment over a culvert, or on a bridge, on the property of the Brilliant Oil Works; and then the pipes must be laid on the sloping side hill, rising from the mouth of the run about 200 feet vertical, in a distance of about 1,500 feet.

It has been suggested that the force mains might be carried down the Allegheny Valley Railroad, (or along the shore below it,) to a small ravine which enters the river eight hundred feet below Negley's run, and directly up that run to the reservoirs. It would still involve the crossing of Negley's run, with the force mains at or very near its mouth.

Unfortunately for this plan, it adds about 950 feet in length to the mains, and adds it upon that portion of the route having the heaviest pressure,

† MEMORANDUMS OF PHILADELPHIA RESERVOIRS.

There are seven reservoirs in Philadelphia, of capacity varying from 2,083,875 gallons, the smallest, to 40,000,000 gallons, the largest. The aggregate capacity of the seven reservoirs is 153,000,000 gallons; while the capacity of the Brilliant Hill and Hiland avenue reservoirs is 174,000,000 gallons, or 21,000,000 gallons more than the seven Philadelphia reservoirs.

Including Herron Hill reservoir, the aggregate capacity of the three Pittsburgh reservoirs is 31,000,000 gallons more than that of the seven in Philadelphia.

The quantity of water pumped per day into the seven reservoirs in Philadelphia, in 1872 was 37,583,594 gallons for a population, as stated by Mr. Graff, the Chief Engineer, of 800,000; an average of 47 gallons per head.

As the height of pumping in Philadelphia is less than in Pittsburgh, this shows that one pair of the proposed large engines would have enough power to do all the pumping for more than is now used in Philadelphia.

where the pipe must be more than double the thickness required at the top. This ravine would, however, be much more advantageous for laying and securing the force mains, and for permanent security, than along the side hill of Negley's run valley.

It has also been suggested, in view of the situation, that the pumping works might be put at or near this small ravine, instead of where they are; thus materially shortening the costly force-pump mains. Such change of location would require the construction of a brick conduit to convey the pure water of the river from some point above Negley's run to the pumping works, in order to escape contamination by the drainage from Negley's run. The Water-works building could probably be founded on rock at this point, but there is very little room beyond what might artificially be made in the river outside of the Allegheny Valley Railroad, for the necessary buildings, for the engines and boilers, and for the storage of coal. Such change, from the present site, would probably cause a delay of three months, to place the work in an equal state of forwardness with that at the present site.

The saving in the cost of force mains that might be effected by such change of site, will depend greatly on the size of mains that may be adopted, and the pressure that is to be upon them; whether 50-inch, or 36-inch; whether single, or double; or whether for 356 feet, or for 228 feet head of water.

If a double line of 50-inch mains were to be called for, the saving might amount to nearly $200,000; and half of that for a single main. If a double line of 36-inch mains were to be called for, the saving might amount to nearly $100,000, and half of that for a single main. That is, compared with carrying the pipes down to said ravine; but the saving would not be quite so great compared with carrying them directly up the valley of Negley's run, as just described, on account of the Negley's run route being 950 feet shorter. I have, however, understood that the route from the present location of the works down to said ravine (at Callahan's house), and up the ravine, has been regarded with most favor.

REFERRING TO THE LARGE PUMPING ENGINES.

The engines as designed, and now being built, are so far advanced that no *radical* change of the general plan could be made without great expense, if such were desirable; concerning the advisability of which I may not be called upon to decide. Some changes might be made, if they should be deemed advisable.

Although the engines are calculated to be, and may be, strong enough to sustain the unusual pressure, and with safety to force the water to the elevation of 356 feet, to the Hiland avenue reservoir, it appears to be an undesirable arrangement; since it involves the necessity of very much more costly force-mains, to resist the pressure and the shocks of so large a body of water *of that great height*, and extraordinarily heavy and costly fittings of the gates and valves; upon all of which the liability to derangement and accident will be greatly more than it would be if the head were only 228 feet, which itself is above the usual height for engines of such great capacity as these.

There are some practical difficulties attending the working of very heavy-coupled engines, *designed to work singly at times*, having but one heavy fly-wheel. If the fly-wheel is properly proportioned for the two engines, when coupled, it will be too heavy for the engine working singly; and it does not follow that if the two engines coupled do the work handsomely and smoothly, forcing the water through a 50-inch main 356 feet high, that one engine working alone, with the same fly-wheel, will also do the work as smoothly and well, through the same 50-inch main.

(A single engine, of the first pair, according to the calculations of the designer, will pump 20,000,000 gallons per 24 hours, which is considerably more than the present daily consumption, even in summer.)

With only one fly-wheel for two engines, if the wheel, or the crank, or the crank-axle should give out, both engines would be disabled and thrown out of service. If the engines could now be arranged so that they would work separately, with separate fly-wheels, with 36-inch force mains, instead of 50-inch force mains, *one* pair of engines would be more than enough to do all the pumping required during the next twenty years, if they can pump 40,000,000 gallons to the Brilliant Hill reservoir, 228 feet high; and as they have been calculated to throw that quantity to the height of 356 feet, there should be no doubt of their sufficiency for the lower elevation.

It is unnecessary here to enter into a critical investigation of all the details of these large engines. Whatever defects there may be, if any, in the arrangement of the parts, there is no doubt that they are immense, powerful machines, and, so far as I can judge from a cursory examination of the plans, and of many of the most important portions already manufactured, they possess great strength. The castings, wrought-iron work, and brasses, so far as constructed in Mr. Hartupee's shop, appear to be admirably executed.

Thinking most favorably of the workmanship, I confine my study, for the present, chiefly to the manner of utilizing the engines, so that the work to be done, and the machines for doing it, may be, as much as possible, in harmony. The second pair of double engines are *obviously not now needed;* nor would they be needed till the demand for water should greatly exceed 40,000,000 gallons per day, which quantity, at 60 gallons per inhabitant, gives a population of 666,000, or about three times the present population of Pittsburgh, Allegheny, Birmingham, &c., embracing all the region that can be supplied by the new Water-works, at some future day. It may be proper to mention here, that the city of Allegheny is at this time putting up a very powerful engine, planned by Mr. Lowry, capable of throwing 15,000,000 gallons daily, into the Allegheny reservoir, through a 36-inch force main, to the height of 203 feet. Two engines, each of about that capacity, would have been sufficient to throw 30,000,000 gallons daily, into the Brilliant Hill reservoir, which would have answered for ten to fifteen years. The erection of these new works in Allegheny, on such an extensive scale, does not favor the plan referred to a few years ago, of supplying Allegheny from the Pittsburgh reservoir, by means of a pipe laid across the river. This is an additional reason for not expending too large a sum in the beginning, in the construction of the pumping works at Negley's run.

In stating the difficulties that may be encountered in devising the important details required to meet and resist the strains to which they would be subjected from the head of 356 feet, through a force main of 50 inches diameter, it is not necessary to refer to them merely on the ground of their novelty or rarity in hydraulic operations; they may be considered wholly on the ground that there is no necessity for such costly arrangement; that, on the contrary, the arrangement of two lifts, one of 228 feet and one of 128 feet, in view of the circumstances of the case, is far superior, safer, and more economical in first cost, and in the daily running.

RESERVOIRS AT BRILLIANT HILL, HILAND AVENUE AND HERRON'S HILL.

I found contractors at work upon all of these reservoirs, and a large amount of work already done. The Chief Engineer, Mr. Kennedy, furnished me with copies of the contracts and specifications, and with the original maps and levels made by Mr. Lane, Consulting Engineer, containing the data upon which the proposals and contracts were based.

Mr. Kennedy and his assistants, at the reservoirs and in his office, gave me all such information in their possession as would enable me to understand the past operations and present condition of the reservoirs. The re-measurements and calculations were made by my own assistants, under my instructions, independently of the engineers in charge. The general situation of the work is as follows:

BRILLIANT HILL RESERVOIR.

In the Brilliant Hill reservoir no masonry is yet laid, although a large quantity of stone has been delivered on and near the ground. The excavation is about half done. The total amount of work estimated for this reservoir is about four-tenths done. The topography was quite irregular, portions being in heavy cutting and portions in deep filling.

HILAND AVENUE RESERVOIR.

In the Hiland avenue reservoir the masonry and pipes of the influent chamber are about completed. A small amount of the slope wall has been laid on the face of the embankment, and a considerable quantity of stone has been delivered at and near the reservoir. The excavation is about two-thirds done. The total amount of work proposed for this reservoir is about one-third done.

HERRON HILL RESERVOIR.

In the Herron Hill reservoir the masonry of the chambers has been laid. The excavation is about three-fourths done. This excavation is largely rock, which, unfortunately for all parties, is troublesome to remove, but of no value for building purposes; so that most of it has to be wasted. It consists of argillaceous material, and, when exposed to the atmosphere, it soon crumbles into a slaty clay.

RESERVOIRS—MEASUREMENTS.

The measurements of the three reservoirs were made very carefully, and the calculations have been fully checked. Much more care was used than is usual or necessary in making current monthly estimates on public work, because the occasion seemed to require it. It could not, of course, be expected that they should *exactly* correspond. Indeed, they could not do so, for the work was in daily progress all the time. It would be out of the question for engineers in charge of work in progress to devote the time needed for my measurements. For convenient reference and proper explanation of the figures, the quantities resulting from my measurements are set opposite the quantities estimated by the engineers in charge of the respective reservoirs and returned, to the close of 1873; to which time, say January 1st, 1874, my measurements conform as nearly as the circumstances would pemit.

BRILLIANT HILL RESERVOIR.

In charge of Robert McClelland, Resident Engineer.

Kind of Material.		Engineer's Estimates Return'd. Cubic Yards.	Re-measurements. Cubic Yards.	Difference. Cubic Yards.
Earth Excavation..................	1	129,770	127,141	2,629
Solid Rock............................	2	957	1,200	243
Soiling................................	3	6,430	5,780	1,152
Broken Stone.........................	4	9,025	9,025	None.
Stone Paving.........................	5	3,168	3,168	None.
Rubble Masonry......................	6	4,926	2,807	2,119

Some of these differences are only apparent.

It may be said that, practically, the current monthly estimates made by the engineers on this reservoir approached as nearly to our measurements as could be expected; but some explanatory remarks are deemed necessary.

First. In regard to these measurements of excavation: The area covered is so large that a difference of three inches in assumed depth would amount to about twenty-five hundred cubic yards, and whatever difference of this kind there might be in taking current monthly estimates would be corrected in the final measurements.*

Second. My measurements of rock show rather more rock taken out. It could not all be accurately ascertained; but sufficiently so to show that it had been somewhat underestimated to the contractors.

Three. SOILING. According to the letter of the contract the item of soiling would appear to have been considerably overestimated; but, on inquiry, I learned that the Board of Water Commissioners, on the 26th of August, 1873, had instructed the "engineer to allow the contractor on the reservoirs soiling and puddling stipulated in their respective proposals, without making any deductions on account of excavating;" and also that the Chief Engineer had directed that the soiling taken from the reservoirs should be put upon the outside of the banks to the depth of eighteen

*The engineers claim that the contractors are entitled to pay for 2,200 cubic yards of material for puddling, which has been put upon the banks, at excavation price. This is not included in my measurement.

(18) instead of six (6) inches. My calculations still show a difference of 1,152 cubic yards on this item, which appears to be an over-estimate on current estimates.

ITEMS Four, Five and Six. BROKEN STONE, PAVING AND RUBBLE MASONRY. There is no rubble masonry yet laid; the stone for broken stone, paving and rubble is delivered chiefly in Haight's run, and it lies in such a mass over the ground that accurate measurement of it is impracticable. We were obliged to approximate to it as nearly as the circumstances will permit, making in all about 15,000 cubic yards. The current monthly estimates of the engineers aggregate 17,119 cubic yards. The difference is 2,119 cubic yards. The estimating engineer did not put the full contract prices—putting the broken stone item $1.50, when the contract price is $2.00, the stone paving at $5.00 when the contract price, when completed, is $9.00, and the rubble masonry at $4.00 when the contract price, when completed, is $7.00.

The original estimate of the quantity of rubble masonry required, was 1,587 cubic yards, and I therefore cannot see the propriety of putting down so large a quantity in the current estimates as 4,926 cubic yards to that item. It appears to me that there should have been less to that item, and correspondingly more to the two other items of broken stone and paving. It is, however, certain that the final estimate would correct it; and I am not able to say, positively, whether a change in it now would add to or reduce the contractor's current estimate. If it were changed to the broken stone item, it would decrease it. If it were changed to the paving item, it would increase it. As a whole, in these three items, the estimate shows $44,569 on 17,119 cubic yards, at $2.60 per cubic yard, average. Since the stone was quarried, some distance up the Allegheny Valley Railroad, and brought down in cars, the total price, compared with the contract prices, on an average, does not appear out of the way.

I do not think the case is one that would warrant me in saying that it has been over estimated.

The following is the aggregate of all the current monthly estimates, up to January 1, 1874.

BRILLIANT HILL RESERVOIR.

129,770	cubic yards of earth,	@ $ 33	$42,824 10
957	" " rock,	" 50	478 50
6,430	" " soiling,	" 50	3,215 00
9,025	" " broken stone,	" 1.50	13,537 50
3,168	" " stone paving,	" 5.00	15,840 00
4,926	" " rubble masonry,	" 4.00	19,704 00
			$95,599 10

Brought forward...$95,599 10

Railroad track, incline-plane and fixtures, engine and house, locomotive and cars. I understand that these were ordered by the Commissioners, but done by the contractors, and for which the engineer has allowed, in current estimates.................................... 15,000 00

Total of work estimated to January 1, 1874.................................$110,599 10

Of which there has been paid.. 99,539 19

Ten per cent. reserved to January 1, 1874.................................$ 11,059 91

The amount reserved by the contract is 20 per cent., but by order of the Commissioners, in consideration of the limited profit on the portion of work being done, it was reduced to 10 per cent., as above shown. Such action is not unusual under similar circumstances.

HILAND AVENUE RESERVOIR.

In Charge of Henry F. Green, Resident Engineer.

Kind of Material.		Engineer's Estimates Returned. Cubic Yards.	Re-measurements. Cubic Yards.	Difference. Cubic Yards.
Earth Excavation..................	1	185,906	174,062	11,844
Solid Rock..........................	2	14,544	12,519	2,025
Soiling................................	3	14,000	9,940	4,060
Puddle................................	4	5,043	4,955	88
Broken Stone......................	5	1,279	1,429	150
Concrete.............................	6	78	78	None.
Stone Paving.......................	7	1,709	1,528	181
Rubble Masonry..................	8	592	592	None.
Cut Stone...........................	9	115.20	115.20	None.

The Brilliant Hill and Hiland avenue reservoirs are in the hands of the same contractors, so that, although the large quantity of stone delivered in Haight's run is now returned in the Brilliant Hill estimates, any portion of it can be made applicable, if desired, in the Hiland avenue reservoir. This should be borne in mind, in case any material changes should be made in the arrangement of these two reservoirs.

There are only three items in the Hiland avenue reservoir to which it is deemed proper to call attention; the differences in the other six items being trifling, and only such as might easily occur between the current monthly estimates, if made by two different persons. The total difference between my measurements and the engineer's estimate of excavation, is 13,869 cubic yards, or about seven per cent. of the quantity estimated.

First. Earth Excavation. My measurements show 11,844 cubic yards less than the aggregate of the monthly returns of the engineers to January 1, 1874. This is about six per cent. less than his monthly estimates. I have carefully examined all the detail notes of the assistant, from which the monthly estimates were made up, from October, 1872, to December, 1873. The engineers in charge claim that the contractors are entitled to pay for 7,900 cubic yards of material for puddling, which they state has been put upon the banks, at excavation price. This is not included in my measurements.

In July and August, 1873, there are memorandums showing 4,000 cubic yards, called rock, to be classed as soiling in the end. The price of rock and soiling is the same; each fifty cents per cubic yard. This may have led to duplication of that number of cubic yards, which should be corrected by a final estimate, if not before, in a current estimate. This would leave 7,844 cubic yards of earth excavation to be accounted for; a difference of four inches in depth on this reservoir, would amount to that much.

Second. The Solid Rock. My measurements show 2,025 cubic yards less than is estimated of solid rock excavation. The contractor's rock price is but fifty cents per cubic yard, while his earth price is thirty cents, the difference being twenty cents; so that the difference in value would only amount to $405. It is proper to state that this item of rock taken out, cannot now be accurately measured. We could only make an approximation. I cannot assert that the engineer's estimate was too much, and I do not think it worth while to pursue the investigation of the difference any farther. The contractors, in the end, would be entitled to be paid for it, at not less than thirty cents per cubic yard, in any event.

Third. Soiling. My measurement of this item, in the nature of the case, consists chiefly of an examination of the memorandums of the engineers who had the work executed.

Taking the strict letter of the contract, and allowing only six inches on the slopes, there would be only one-third of the quantity I have stated; but I have no reason to doubt that the contractors, by direction of the engineer, put on the larger quantity. The difference of 4,060 cubic yards I have no means of accounting for, except from notes of the Assistant Engineer, showing that he calculated the total soiling removed from the entire reservoir, at 21,000 cubic yards, and considered 7,000 cubic yards reserved, as his notes show, which would leave 14,000 cubic yards, the amount he has estimated. The soil removed could not well be accurately measured at any time; but my impression, from all that can be gathered, is that there is an over-estimate of the soiling of about 4,000 cubic yards, and I think it occurred in the October estimate, of 1873, when 12,000 cubic yards were added to the previous estimate of 2,000 cubic yards, making the amount 14,000 cubic yards, when it should, probably, have been 10,000 cubic yards. The engineer thinks he was justified in estimating this item of soiling as it appears in the monthly estimates, by authority from the Commissioners.

HERRON'S HILL RESERVOIR.

In charge of Gorham P. Low, Jr., Resident Engineer.

Kind of Material.		Engineer's Estimate Returned. Cubic Yards.	Re-measurements. Cubic Yards.	Difference. Cubic Yards.
Earth Excavation.............	1	11,116	....	....
Loose Rock.....................	2	33,562	....	....
Total Excavation..............	3	44,678	44,193	485
Puddle..........................	4	396	396	....
Concrete........................	5	14.3	14.3	....
Rubble Masonry...............	6	295.4	295.4	....
Cut Stone.......................	7	8.28	8.28	....

This reservoir is very much smaller than the others, covering only two acres of water surface. The result of my re-measurements shows that the current monthly estimates have been carefully and correctly made. The difference in the total excavation, of 44,678 cubic yards, being but 485 cubic yards, or a trifle over one per cent. For the classification of the material taken out, I could only judge from that which remains to be excavated, and the general appearance. It is obvious that but a small proportion of the whole was earth excavation. About one-fourth has been called earth, the residue "loose rock."

The price for earth is 41 cents, and for loose rock 60 cents per cubic yard. There is considerable troublesome harder rock, that is worth much more than 60 cents per cubic yard to remove.*

I understand that the old coal-mine, under this reservoir, is about 175 feet below sub-grade. From the shape of this hill, and the character of the material encountered in the excavation, I do not anticipate danger to the reservoir from any caving in of the mine.

Owing to the scarcity of good material in the immediate vicinity, it will require care to ensure a water-tight reservoir, but I am satisfied that it can be rendered perfectly safe, by thorough puddling with good material.

* I have understood that recently the Water Committee raised the price for this hard material to $2.10 per cubic yard.

RESERVOIRS—TOTAL QUANTITIES, &c.

Approximate Estimate, Showing total Quantities of Work on Reservoirs, total Estimated Cost, Amounts Paid to January 1, 1874, and the Amount Required to Complete them, as Planned, including Contingencies, Engineering, &c.

BRILLIANT HILL RESERVOIR.

Kind of Work.	Price.	Quantities of Work in Cubic Yards.	Estimated Cost, at Contract Prices.
Earth Excavation	$ 33	195,374	$ 64,473 00
Solid Rock	50	26,200	13,100 00
Soiling	50	4,859	2,430 00
Sodding, square yards	20	26,362	5,272 00
Puddle	50	24,063	12,032 00
Broken Stone	2 00	5,040	10,080 00
Concrete	6 00	3,896	23,376 00
Stone Paving	9 00	8,260	74,340 00
Rubble Masonry	7 00	1,587	11,109 00
Cut Stone Masonry	15 00	403	6,045 00
Coping	20 00	120	2,400 00
Lineal feet 36-inch pipe	2 00	935	1,870 00
" " 12-inch "	1 00	695	695 00
" " 50-inch "	2 50	190	475 00
			$ 227,697 00
Add 5 per cent. for contingencies, including Engineering and Superintendence			11,384 00
Total			$239,081 00
Deduct amount paid to January 1, 1874			99,539 00
Amount required to complete			$139,542 00

HILAND AVENUE RESERVOIR.

Kind of Work.	Quantities of Work in Cubic Yards.	Price.	Estimated Cost at Contract Prices.
Earth Excavation	240,570	$ 30	$ 72,171 00
Solid Rock	38,704	50	19,352 00
Soiling	5,278	50	2,639 00
Sodding, square yards	28,633	20	5,726 00
Puddle	45,555	50	22,777 00
Broken Stone	7,119	2 00	14,238 00
Concrete	10,837	6 00	65,022 00
Stone Paving	11,765	9 00	105,885 00
Rubble Masonry	1,092	7 00	7,644 00
Cut Stone Masonry	140	15 00	2,100 00
Coping	163	20 00	3,260 00
Bricks in culvert, No.	10,000	15 00	150 00
Lineal feet 30-inch pipe	320	2 00	640 00
Lineal feet 24-inch pipe	160	1 50	240 00
Lineal feet 12-inch pipe	130	1 00	130 00
			$321,974 00
Add 5 per cent. for contingencies, including Engineering and Superintendence			16,098 00
Total			$338,072 00
Deduct amount paid to January 1, 1874			81,866 00
Amount required to complete			$256,206 00

HERRON'S HILL RESERVOIR.

Kind of Work.	Quantities of Work in Cubic Yards.	Price.	Estimated Cost, at Contract Prices.
Earth Excavation	12,000	$ 41	$ 4,920 00
Loose Rock	46,500	60	27,900 00
Soiling	1,900	75	1,425 00
Sodding, square yards	11,275	35	3,946 00
Puddle	7,946	75	5,960 00
Broken Stone	1,431	2 00	2,862 00
Concrete	806	7 00	5,642 00
Paving	2,335	9 00	21,015 00
Rubble Masonry	300	8 00	2,400 00
Cut Stone Masonry	10	15 00	150 00
Dressed Coping	41	20 00	820 00
Lineal feet 12-inch pipe	720	1 50	1,080 00
			$78,120 00
Add 5 per cent. for contingencies, including Engineering and Superintendence			3,906 00
Total			$82,026 00
Deduct amount paid to January 1, 1874			31,190 00
Amount required to complete			$50,836 00

RECAPITULATION—RESERVOIRS—COST.

Name of Reservoir.	Total Estimated Cost at Contractors' Prices.	Amount Paid to January 1, 1874.	Amount Required to Complete.
Brilliant Hill	$239,081 00	$ 99,539 00	$139,542 00
Hiland Avenue..............	338,072 00	81,866 00	256,206 00
Herron's Hill................	82,026 00	31,190 00	*50,836 00
	$659,179 00	$212,595 00	$446,584 00

*This sum of $50,836, estimated amount required to complete Herron's Hill reservoir, does not include any allowance already made, or that may hereafter be made over and above the contract prices. All the reservoir estimates are made out without reference to such allowances, so that any such allowances heretofore made, or that may hereafter be made, will augment the total estimated cost accordingly.

Should it, however, be deemed advisable, some changes can be made that would reduce the total cost, as elsewhere referred to.

LOCATION OF THE RESERVOIRS, &c.

The three reservoirs were located by Messrs. Chesbrough and Lane, engineers, with the approval of the Board of Examiners, in 1871. The general plan of construction, as devised and recommended by them, has been carried out thus far in the prosecution of the work at the reservoirs, excepting some minor changes of dimensions and shape, and in the thickness of the slope walls and concrete, which changes, as I understand, have been approved by Mr. Lane, Consulting Engineer.

The change in the diameter of the influent pipe, as now laid, in the masonry of the Hiland avenue reservoir, from 36 inches to 50 inches diameter, was made, as I learn, at the instance of Mr. Lowry, Mechanical Engineer of the new Water-works, although the work was executed under the direction of Mr. Kennedy.

Proper care seems to have been exercised in preparing the ground under all the reservoir embankments, in order to insure them against leakage, by excavating puddle ditches, and by benches, when necessary, to prevent the tendency of the banks to slide. Care has also been taken to select the best material for the inner slopes and middle of the embankments, putting the inferior material on the back of the banks.

The work, in general, at the reservoirs, appears to have been systematically conducted. I have examined it all carefully, so far as it now admits of examination, and there is nothing to show that it has been slighted by the contractors in any part ; on the contrary, it has every appearance of being thoroughly executed.

The details of the work inside of the reservoirs could have been arranged somewhat more economically ; not that the reservoirs would thereby have been any better, when finished, but to save cost. Thus, instead of the heavy paving on the inner slopes, with large stones, 15 inches thick, laid in cement, there might have been a thinner paving, or slope wall, of small stones, laid without cement, designed merely to prevent the wash of the face of the banks.

It is, however, true, that if the paving laid in cement remains intact, and is not dislocated by any settlement of the embankments, it will prevent the water in the reservoir from leaking through into the banks, but the two feet thickness of puddling, which is also used, should answer that purpose. The heavy stone paving costs $9 per cubic yard, or $3.75 per superficial square yard. Gravel placed back of the paving would be better than broken stone, if it could be obtained. There is no good gravel convenient.

The estimated cost of the paving of the slopes of the three reservoirs, when the contracts were made, was $190,350. The cost in round numbers will be, say $200,000. A large quantity of stone for the paving has been quarried, brought down the Allegheny Valley Railroad, and delivered at or near the works; but only 417 cubic yards have yet been laid in the Hiland avenue reservoir.

The material excavated at the Brilliant Hill and Hiland avenue reservoirs, is a good clayey soil, well adapted to holding water; such portions as were not of good quality for this purpose, have been either put into the back part of the banks, or wasted. At the Herron Hill reservoir, the material is of a different character, being mostly rocky, with occasional seams; not good for making water-tight banks. With careful puddling, however, the bottom and banks can be made water-tight.

DEPTH OF WATER IN RESERVOIRS. (Proposed.)

In regard to the proposed depth of water in these reservoirs, namely, 24 feet at the Brilliant Hill reservoir, and 20 feet in each of the others, I would suggest that they could be arranged at first for a less depth, which, when it is hereafter required, could be increased gradually. It is a safer plan, and a more economical expenditure of means, than to complete every thing about them immediately for such full depth. Of course, at half the designed depth, they will contain rather less than half of their full capacity, owing to the sides having slopes of 1½ to 1; but with good pumping engines, working perfectly, the reservoirs would rarely be drawn down materially, and for a few years would work well partially filled.

SHALL THERE BE THREE OR ONLY TWO RESERVOIRS?

That is, shall the Brilliant Hill reservoir be dispensed with? or shall it be finished and made useful, as originally designed by the engineers who located the three reservoirs?

The most advantageous time for settling this important question was when the plan and the power of the pumping engines were fixed upon and adopted.

The plan and number of the reservoirs, and their systems of force mains and supply mains, should, of course, have been arranged in harmony with the engines which were to supply them with water.

Such appears to have been the design of Messrs. Chesbrough and Lane, the engineers who recommended the three reservoirs. If they had thought it best to recommend a system with only two reservoirs, those reservoirs might have been differently located; they might have located the lower reservoir at some other point better adapted to such other elevation, and they would certainly not have chosen so high a level as 356 feet above the river *for their lower reservoir;* because the requirements of the different portions of the city, lying at different elevations, call for four-fifths of the whole supply to be pumped to a height less than 228 feet, which is 128 feet lower than the Hiland avenue reservoir.

It would seem to be sound engineering to perform as little unnecessary labor, in raising water, as possible. It costs money to lift water, and *it costs in proportion to the lift, for the leading items;* which are: first, the wear and tear of the machine and interest on first cost; and, second, the fuel, manual labor, and repairs. For a small lift, lighter and cheaper engines, with less daily labor, and less fuel. For a high lift, heavier and more costly engines, with more daily labor, and more fuel. Knowing the work required, it is not difficult to adapt engines to that work.

If an engine is properly adapted to throw water into the Hiland avenue reservoir, 356 feet above the river, it is certainly unnecessarily strong and expensive, both in first cost and in its workings, if afterward required to throw the same quantity only 228 feet high, into the Brilliant Hill reservoir. And if it is properly adapted, and only strong enough to throw water 228 feet high, it is not competent to throw the same quantity 356 feet high. There must be waste in the one case, and inadequacy in the other.

Now, as matters are presented for consideration, either of the two pairs of double engines under contract is considered powerful enough to throw 40,000,000 gallons per twenty-four hours to the highest or Hiland avenue reservoir; and yet the present requirements of all that part of the city to be supplied from the Hiland avenue reservoir, is under 4,000,000 gallons per twenty-four hours, or only one-tenth of the capacity assigned to one pair of the large engines. And since that middle level is above the range at which the bulk of the manufactories can be advantageously located, a great many years must elapse before there would be even 10,000,000 gallons required to be supplied from Hiland avenue reservoir; and still, that is but *one-fourth* of the assigned capacity of one pair of these large engines. This is, of course, upon the assumption that the Brilliant Hill reservoir, or some reservoir of about that elevation, is to be used to supply all that part of the city lying below it, including nearly all the manufactories, and including all of the city at present supplied from the old lower reservoir.

It is, however, only a liberal and proper policy for the present generation, while erecting costly Water-works, to look forward and provide in a reasonable manner for the future increasing demand for water, arising from future increase of population; but, since it is easily susceptible of calculation, based on ample experience in numerous cities, the provision for the future should be arranged, accordingly, *with reference to probable needs.*

Selecting a few important cities, the following shows the daily supply of water:

Name of City.	Year.	Daily Average. Gallons.	Population.	Gallons per Head.
St. Louis	1872	15,000,000	310,000	48
Cincinnati	1869	11,559,000	216,000	53
Chicago	1868	16,414,000	290,000	57
Louisville	1872	2,950,000	110,000	27
Brooklyn	1872	26,020,000	450,000	58
Boston	1861	21,000,000	200,000	105
"	1871	16,500,000	260,000	63

The quantities given for St. Louis, Cincinnati, Chicago, Brooklyn and Boston, are the daily average for the *highest months.* In my preliminary report of 1868, I assumed for the future Pittsburgh, when it should have a population of *five hundred thousand*, 30,000,000 gallons as the daily average, or sixty gallons per day per head. Boston is the only one of the above cities which has exceeded that quantity per head; and in Boston they have been economizing the previous waste, and reducing the daily average from 103 gallons per day, in 1861, to sixty-three gallons per day, in 1871.

Brooklyn, with a population of 450,000, shows an average of fifty-eight gallons per head. For a future population of 300,000 in Pittsburgh, at sixty gallons per head, the supply would be 18,000,000 gallons daily.

Messrs. Chesbrough and Lane recommended engines in the first nstance of sufficient power to throw one-third more than this, or 24,000,000 gallons per day.

Studying these and similar statistics, there seems to be hardly warrant for adopting, at this time, engines with sufficient capacity to throw 80,000,000 gallons 356 feet high, or even 40,000,000 gallons; the latter quantity being 270 per cent. more than the quantity now used in Pittsburgh.

The annexed table shows the cost, at a number of places, of pumping 1,000,000 of gallons one foot high, all of them by steam power, excepting one, at Fairmount, Philadelphia, where water power is employed.

COST OF PUMPING WATER.

Name of Place.	Year.	Cost per 1,000,000 Gallons Pumped 1 Foot High.	Lift, Feet.		
Fairmount, Phila......	1869	2 cents.	94	Water	Power.
Schuylkill, Phila.......	1866	13 "	115	Steam	Power.
Charlestown, Mass....	1868	13 "	147	"	"
Cambridge	1869	15 "	110	"	"
Salem	1868	12 "	114	"	"
Louisville................	1869	10 "	144	"	"
Wheeling	1869	6 "	200	"	"
Allegheny................	1869	7 "	203	"	"
Brooklyn..................	1871	13 "	161	"	"
Chicago....................	1865	12 "	125	"	"
Cincinnati	1866	18 "	165	"	"
Detroit.....................	1867	18 "	75	"	"
Cleveland................	1865	18 "	158	"	"
Hartford	1866	16 "	120	"	"
Pittsburgh	1867	6.8 "	162	"	"

From this it will be observed that, with the exception of the Fairmount works, at Philadelphia (water power), Wheeling shows the lowest cost per million gallons, raised one foot high; Pittsburgh and Allegheny being the next lowest, and within one cent, or less, per million, of Wheeling; and that, leaving out these three places, the cost ranged from 10 cents to 18 cents for the same amount of work in the other cities. To the cheapness of the fuel in the three cities named, may be ascribed, in a large degree, the comparatively low cost of the work accomplished.

PRESENT CITY WATER WORKS.

Something on this point of cost has been gathered from the reports of Mr. James M. Atkinson, Superintendent of the Pittsburgh Water-works, and the Assessor, Mr. Chauncey B. Bostwick, for the year 1872:

The quantity of water furnished daily from the lower (old) works, raised 162 feet high, was 12,751,204 gallons. Consumption of coal, daily, 1,108 bushels.

Cost of running (current expenses for the year) was	$48,423 46
Cost of repairs, boilers, extraordinary	18,948 85
Current expenses per day, say	133 00
To raise 12,751,204 gallons 162 feet high	133 00
To raise 1,000,000 gallons 162 feet high	10 43
To raise 1,000,000 gallons one foot high	$6\frac{4}{10}$

Exclusive, however, of any proportion of extraordinary repairs, or salary of Superintendent, or interest on cost of works, or any fund for renewal of works.

The quantity raised daily from the lower (old) reservoir to the upper (old) reservoir, say 236 feet, was 2,912,310 gallons. Consumption of coal, 270 bushels, daily.

Cost of running, (current expenses for the year) was	$14,368 83
Cost of repairs, extraordinary	7,070 24
Current expenses per day	39 37
To raise 2,912,310 gallons 236 feet high	39 37
" 1,000,000 " " "	13 52
" " " one foot high	$5\frac{73}{100}$

The actual *current cost* at the works in Pittsburgh, at the present time, may be set down at a trifle over six cents per million gallons raised one foot high.

At the same rate, (six cents) the current cost of raising 40,000,000 gallons one foot high, would be	$ 2 40
And 40,000,000 gallons 356 feet high	854 40

Supposing the engines to be similarly proportioned to the duty.

At the same rate, the cost of raising 20,000,000 gallons 356 feet high, to Hiland avenue reservoir, would be		$427 20
The cost of raising 20,000,000 gallons 228 feet high, to Brilliant Hill reservoir, would be	$273 60	
Add the cost of raising 4,000,000 gallons 128 feet, from Brilliant Hill to Hiland avenue reservoir	30 72	
	$304 32	

The current daily difference of cost between pumping all the water to Hiland avenue reservoir, 356 feet high, and pumping all first to the Brilliant Hill reservoir, 228 feet high, and thence pumping one-fifth, or 4,000,-

000 gallons, to the Hiland avenue reservoir, at the same rate, is $122.88. Additional cost per day, $122.88.

Difference for one year, $44,851.20. This is independently of interest on the first cost, repairs, and wear and tear of the engines.

If we take the cost of pumping by steam with heavy engines in most of the large cities, where the engines are proportioned nearly to the work they have to perform, it is seen that the cost per million feet raised one foot, is generally double or more of the cost of the Pittsburgh pumping; in some cases, as in Cincinnati, Detroit, and Cleveland, it is *three times;* probably owing, in part, to the higher price of fuel in those cities. Although the Pittsburgh pumping works have been economically conducted, it may be possible, in new works, in the arrangement of the boilers, and in the mode of using the steam, to effect a further reduction of the cost of fuel compared with work accomplished. It is fairly presumable.

The greatest elevation to which water is pumped in any of the cities just quoted, away from Pittsburgh, Allegheny and Wheeling, is 165 feet at Cincinnati, and 285 feet at Burlington, Vermont, (small works pumping only 247,000 gallons per day;) the fuel at Burlington consisting of shavings, costing only $1.60 per day. Yet the cost, there, of raising a million gallons one foot high, is eight cents.

PIPES.

I have examined the method of manufacturing, inspecting, and testing the pipes made by contract, at Mr. William Smith's foundry, in Pittsburgh. So far as I can judge, the pipes appear to have been manufactured of good iron, and with proper care, and the city has had its own inspector to examine and test each pipe. The test is a severe one, being a water pressure of 300 pounds per square inch. A number of pipes, which exhibited no sign of rupture at 280 pounds pressure, burst before the indicator showed a pressure of 300 pounds.

The pipes are all classed and numbered, and the class and number, and date of the year, with the manufacturer's initials, cast on the pipe.

Each pipe is weighed, and a record kept of its class, number and weight, and the weight painted on it. No pipes are received the weight of which is over 3 per cent. below the specified weight for the 12-inch and upward, or more than 4 per cent. below for the 6, 8, and 10-inch pipes; and no excess of weight above the average, beyond the said percentage, is paid for.

The straight pipes are cast in dry sand moulds, in a vertical position. After passing a hammer inspection, they are cleaned, and then thoroughly coated inside and outside with coal pitch varnish, according to Dr. Angus

Smith's process; each casting being previously heated to a temperature of 300 degrees Fahrenheit.

The contract for the manufacture and delivery of the pipes is very carefully drawn, so that all contingencies appear to be provided for to ensure perfect castings.

The contract is dated December 31, 1872, the delivery to commence March 1, 1873, to be completed June 1, 1874. The contract is for the following pipes:

Tons.	Size.	Class.	Prices per ton.
264	36 inch	A	$ 83 00
1,248	36 "	B	83 00
6,134	36 "	C	83 00
445	30 "	A	83 00
436	30 "	B	83 25
319	30 "	C	83 25
130	20 "	B	83 50
873	20 "	C	83 50
689	8 "	A B & C	83 50
520	6 "	A B & C	83 50
300	Special castings...	....	110 00

In all 11,058 tons of regular, and 300 tons of special castings.

The prices are per ton of 2,000 pounds.

At the above prices and quantities the contract would amount to $952,108.75.

Payments to be made monthly, on the certificate of the engineer, ten per cent. to be reserved till the fulfillment of the contract. In the contract and specifications, in the inspection and testing, in the recording of the pipes manufactured, in the record of their delivery on the streets where they were to be laid, and in the record of their laying, all proper and intelligent care seems to have been exercised to protect the interests of the city, and to guard against current over-payments to the contractor at any stage of the work.

The work of excavating trenches and laying the pipes is separate; it has been done under the supervision of the same engineer, under the management of foremen, by day's work.

I passed over all the principal streets where these pipes have been laid, in company with Mr. Harlow, the engineer in the immediate charge of the laying of the pipes, and I have received from him straightforward and intelligent explanations of this part of the work. It was intimated to me, by several persons, that I could only know that pipes of certain size and quality had been laid at any particular place, by digging down to them and examining them. It was obvious that nothing could be learned in that way respecting the quality of the pipes, and I have every reason to feel satisfied that an examination of the records of the Inspector at the manufactory, and in the Engineer's office, of the pipes in their different stages of manufacture, testing, delivery, and laying, convey sufficient reliable information to enable me to judge whether there has been any material error in the estimates, either inadvertently or intentionally. The only material error, or omission, that has come under my notice, is one discovered by the engineer himself. It was a clerical error, by the omission of 47.29 tons of pipes, in the current monthly estimates, but it was against the contractor and not in his favor. The amount was $4,050.40. It was of such a nature that it must surely have been rectified before a final settlement.

The contractor, of course, had a right to complain of such an error. Had I been called upon to make a final estimate of the amount and value of work done by Mr. Smith, I might have devoted much more time to this branch of the investigations; but no such duty was called for, and I have only made such examinations as seemed proper to afford a complete insight into the system; from which I could judge reasonably well, whether a fair or unfair method was used; whether there was system or want of system, and whether the city was justly dealt with.

It is due to all the parties interested to say, that under this contract the system of manufacture, inspection, testing, delivery, and estimating current monthly estimates, is good; and there appears to be no reason to think that it has not been fairly maintained for the rights and interests of both parties to the contract. When a final estimate of the manufacture and delivery of the pipes shall be called for, it will not be difficult to ensure a correct return of the total amount, within a very small fraction of possible discrepancy, and quite possibly with exactness; so that the city need suffer no loss in this branch of her operations. The question has been mooted as to the advisability of entering into such a large contract in the start, when iron was at a very high figure. Perhaps the city might have saved something by making a smaller contract; but it seems to have been contemplated to push all the work through to completion at the earliest possible date. The contractor, certainly, has a price which warrants him in furnishing first-class work. I have seen a large number of the pipes, and so far as appearance goes, I have never seen better looking pipes in any city; and I think that Mr. Smith has employed his best appliances to turn out superior work, and his appliances are admirable.

The laying of the pipe is separate from the contract for their manufacture, and it has been done, as already mentioned, by day's work. The cost thus far, as shown to me by the engineers, seems to compare favorably with the cost, at contract prices, in other cities, more so than I would have assumed.

General experience, everywhere, would lead to the avoidance of day's work in cities as much as possible, although some work can be *better* done in that way. I understand that all the pay rolls for the work of excavating the trenches and laying the pipes, are sworn to by the foreman in the immediate charge of each particular street, and that the engineer of this branch of the work, Mr. Harlow, who has previously had special experience in this duty, keeps such personal supervision of the laying as to guard against any gross fraud, in case any should be attempted. The objection to carrying on public operations by *day's work*, need not rest wholly upon apprehensions of fraud; but chiefly upon the well known fact that laborers, as a rule, do not work so hard for a city, as they do for contractors.

Statement of pipes made under the contract with Wm. Smith, quantity laid, amount of value of estimates, amount paid, and the amount of per centage reserved, to January 1, 1874.

Pipes made.	Pipes laid.
6,863.7 tons of various sizes.	4,133 tons of various sizes.
187.1 " special pipes.	116.5 " special pipes.

Total value, estimated to January 1, 1874	$584,142 34
Total amount paid to " "	525,728 11
Amount reserved	$58,414 23

I examined a number of pipes laid aside in Mr. Smith's pipe yard, on account of being too light, according to the strict letter of the specification, although they stood all the tests, including the pressure of 300 pounds per square inch, and are in all respects perfect pipes. No discretion to vary from the specification has been given to Mr. Dickson, the Inspector, which is proper; so that, although these pipes are as good as the best, they are a few pounds below the prescribed weight.

I would recommend that, at the closing of the pipe contract, authority be vested in some proper, intelligent person, to examine and accept such pipes as have stood all the tests, paying for them at their actual weight, where they are lighter than the specification demands.

I would not advise any change in the specification, or the system of inspection.

COST OF LAYING PIPES IN 1873.

I have obtained, at the office of the engineer in charge, the following data relating to the sizes of the pipes, and the extent and cost of excavating trenches and laying pipes during the year 1873:

Size of Pipe.	Length in Feet.	Cost of Labor, Excavation and Laying.	Cost of Material.	Whole Cost of Laying.	Cost per F't Lineal.
3, 4 & 6-inch.	19,956	$ 5,251 65	$2,256 08	$ 7,507 73	$ 38
8 "	13,589	5,372 99	1,954 99	7,327 98	54
12 "	316	52 62	79 43	132 05	42
15 "	8,379	8,441 62	2,364 84	10,806 46	1 29
20 "	2,828	3,387 59	981 95	4,369 54	1 54
30 "	7,705	12,419 87	5,049 82	17,469 69	2 27
36 "	4,024	7,304 67	3,849 97	11,154 64	2 77
50 "	56	34 16	99 39	133 55	2 39
	56,853	$42,265 17	$16,636 47	$58,901 64	

On the few 50-inch pipes (total length, 56 feet) the cost shows only the material, and running and caulking the joints.

In the excavation of the trenches, there were 7,788 cubic yards of rock, which occurred chiefly on Hiland avenue, where the 30-inch pipe was laid.

The total length of the above laying of pipes, of all sizes, is 10.77 miles; showing an average cost of $5,469 per mile; which is an average of $1.03½ per foot, lineal.

There were $4\frac{35}{100}$ miles of pipes, from 15 inches diameter up to 36 inches diameter; the residue, $6\frac{42}{100}$ miles, being chiefly 6-inch and 8-inch pipes.

Where a city is engaged in laying pipe of various sizes, at irregular intervals, in some places before streets are graded, and the workmen may be required to move frequently from one point to another, it is more difficult to conduct it satisfactorily by contract, though it admits of an arrangement which, on the whole, might be more satisfactory than the system of day's work. In the fittings of the pipes together, running the lead, and caulking the joints, it is, however, essential that experienced experts should be employed, in order to prevent the risk of having leaky junctions.

Taking the average of the several cities of St. Louis, Milwaukee and Lowell, and comparing the cost of laying pipes of different sizes with the cost, thus far, in Pittsburgh, we have the results in the annexed tabular statement:

COMPARATIVE COST OF LAYING PIPE.

Size of Pipe.	Average of the three Cities, Per foot.	Cost in Pittsburgh, Per foot.
† 6 inch.	$ 51	$ 38
8 "	66	54
15 "	1 23	1 41
20 "	1 46	1 54
30 "	2 89	2 27
36 "	3 32	2 77

† In Pittsburgh a small portion consisted of 4-inch and a very small portion of 3-inch. The bulk of the smaller size being 6-inch pipe.

From this it may be judged that the laying of the new pipes in the city of Pittsburgh has, on the whole, cost less per foot than in the cities just named, for similar work. The average cost per foot lineal of the whole $10\frac{77}{100}$ miles laid in Pittsburgh, in 1873, was about $1.03 per foot, or $5,469 per mile.

As a whole, the system of pipe manufacture, inspection, delivery and laying, so far as I can judge, has been judiciously planned and executed, with careful regard to the interests of the city.

This report has extended to a much greater length, and has occupied more time than was anticipated; yet the nature of the circumstances has demanded it. My object has been to convey to the Committee the same impressions made upon myself by the facts elicited. The following suggestions are respectfully presented for the consideration of Councils, or of the Committee having the Water-works matters in their charge.

SUGGESTIONS.

First. That the foundations of the Water-works buildings be secured in such a manner as to remove all just cause for apprehension.

Second. One pair of the large engines may be advantageously utilized, especially if the engines be arranged so that they can be readily changed from double to single working, or single to double; planned to pump the water to the Brilliant Hill reservoir. Then, if an arrangement can be made, satisfactory to the city, the work on the second pair of engines could be stopped (being but little over one-fourth done,) under some amicable agreement with the contractor. The parts could be sold, or retained for future sale, (or use), as might seem best for the city.

Third. The engine-house can be built so as to accommodate one pair of the large engines; with room for another pair of smaller engines; but without at present contracting for the smaller engines.

Fourth. Two force mains to be laid, each 36 inches in diameter, arranged so that each one of the pair of large engines can pump through both, or through either one, as circumstances or accident might render advisable.

Fifth. The 36-inch distributing main, which is being laid along Butler street, can be continued, as designed, from below the Sharpsburg bridge, (about half a mile below), where it is now laid, to the Brilliant Hill reservoir, about one and a half miles above said bridge, in time to meet the completion and use of the works at Negley's run. There is only one place, a few hundred feet in length, about half a mile above the Sharpsburg bridge, where the surface of the hill-slope is slipping; and even there, the rock below, as shown by the cutting of the Allegheny Valley Railroad, is in place, and undisturbed.

All the residue of the route is underlaid with rock, in place, which, as the cuttings of the railroad show, is not inclined to slip. I examined this myself carefully. At the crossing of Haight's run, in case the street should not be first graded at that point, a short culvert and embankment can be put in, at moderate cost, over which the pipe can be carried.

Sixth. All work that admits of being done by contract, can be done at less cost to the city than when done by day's work, if it be let at fair prices; especially such work as quarrying, dressing, cutting, and laying stone masonry of foundations and walls.

Seventh. A pair of small engines could be put up at Brilliant Hill reservoir to pump the required quantity of water thence into the Hiland avenue reservoir. There is ample time.

Eighth. It does not seem to be necessary to finish any of the new reservoirs to their full height, or to arrange them at once for the full depth of water proposed. The city can be well served for many years with the reservoirs, if used to half the proposed depth, namely, with 12 feet in Brilliant Hill, and 10 feet in each of the others, or some other depth that may be deemed most advantageous. In the case of the Hiland avenue reservoir, it may be advisable to complete, at present, only the eastern compartment, which is already excavated nearly to grade.

It will readily occur to the Committee, that there are numerous details which must be entered into when the general plans are finally determined, which cannot be considered in advance.

It is safe to assume that half a million of dollars can be saved in the present expenditure, in connection with the foundations, buildings, engines, boilers, force mains and reservoirs, and still secure ample provision for a full supply of water.

It is due to the citizens of Pittsburgh, as well as to the engineers in charge of the works, to state that I have seen no evidence of an intention to defraud the city. It is equally imperative to state the fact, that the want of harmony, and lack of unity of design in the plans, between the two principal departments of the new Water-works, have placed the affairs in an awkward position.

No harmonious or economical system can be inaugurated until this peculiar condition of things shall be remedied by the proper authority.

Respectfully submitted,

W. MILNOR ROBERTS,
Consulting Engineer.

Pittsburgh, Feb. 19, 1874.