REPORT

ON THE

Water Supply

FOR THE

CITY OF PHILADELPHIA,

MADE BY THE

COMMISSION OF ENGINEERS

APPOINTED BY THE

MAYOR

UNDER THE

ORDINANCE OF COUNCILS,

Approved June 5th, 1875.

PHILADELPHIA:
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APPENDIX.

AN ORDINANCE

To appoint a Commission on Supply of Water for the City of Philadelphia.

SECTION 1. *The Select and Common Councils of the City of Philadelphia do ordain,* That the Mayor be requested to appoint a commission of five scientific and practical engineers, to be selected by him from not less than eight names, which are to be recommended by the Board of Managers of the Franklin Institute, to whom, in connection with the Chief Engineer of the Water Department, shall be referred the entire subject of the present and future water supply of the City of Philadelphia, and to report their views to Councils. Approved June 5th, 1875.

In accordance with the foregoing Ordinance, the following five Civil Engineers were appointed Commissioners by the Hon. William S. Stokley, Mayor of Philadelphia:

W. MILNOR ROBERTS, of New York.
WM. J. MCALPINE, of Albany.
JULIUS W. ADAMS, of Brooklyn.
WM. E. MORRIS, of Philadelphia.
SOLOMON W. ROBERTS, of Philadelphia,

Who, in connection with WM. H. MCFADDEN, Chief Engineer of the Water Department, constitute the Commission.

REPORT.

To Hon. William S. Stokley,

Mayor of Philadelphia.

Sir:—In accordance with the requirements of the Ordinance of Councils, approved June 5th, 1875, we have the honor to submit the following report upon the subject of "the present and future water supply of the City of Philadelphia," respectfully requesting that the same be transmitted to the City Councils.

INTRODUCTORY.

For many years, and to within a recent period, the Schuylkill water has been remarkably pure and wholesome; but it has been impaired by impurities, accompanying the growth of population and the extension of industries.

The contamination of this stream is not alarming, yet it is believed that unless a remedy be applied it will ultimately be rendered unfit for domestic uses.

The principal causes of deterioration are, the sulphuric acid from the coal mines, and the refuse and the sewage from population and from the numerous manufactories which drain into the Fairmount pool.

The history of the Water Works shows what has been done, by gradually increasing the pumping facilities, so as to meet the augmenting demands for water; and the annual reports of the Chief Engineers of the Water Department contain various recommendations for improving the quality of the water supplied. In 1867 a Special Committee of the Park Commissioners made an able report devoted chiefly to the subject of the purity of the water, recommending measures, which, in their opinion, would augment the quantity and improve its quality.

In 1865, Mr. Henry P. M. Birkinbine, then Chief Engineer of the Water Department, made a survey and report, urging the construction of a large impounding reservoir on the Perkiomen, and conduit to supply by gravity. He is entitled to the credit of having been the first to recommend this particular plan.

So far, nothing of consequence has been done to improve the quality of the water, except to construct a sewer on the west side of the river to drain that portion of the city, and to keep the sewage from the Fairmount pool; although the means for furnishing greater quantities of water have kept pace with the rapidly increasing requirements.

The consumption of water has increased in a greater ratio than the population; owing to the great number and extent of the manufactories centered here.

Philadelphia is so happily located, favorable in climate, accessible from the ocean and the interior, that it will become a very populous city, and all that has been accomplished in connection with the water supply, will be exceeded by works of greater magnitude.

The several Chief Engineers of the Water Department have not overlooked or undervalued the importance of the question of a future water supply, as is shown by the suggestions and recommendations in their annual reports. Attention has frequently been called to this subject by public spirited individuals, and by the press.

Appreciating the importance of the duty devolved upon us, and regarding the magnitude of the interests to be affected, we have earnestly sought to obtain a correct knowledge of all the facts bearing upon the subject.

The ordinance under which we were appointed requiring us to report our views upon the "present and future water supply of the City of Philadelphia," opens a wide scope to our investigations, as it assigns no limit, or any intermediate point between the present and an indefinite future. In the absence of more specific instructions, one of our first duties was to determine the meaning of the terms "present" and "future," as expressed in the ordinance.

Without fixing strict lines of demarcation, we have assumed that the "present" applies to all works of pressing necessity, and to such as may be required within the next few years. And that the "future" refers to more extensive and costly works, such as may hereafter be demanded. As it was necessary for calculation and comparison to refer to some definite time, we agreed upon a period of forty years.

The size of the works and the cost of operating them is determined by the quantity of water required, which depends upon the population and the demand for manufacturing and other purposes.

It is customary to include these demands under one rate per head of the population. Under good management an average rate of 60, and a maximum of 80 gallons per day is considered ample.

The future population of the City has been based upon its past increase, and in view of the diminished percentage of growth of cities. It has been assumed for periods of five years, as follows:

YEAR.	1875.	1880.	1885.	1890.	1895.	1900.	1905.	1910.	1915.
Population..	750,000	880,000	1,025,000	1,175 000	1,340,000	1,500,000	1,675,000	1,840,000	2,000,000

Assuming 80 gallons per head as the basis of calculation, in 1875 the maximum daily summer demand is set down at sixty million gallons,* in 1880 at seventy million gallons, and in 1915 at one hundred and sixty million gallons. It has been found, however, that the maximum consumption in the summer of 1875 was but 50 million gallons, as there has been much depression in manufacturing industries, but next year, on account of the Centennial Exhibition, a larger amount than usual will be required.

Pursuant to these general principles, we have carefully studied all of the practicable plans, and made estimates of their cost.

The subject of the "pollution of rivers," regarded as of the greatest importance, has engaged our special attention. A paper devoted to the careful study of this question, has at the request of the commission, been prepared by Col. Julius W. Adams, one of our members, and will be found in the Appendix marked A. It is an able and almost exhaustive treatment of the subject. In the principles stated and the general conclusions arrived at, the commission concurs. In its preparation, Col. Adams had access to the latest deductions of both European and American authors upon the subject, and numerous analyses of the waters of the Schuylkill and Delaware made at former periods, also others made at our instance during the present season, by eminent chemists, whose reports will be found in the Appendix.

We quote in this place, a few paragraphs from the paper of Colonel Adams, containing views which we specially commend to the consideration of Councils.

"Testimony can be multiplied to almost any extent in

* In 1874 and 1875, the maximum summer consumption, was 51 and 50 millions respectively.

support of the position, that manufactory refuse renders water unfit to drink, and we should condemn the admission of all filth, without waiting for scientific reasons, or demonstrative proof. That which is any way offensive to the sight, taste, or smell, or the sense of decency or propriety, has no more right to a part in the composition of our drinking water, than those substances which are actually proved to be deleterious to health."*

"Another most important thing is this: That really there is no reason whatever to believe that the injurious character, either of sewage or of the gases from a drain, depends, fundamentally, upon the quantity of that sewage or of that gas, in all probability it far more depends upon the quality of the sewage, namely, what it consists of."

"Now what is the nature of the poisonous matter in the atmosphere or in the sewage?"

"We do not know that at all."

"Therefore how can you possibly say when that poisonous matter is got rid of from the water or from the air. It is a question that with the means at our disposal it is absolutely impossible to answer; and I say as I said before, that I think you have a much better chance of getting at these relations through accurate statistics properly applied, than you have through chemical analysis, because chemical analysis is one of the poorest things possible to reach those delicate quantities."†

"You cannot get at those small quantities at all. Chemical analysis must be limited by our power of weighing and measuring; we can only do those. We can weigh and we can measure, and we can do that with certain accuracy, and

* Report of Medical Commissioners on Sanitary Qualities of River Water Boston, 1874.

† Report on Water Supply of London, Evidence, 1868.

there we stop; but that accuracy is not capable of being multiplied *ad infinitum.*"*

We desire, also, to call particular attention to that portion of Col. Adams' paper, which speaks of the great value to the City of Philadelphia of the manufacturing industries, present and prospective, in the Schuylkill Valley, above Philadelphia, and of the importance of encouraging their increase, notwithstanding the fact that they may be the direct cause of material additions to the impurities of the river.

In preparing our report, the result of much investigation, of many calculations and discussions, it has been deemed highly important that it should present a unanimous expression of views.

It has been found, that the more thoroughly points have been investigated upon which differences of opinion existed, the more nearly those opinions have approximated.

With regard to new work, which the needs of the City require to be prosecuted promptly, the Commission has aimed to arrive at distinct and positive conclusions, and to express their views clearly for the information of Councils. In reporting upon the various plans which have been proposed for the supply of the City with water for many years to come, the Commission has thought it best to present comparative estimates, in such a way that the City Councils may themselves be able to discuss those subjects hereafter more thoroughly than heretofore.

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*Report on Water Supply of London, Evidence, 1868.

History and Description of the Works.

The Philadelphia Water Works are varied and complicated, resulting from their construction under different municipalities, at various points, planned by different engineers, and intended for independent operation, to supply distinct and separate districts, situated at elevations from the level of tide to four hundred and forty feet.

The first works were begun in 1799, under the superintendence of Mr. Latrobe; the water was taken from the Schuylkill near Chestnut Street, and raised by steam-power some 50 feet, whence it flowed in a brick tunnel 6 feet in diameter to Broad Street, thence to Market Street, where it was again lifted by steam-power 36 feet higher into a reservoir containing 16,000 gallons, from which it was distributed through the City.

In 1812 steam works were commenced at Fairmount, to take the place of those at Broad and Market Streets, and were completed in 1815.

In 1817 Josiah White and Joseph Gillingham, of Philadelphia, offered to supply the city with three millions of gallons of water every twenty-four hours, for twenty years, for twenty-five thousand dollars a year, and thereafter at three thousand dollars a year forever. Mr. White proposed to build a dam above Callowhill Street Bridge. Negotiations for the sale of the water-power of White and Gillingham, at the Falls, five miles above, resulted in its purchase by the the City in 1819. This led to the adoption of pumping by water-power at Fairmount.

The original water-power works were designed and built by Frederick Graff, father of Frederick Graff, of Philadelphia. These were the pioneer water-power City water works of the United States.* They stand to-day a monument of high engineering judgment and skill, although the increased demand for water has compelled many changes in the arrangements, and the introduction of turbines in place of the old breast wheels.†

The reduction in the cost of furnishing water to the City by the erection of the Fairmount water power works was very great, although the quantity for some years did not exceed four million gallons daily. Previous to 1821 the water from Fairmount Reservoir was distributed through the City by means of wooden pipes, the whole extent of which in 1819 was about 32 miles. Up to 1842, thirty-three years ago, there were only 113½ miles of iron pipes laid.

The contract for supplying the district of Spring Garden with water, was signed April 26th, 1826; with the Northern Liberties June 6th, 1826; with the district of Southwark October 10th, 1826; with Moyamensing January 6th, 1832; and with Kensington October 5th, 1833.

In 1845, the citizens of the Districts of Spring Garden and Northern Liberties, dissatisfied with the charges made for water by the City of Philadelphia, and with the imperfect supply furnished from Fairmount Reservoir to the

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*It is claimed that the water works at Bethlehem, Penna., were built before, in 1788, and those at Bellefonte, Penna., before the erection of the Fairmount Works.

† The following high freshets have occured, since the completion of the Fairmount Dam, which has an oblique over-fall 1,112 feet long, viz.:

HEIGHTS ABOVE COMB OF DAM.

February 21, 1822—9 feet 1 inch; June 26, 1839—10 feet 2 inches (inundated the pumping machinery); February 10, 1840—7 feet; January 7, 1841—8 feet; March 14, 1846—7 feet 1 inch; July 19, 1850—8 feet; September 2, 1850—10 feet 11 inches; August 16, 1867—7 feet 4 inches; October 4, 1869—11 feet 5 inches.

higher portions of those districts, built the Water Works now known as the Schuylkill or Spring Garden Works.

In 1851, the District of Kensington constructed the works at the Delaware River, now known as the Delaware Works.

About 1851, a private company erected works at Germantown, elevating the water, by steam power, from a small stream into a stand-pipe, and afterward into a reservoir at Mount Airy, and supplying the citizens of Germantown.

Chestnut Hill was also supplied through individual enterprise, from springs in the vicinity by means of steam-power, and a small tank placed on top of a stone tower.

In 1854, the City of Philadelphia, previous to that time, bounded on the north by Vine Street, and on the south by South Street, and extending from the Delaware River to the Schuylkill, contained an area of about two and a-quarter square miles. It was extended by consolidation with the districts, to include the whole county of Philadelphia, with a territory of 129 square miles, or fifty-seven times its size as laid out by the original proprietor, William Penn. A large portion of this territory is still rural in character.

With consolidation the control of all of the municipal works came under the City Government, and since then the Germantown and Chestnut Hill Works have been purchased by the City.

In 1855, soon after consolidation, the territory on the west side of the Schuylkill was supplied with water from the Twenty-fourth Ward Works, which had been begun prior to consolidation, using a stand-pipe, still existing, but not in use. These works, a few years since, were abandoned, and the Belmont Works took their place. These are located on the west side of the Schuylkill, but are connected by a 36-inch submerged pipe with the distribution on the east side of the Schuylkill.

The City, also, to give a better supply to Germantown, and to reach Roxborough and Manayunk, built the Roxborough Works, with a pipe and bridge extending from the Roxborough Reservoir to Germantown and to the Mount Airy Reservoir. In the appendix is a map showing the location of the different pumping stations and their respective reservoirs, and districts supplied from them, and also a table giving the elevation above City datum of the reservoirs, their depths, and capacity.

Capacity of Present Works.

Without any deduction for loss by leakage of pistons or pipes, or in the closing of valves or their imperfection, the *theoretical* capacity of the works is as follows:

Fairmount Water Power.

	gals. per day.	
No. 1. Turbine, - - - -	2,110,060	
" 2. Breast wheel, - - -	1,387,260	
" 3. Turbine, - - - -	5,318,553	
" 4. Turbine, - - - -	5,318,553	
" 5. Turbine, - - - -	5,318,553	
" 6. (Removed), - - -	———	
" 7. Turbine, - - - -	5,130,576	
" 8. Turbine, - - - -	5,130,576	
" 9. Turbine, - - - -	5,166,690	
Total of water-power, - -		34,880,821
Fairmount steam-power, - - -		2,364,249
Carried forward, - - -		37,245,070

Steam Power.

	Brought over,		37,245,070
Name of works.	Kind of engine.	Gals. per day.	
Schuylkill Works,	Old Cornish,	5,287,680	
	Side lever,	7,598,880	
	Compound,	10,132,416	
			23,018,976
Belmont Works.	No. 1 Worthington,	5,400,000	
	No. 2 "	5,620,147	
	No. 3 "	8,729,579	
			19,749,726
Delaware Works.	Worthington,	6,428,229	
	Beam Engine,	4,696,807	
	Horizontal,	3,960,887	
			15,085,923
Roxborough Works.	Cornish,	2,409,120	
	Worthington,	4,454,553	
			6,863,673
Total,			101,963,368

of which

By water power	34,880,821
By steam power,	67,082,547

Actual Practical Capacity.

To arrive at this the following deductions must be made, viz:

At Fairmount.—Allow one wheel or its pumps to be undergoing repairs, say -	5,000,000 gallons.
At Schuylkill and Delaware Works.—Each having three engines, allow one engine at each to be disabled or undergoing repairs, - - - -	12,000,000 "
Carried forward, - -	17,000,000 "

Brought over, - -	17,000,000	galls.
At Roxborough.—With a service 365 feet high, and a capacity, nominally of 6,800,000, the supply is limited to Germantown and Manayunk, where the demand is about 2,800,000 gallons, leaving unavailable - - -	4,000,000	"
At Belmont.—Having the reservoir 212 feet high, the supply is limited to West Philadelphia, and a high section of the City on the east side of the Schuylkill, reached by means of the submerged main. And with a capacity here of 19,700,000 gallons, the consumption may be placed at 9,700,000 gallons, leaving unavailable - -	10,000,000	"
Making the deductions, - -	31,000,000	gallons.

Which taken from the whole theoretical capacity, - - - -	102,000,000	gallons,
leaves the actual working capacity,	71,000,000	"
Of which, by water-power, -	30,000,000	"
And by steam-power, - -	41,000,000	"

In this calculation all the wheels at Fairmount except one are assumed as running, and of course that a full supply of water is flowing in the Schuylkill to propel them.

The ability of the works to furnish *seventy-one* millions gallons per day is therefore limited to times of a full river.

CAPACITY DURING DROUGHTS IN SUMMER.

During periods of low water in the river the capacity of the works is greatly reduced.

In the calculation just made, and with a full river, the delivery per day by water-power is taken at - - - - - 30,000,000 galls.

In the chapter upon Fairmount dam and minimum flow of Schuylkill, it is shown that in dry weather Fairmount can only be relied upon for - - 14,000,000 galls.

Add the effective steam capacity, as above, - - - - 41,000,000 "

Makes the actual present summer capacity of the works. - - - 55,000,000 "

In 1874, according to the recent statement of the Water Department, the average consumption was 51,000,000 gallons in July.

For 1875, in July, it averaged 50,000,000 gallons per day.

Both of these were exceptional years, with diminished consumption, caused by an apprehended scarcity of water, and the general depression in business.

By this calculation the demand in summer is nearly equal to the capacity of the works.

In view of this fact, and of the prospective increased demand during the Centennial year, immediate provision should be made for increasing the supply.

WATER-POWER OF THE SCHUYLKILL RIVER.

Fairmount Dam.

This structure was built to serve the double purpose of forming a pool for slack water navigation, and furnishing power to drive the Fairmount pumps.

There is, therefore, a divided interest in the water and its use.

First. By the decisions of the Supreme Court of the State, the people upon its banks have the right to the water for the purposes of life, and the Navigation Company for transportation.

Second. By agreement between the City and the Navigation Company, there is reserved to the use of the company, the water necessary for the passage of boats through the locks*.

Third. The remainder of the water can be used by the City as power. Provided, that in using it the water is not drawn below the comb of the dam.

In the Appendix is a diagram, marked (A), that will explain the subject more fully.

By the contract before mentioned, the water was not to be drawn below the comb of the dam, marked in the drawing "Old Comb," or legal comb. If drawn below it, the City became liable to damages; if suffered to rise above it, the water ran to waste over it.

Two years ago a strip of timber (A), averaging about five inches thick, was permanently bolted upon the top of the dam, making a new comb, and in addition to this, during dry weather, a temporary plank or "flash" board (B), eleven inches in width, is fastened to the five inch timbers, thus raising the surface of the pool sixteen inches and allowing the water between these two levels to be drawn down, without violating the contract, and, improving the navigation.

This depth of sixteen inches over the area of the pool, (480 acres), becomes a storage reservoir, in which the water is retained and permits the wheels to be stopped at and near high tide, when the power is least, and started at and near low tide, when the power is greatest.

* See agreement published in Report of the Water Department for 1863.

This is the proper manner of running the wheels, at low stages of the water. By pursuing it, more water is pumped than if the wheels are run constantly.

Minimum Flow of the Schuylkill River.

In 1816, from measurements made by a Committee of the Schuylkill Navigation Company, at a time when the river was said to be as low as at any previous period for 20 years, the flow was stated to be, per day, - 500,000,000 galls.

About 1825 the flow was estimated at -	440,000,000	"
And in 1867, a Special Committee of the Commissioners of Fairmount Park stated that "the minimum flow of the Schuylkill has been set down at -	400,000,000	"
In 1874 a careful measurement was made by James F. Smith, Chief Engineer of the Canals of the Philadelphia and Reading Railroad Company, details of which appear in the Appendix. By this measurement the minimum flow in 1874 was - - -	245,458,000	"

During the month of July of the present year, no water passed over the dam at Fairmount, except for a portion of two days. The whole flow was used for driving the wheels at Fairmount, and for supplying the pumps at the different works, and for the passage of boats through the locks.

Rating the wheels as producing a net result of sixty per cent., the quantity of water flowing in the river daily for the month of July was as follows:

Used per day upon the wheels, -	203,000,000	gallons.
Pumped by all the works upon the Schuylkill, - - -	42,000,000	"
Carried forward,	245,000,000	"

Brought forward,	245,000,000	galls.
Used by locks and leakage of dam,	7,000,000	"
Total, - - -	252,000,000	"
Deduct the flow from Silver Creek and Tumbling Run Reservoirs, included in the above quantity, - -	3,000,000	"
Leaves the daily flow of the river in the month of July, 1875, - -	249,000,000	"

This agrees very closely with the minimum flow in 1874, as made by Mr. Smith, and together they may be considered as establishing the present volume of the river in dry seasons.

In this connection it may be well to state that there seems to prevail an idea that a large proportion of the water in the river is consumed by the locks in the passage of boats, and that the City's supply is jeopardized thereby; but, in truth, this quantity is comparatively small. By Mr. Smith's report, estimating the forty-five lockages per day, (which is more than the present business requires,) and with liberal allowances for leakage, the maximum daily demand for the purposes of navigation is but seven and a half millions of gallons, out of the two hundred and forty-five millions flowing at a dry time, or about three per cent. of the whole; and if applied upon the wheels, would add but half a million gallons per day to the amount of the water which could be pumped at Fairmount.

Machinery at Fairmount.

This machinery consists of one small and six large turbine wheels, and one breast wheel; for the details of which see Appendix.

We refer to our remarks upon "Fairmount Dam" and

"Minimum Flow of the Schuylkill River," to explain the circumstances under which these wheels operate.

We have assumed the net effective result yielded by them at 60 per cent.

It was impossible to measure the actual quantity used by the wheels, on account of the tide and low arch-ways of the tail race, without a very considerable expenditure; but from a consideration of their openings, the observations we could make, and the best data obtainable, we are satisfied that they do not exceed this duty.

It is a low result. Under favorable circumstances 80 per cent. can be realized, and seventy-five per cent. ought to be obtained, when "flash boards" can be used on the dam, and the wheels run only when the tide is below its mean height.

We recommend, therefore, that the six larger turbines be altered, so as to operate more economically.

The cost of this change will be about $16,000.

We also recommend the construction of two new turbines, one in place of the old breast wheel, No. 2, and one to occupy the vacant space of No. 6.

The estimated cost of these changes, including the masonry, &c., is $70,000, and they will increase the capacity of the works from 35 to 50,000,000 gallons per day.

Leakage of the Fairmount Pumps.

We made, on three different days, careful measurements by weir of the actual delivery into the Corinthian Reservoir of the pumps driven by wheels Nos. 5, 7, 8, and 9, as compared with their theoretical delivery, and also made numerous tests by the pressure gauge for leakage in the mains.

There was found to be an average leakage of 20 per cent. This might be reduced to 10 per cent.

In this connection we would suggest that there should be check-valves placed on all of the pumping mains, to prevent waste of water.

Chestnut Hill Works.

The machinery of these works is inferior, and should be replaced by better. The cost of which will not be great.

In dry seasons, as was the case this year, the springs at Chestnut Hill are insufficient to meet the demand. The best mode of remedying the evil is to lay a pipe, say of ten inches diameter, from Mount Airy Reservoir to the Chestnut Hill Pump Well, connecting also with the small reservoir adjoining the springs.*

When the springs are full, their water will flow into the Mount Airy Reservoir, when they are insufficient for the supply of Chestnut Hill, the water from the Mount Airy resservoir will flow only into the Chestnut Hill Pump Well.

Pipe Bridge.

This structure spans the Wissahickon Valley, and carries the water from the Roxborough reservoir to Germantown.

It is 660 feet long; was built with two twenty-inch pipes, forming the chords of an iron suspension bridge. One range of the pipes was badly injured by the freezing of the water in it last winter, and cannot be used for that purpose. The other range of the pipes is now used for conveying the water from the Roxborough to the Germantown reservoir.

We recommend that the broken range of pipes be sufficiently repaired, to be safe as a chord for the bridge, without being used for the passage of water. And to prevent

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* Since writing the above, this pipe has been laid.

a similar accident by freezing, that the other pipe be covered with wooden staves, placed from flange to flange, and leaving an air space.

And, for further security, that an inverted syphon pipe be laid across the Valley.

Impounding Reservoirs.

It has been suggested that the storm water of the Schuylkill should be stored in impounding reservoirs, to be drawn out in dry weather, thereby increasing the minimum flow of the river and the water-power.

In the valuable communication of Mr. James F. Smith, Chief Engineer of Canals of the Reading Railroad Company, given in the Appendix, it is proposed, for this purpose, to build, in the Valley of the Schuylkill, fourteen new dams and three new reservoirs, and also to use eight of the dams and the water of the existing navigation above the Blue Mountain, as well as the waters of the present reservoirs at Tumbling Run and Silver Creek. Their aggregate contents would be nearly 4,600 million gallons.

This quantity would furnish, for seventy days, about sixty-six million gallons per day, which, if applied for pumping at Manayunk, at eight gallons to raise one, and afterwards upon the wheels at Fairmount, at fifteen to raise one, would furnish power sufficient to raise into the reservoirs about thirteen million gallons per day.

This would be the result, considering the dams and reservoirs full at the commencement of a dry season, to be drawn down and emptied but once, and not filled again during a drought of seventy days duration, which in extremely dry seasons would probably be the case.

In regard to the cost to the City, of the plan proposed by Mr. Smith, we have no data, but for the purpose of making some comparison with other modes of supply, we have placed the cost at a million of dollars.

The interest upon this sum, at 6 per cent., is $60,000; the total quantity pumped, during the 70 days, by the impounded water used both at Manayunk and Fairmount, would be, in round numbers, 900 million gallons.

This divided into $60,000, gives nearly $67 as the cost for furnishing the power to raise one million gallons into the reservoir, no other expense being included.

This is far beyond the cost of raising one million gallons into the reservoirs by steam, and the result seems conclusive against the project of impounding water in low dams along the Schuylkill Valley, and in small reservoirs, for the purpose of using it as power, however much it might improve the navigation.

To impound water successfully for this purpose, requires localities seldom to be met with, where comparatively inexpensive dams will create large pools. The site proposed for the Perkiomen Dam and Reservoir, is one of this character, where a water raise of seventy feet would flood nearly 2,000 acres of land, and the pool would contain more than 20,000 million gallons of water.

Its estimated cost, built in the most substantial manner, and including the reconstruction of eight miles of railroad, is about $800,000. This water, if applied as power at Flat Rock and Fairmount, would elevate 3,830 million gallons into the reservoir, being 55 million gallons per day for 70 days.

Taking interest and cost of attendance and repairs at $60,000 per annum, the cost per million gallons, for the power, would be about $16.

If we deduct the estimated expenditure for reconstrution of the railroad it would leave $560,000 as the cost proper of the reservoir itself, or of one in another locality equally well suited for the purpose. At this cost, and taking interest, attendance, and repairs at $46,000, the cost of power for raising one million gallons would be $12.

As having an important bearing upon this subject, it may be proper here to state that the water drawn from such a reservoir would, for 80 days, add to the flow of the river 250 million gallons per day, thus doubling its minimum flow, and by the addition of this large amount of pure water adding materially to the purity of the City's supply.

PUMPING BY WATER AT MANAYUNK, USING THE POWER OF FLAT ROCK DAM.

It has been proposed that the City should lease or purchase the surplus water-power of the Flat Rock Dam and use it for pumping into the East Park Reservoir.

The total fall from the pool of this dam to that of Fairmount is 26 feet, and of this there is now available for power about 22½ feet, and with well constructed wheels eighty per cent. could be realized as useful effect.

At present seventy-two per cent. of this power is rented temporarily, on short leases to different parties, for the sum of $33,443 per annum, and these leases can be terminated within twelve months, and probably might be transferred to the City upon fair terms.

At times of the minimum flow of the river, say for three months, this seventy-two per cent. of the water would raise into the East Park Reservoir, through one pipe of 4 feet diameter, 20 million gallons per day, and during the remaining nine months of the year when the river is above its minimum flow, and with proper arrangements for its use and application, it would raise about 27 millions per day.

From the Flat Rock Dam, to the East Park Reservoir, the distance is nearly 30,000 feet, or about five and two-thirds miles, and the elevation of the reservoir above the pool is 104 feet.

It is not contemplated to take the water from the Manayunk Canal to supply the pumps, but from the Flat Rock pool, and the above length of pipe is sufficient for both the pumping and supply main.

To erect two turbine wheels, with pumps suited to the above purpose, with land and buildings, and to lay this 4 foot pipe would cost seven hundred and twenty-five thousand dollars ($725,000.)

To arrive at the value to the City of the water power proposed to be leased, we will compare the cost of a year's pumping by water with that of pumping by steam. For this purpose we assume the cost of running the water-power machinery, including all repairs and renewals, at three cents per million gallons raised one foot high; and the cost of running the steam machinery, including repairs and renewals, at fifteen cents per million gallons raised one foot high, adding in each case to the elevation, the head due to frictional resistance.

Cost of Water Power.

Pumping 20 million gallons per day, for three months, and 27 million gallons per day, for nine months, from Flat Rock Pool into East Park Reservoir.

Running expenses, repairs, and renewals, -	$37,881
Rental, as above, - - - -	33,443
Interest upon cost of works ($725,000), -	43,500
Annual cost by water power, - -	$114,824

As it is not necessary that the steam works should be placed at Manayunk, if built, they should be located at the Spring Garden Works, distant from the reservoir 2,000 feet, and having a four foot main and an elevation to overcome of 130 feet above Fairmount pool.

Cost of Steam Pumping.

To raise 20 million of gallons for three months,
and 27 million " nine "

The machinery required, with buildings, including 2,000 lineal feet of four foot pipe, would cost $346,000.

Running expenses, repairs and renewals, -	$183,049
Interest upon cost ($346,000), - - -	20,760
Cost of pumping by steam, - - -	$203,809
Deduct cost by water-power, - -	114,824
Difference in favor of water-power, -	$88,985

To this it is proper to add something for the saving that would result in case of adopting the proposed water-power, by supplying Manayunk from the East Park Reservoir, 135 feet above City datum, through the proposed four foot main instead of the Manayunk supply being pumped, as is now done, into the Roxborough Reservoir, 365 feet above City datum, and then drawn down to the low level of the greater part of Manayunk.

About 500 million gallons per annum are thus pumped at a loss of about $17,000 as compared with the water-power pumping.

In our opinion the rental of the 72 per cent. of the Flat Rock water-power and its application to pumping into the East Park Reservoir would be justified.

This view is taken with the proviso that the Reading Railroad Company will favor the arrangement in accordance with the views expressed above, and also that a proper site can be obtained in Manayunk upon which to erect pumping works. The space required would not be large.

If this is not practicable, the suggestion of Mr. Smith to locate the works upon the west side of the Schuylkill is worthy of consideration, although it would probably involve the construction of a new dam and an expenditure of about $75,000.

The cost of pumping by the large pumps proposed to be used, and with the constant head here supplied would be less than at Fairmount, with its smaller pumps and variable head, though we have taken the cost at the latter as the basis of the estimated cost at Manayunk.

If this water-power be leased, the aggregate pumping capacity by water, at the time of a full river, would be more, at present, and for some years to come, than the entire consumption of the lower system of distribution; therefore to make the water-power more available, some of its pumps should be connected with the higher systems, or, water should be taken from the East Park Reservoir, and by a second lift raised by steam into those systems.

And even without the Manayunk power, it is worthy of examination whether such connection with the Fairmount pumps, and such second lift, may not prove to be advantageous.

Prevention of the Pollution of the Fairmount Pool.

Either by a sewer to Tide Water, or by a Pure Water Conduit from Flat Rock Dam.

Several measures have been proposed as preventives, palliatives, or remedies, but little has been carried into effect, except the sewer on the west side of the river; the inflow of polluting matter still continues, being steadily augmented in volume, as the City grows, and even in a greater ratio.

The most prominent and the most effectual remedy hitherto advocated, is by an intercepting sewer, from the upper end of Manayunk to tide water, below the Fairmount dam.

The construction of this sewer was recommended by a Committee of the Park Commission, in October, 1867.

In October, 1868, a report was made upon the subject, by Mr. John D. Estabrook, Engineer, addressed to John C. Cresson, Chief Engineer of the Park. In March, 1870, another report was made upon the same subject by Mr. Estabrook, giving full details of the location and plan of the sewer, which was to be of seven feet diameter, and the cost was estimated to be about one million of dollars. If built it would no doubt tend greatly to improve the quality of the water, in the Fairmount pool.

If not built there remains another way of securing, for a number of years, a water for the pumps purer than that now supplied from the Fairmount pool, namely, by

A Conduit

From the Flat Rock pool, leading to the pumps at Belmont, Spring Garden, and Fairmount.

We believe that the water of Flat Rock pool, at this time is much more free from impurities, than that of the Fairmount pool, and that for an undetermined number of years it may be used.

This Conduit need not be quite so large as the sewer proposed in the last report by Mr. Estabrook.

If made 6½ feet in diameter, the proposed Conduit with the available fall, would furnish 70,000,000 gallons per day. This would be so much drawn from the water-power of Flat Rock pool.

In case the City shall decide not to build the sewer, we would recommend the immediate construction of the Conduit, which would cost about the same as the sewer, namely, one million of dollars.

In case of the construction of this Conduit, it would reduce the water power of Flat Rock dam that may now be leased, about 28 per cent., during the dry season, rendering the leasing of the same by the City less advantageous.

It is also to be borne in mind, that the City would probably be required to compensate the Reading Railroad Company for the water to be abstracted, or to furnish an equal quantity by means of compensating reservoirs.

FUTURE PERMANENT WATER SUPPLY.

There are only two adequate sources of supply, namely, the Delaware and Schuylkill Rivers, including their tributaries. At present the greater portion of the water furnished is taken from the Schuylkill, and with the exception of that pumped by the Roxborough Works, situated on the pool of Flat Rock dam, the water from the Schuylkill is pumped from the pool of Fairmount dam.

There are two plans proposed on the Schuylkill; one which will continue to take the water from the main river, as at present, the other the building of an impounding reservoir on the Perkiomen and a conduit to deliver the water by gravity.

On the Delaware several plans have been proposed. The Water Gap plan, by gravity to the City; the New Hope pumping and conduit plan; the New Hope canal and conduit plan; and the Scudder's Falls canal and conduit plan; the two latter requiring the water to be pumped up after reaching the City.

Water Gap plan from the Delaware.

In order to obtain sufficient height on the river to allow the water to flow by gravity to the City into a proper distributing reservoir, it is necessary to take the water as far up the river as Belvidere, about 11 miles below the Water Gap, at an elevation of 232 feet above tide. The line would follow the river from Belvidere to New Hope, 50 miles, and from there, by an interior route, shorter than the river, reach the City in about 40 miles, making the entire length of the conduit about 90 miles. Our calculations show that the cost would not be less than thirty millions of dollars; which renders its adoption inexpedient.

New Hope Conduit.

The water in the Delaware River at New Hope being only forty-eight feet above tide, it is impossible to obtain a gravity flow thence to the reservoirs in the City. The fall at this place is not more than six feet, so that in the summer the water power would be inadequate, and steam power would be needed to raise the water into the conduit.

At present a portion of the water power is in use raising water into the Delaware Division Canal, and an arrangement would have to be entered into for the right to divert it.

The distance from New Hope to the East Park Reservoir by a conduit route, is about 40 miles.

The estimated cost of a dam, bulkhead, &c., pumping machinery, steam engines, &c., pumping mains, and reservoir, and of conduit 40 miles long, is in round numbers, - - - - - - $13,000,000
Cost of pumping annually, $600,000, which capitalized amounts to, - - - $10,000,000

Making the total cost, including capitalization, $23,000,000
Which includes only a supply of 75 million gallons per day.

New Hope Canal and Conduit.

This scheme involves the purchase of 31½ miles of the Delaware Division Canal, and the change from a navigation to a supply canal; and other works.

Taking the water from the Delaware river 3 miles above New Hope, by means of a low dam, where the water surface is now 55 feet above tide.

For these it would be necessary to purchase the Canal Company's water-power, and 31½ miles of the Delaware Division Canal, and to obtain authority from the states of Pennsylvania and New Jersey, to build the dam, &c.

The works would comprise a dam and bulkhead, 3 miles of river canal, changing 24 miles of navigation canal into a larger supply canal, 9 miles of new canal, and 7 miles of conduit, also a low reservoir at or near Lardner's Point on the Delaware (the distance to that point being 43 miles), erection of steam engines and pumping machinery, the laying of pumping mains to connect with the City distribution, and the raising of all the water by steam power.

Cost of canal, &c., in round numbers, - -	$8,000,000
Add engines, houses, reservoir, and pumping mains, &c., - - - - - - -	3,000,000
Cost of pumping annually, $700,000, which capitalized amounts to say - - -	11,500,000
Making the total cost, including capitalization,	$22,500,000

Scudder's Falls Canal and Conduit.

This scheme requires the purchase of the "Trenton Water Power;" the erection of a low dam and bulkhead, dredging near the head of the canal, the construction of 24 miles of a large supply canal, and 7 miles of conduit; the building of a receiving reservoir at or near Lardner's Point; the erection of steam engines and pumping machinery, &c., and laying mains to connect with the City distribution, and the raising of all the water by steam power.

The surface of the river at the head of Scudder's Falls is only 21 feet above tide, and the erection of a high dam at that place is not admissible.

It would be necessary to obtain authority from the States of Pennsylvania and New Jersey to build the dam, &c.

The works would comprise a dam, and bulkhead, dredging, 24 miles of canal, 7 miles of conduit, and receiving reservoir,

at an estimated cost for 31 miles of canal, &c., of	$7,000,000
Add engines, houses, reservoir, and pumping mains, &c., - - - - - -	3,000,000
Cost of pumping annually, $700,000, which capitalized amounts to, say - - -	11,500,000
Making a total cost of - - -	$21,500,000

The great cost of these schemes, namely, the New Hope conduit plan, the New Hope canal and conduit plan, and the Scudder's Falls canal and conduit plan, and the fact that pumping by steam is unavoidable in connection with all of them, prevent us from recommending any one of them to the favorable consideration of Councils.

We have made numerous elaborate calculations and estimates, in connection with these plans for bringing water from the Delaware, above tide, the details of which it has not been thought necessary to include in this report.

It may be proper to state that, in our judgment, we have so arranged the estimates of the various plans, that they may be fairly compared.

The capitalization of the cost of pumping, does not include that of operating the whole number of pumping engines required to pump the largest quantity of water, but about half that number, the others to be added afterward, as the demand for water should be increased.

Nor do these estimates cover any interest during their construction.

The actual final cost, including the accumulation of interest, on any of the plans designed to meet the future wants of the City, (excepting on the present system which excludes bringing water from considerable distances,) will depend materially upon the number of years which may be occupied in their construction.

The advantage of a purely gravity system is, that no pumping, and therefore no capitalization on that account, as in the case of the other mixed plans of canal and conduit, is required; and hence there is a period in the future, when the annual expenditure by the City, including interest on the accumulation of the first cost and of its maintenance, would be less with a gravity system than with any pumping system.

We have not deemed it necessary to encumber this report with various calculations more or less complicated for the purpose of exhibiting this.

Gravity Supply from the Perkiomen.

In looking for a stream to furnish a gravity supply for Philadelphia, this tributary alone of the many that flow into the Schuylkill has been found to possess the proper requisites. Such stream must possess a sufficient drainage area or watershed, must not be too remote, must have a geological formation that will carry a good percentage of the rainfall to the reservoir, that will retain the water when impounded, and that will impart no mineral impurities. The region must be free now and likely to remain free from causes of pollution. A suitable site must exist for building a safe dam, and where a sufficient quantity of water can be impounded.

All of these requirements are found to exist in the Perkiomen Valley, and Mr. Berkinbine is entitled to great credit for his sagacity in suggesting this system.

The drainage area of this stream above the dam is 220 square miles. The average annual rain fall at Philadelphia for the last 20 years, was 48 inches, and the least rainfall during the same term, in 1856, was 34 inches. Upon the elevated region of the water shed of the Perkiomen it would no doubt be more than at Philadelphia.

In view of the compact soil, steep slopes, and large areas of woodland and grass, an average of sixty per cent. of the rainfall would probably flow into a reservoir. This would equal 20.4 inches of the minimum yearly flow.

If taken at 50 per cent., 17 inches could be collected. The greatest quantity required for two millions of people, at a daily summer consumption of 80 gallons each, is per day, 160 million gallons.

The 220 square miles of drainage area above the site of the dam, at 16 inches depth, would yield per annum, more than enough water to supply two millions of people.

The sufficiency of the quantity of water which can be obtained from this stream is thus demonstrated. If at any time a still larger supply should be called for, other drainage areas in the Perkiomen Valley could be made available at moderate expense, and the Wissahickon, with its drainage of 44 square miles, might be added to the system.

The quantity of water being ample, the next question to be examined is whether this quantity can be made available for a regular supply for the City throughout the year?

At the proposed site there is no objection to its being made 75 feet in height.

Our plan fixes the water-raise at 70 feet, with 25 feet to be drawn out, which will furnish 10,000 million gallons of available water, exclusive of two feet in depth allowed for evaporation.

A rain fall collected of three inches in depth over the 220 square miles, would yield 11,499 million gallons, being more than is required to fill the reservoir.

In view of the full flow of the stream in the fall, winter and spring, it is clear that the reservoir will be full at the commencement of dry weather, and that a large body of water will have run to waste over the weir.

The minimum flow of the Schuylkill has been ascertained to be 245 millions of gallons per day, and the area of its water shed is about 1,800 square miles. Allowing the 220 square miles of the Perkiomen water shed to have the same minimum flow per square mile as that of the Schuylkill, it would give 30 millions of gallons for that of the Perkiomen.

From our observations and from measurements made of the flow in July of this year, we have decided to assume the minimum flow of the Perkiomen at the site of the dam to be 20 million gallons per day.

Under this state of facts, namely: having one reservoir containing 10,000 million gallons available, always full at the beginning of the dry season, and a minimum flow in the Perkiomen of 20 million gallons per day, what daily supply of water can be realized?

This will depend upon the length of the dry season.

James F. Smith, Esq., who is now, and who has been for many years, Chief Engineer in charge of the Schuylkill Navigation, says that seventy days will cover the drought of the longest dry season.*

The above content, 10,000 million gallons, divided by seventy days, gives 140 million gallons per day. Adding the minimum flow of the stream, 20 million, makes 160 millions that can be drawn daily from this reservoir for seventy days.

This calculation is conclusive as to the sufficiency of the supply for the longest period of drought. It may be asked whether the dry months immediately preceding and follow-

* An interesting report by Mr. Smith, relating to the Schuylkill river, impounding reservoirs, &c., will appear in the Appendix (marked D.)

ing these seventy days can with certainty be supplied by the natural flow of the stream?

To this it is answered, that the tables of rainfall, kept for fifty years, in no case show a less rainfall during the four driest months than seven inches; and that one and a-half inches collected from 220 square miles, will more than supply two millions of people for one month. These seven inches of rainfall, and the storm water accumulated in the reservoir, amply cover the four driest months. During the other eight months of fall, winter, and spring, there can be no doubt as to the supply.

But should this work be built and experience prove the reservoir to be too small, supplementary storage reservoirs could be established at points higher up the stream.

Upon the preliminary surveys, as made this summer under the direction of the commission by Mr. Chas. G. Darrach, Assistant Engineer in the Water Department, careful estimates have been made, based upon the plans (designed chiefly by Mr. McAlpine, who has had great experience in such work), the description of which, with drawings of the different structures, will be found in the Appendix.

In the plan upon which our estimate is based, the water is proposed to be carried across the larger valleys by inverted syphons of four feet cast-iron pipes, which would have a daily capacity of two hundred million gallons, the same as the conduit.

A demand of one hundred million gallons per day would require only three of these pipes. The expenditure, therefore, for the other three, amounting to $1,352,000 can be postponed until such time as the whole quantity may be required. Other savings may be made in the construction without impairing its efficiency. We have estimated that the cost of the works may be $12,000,000 from which deducting $2,000,000 for work that might be deferred, leaves $10,000,000 as the estimated cost of the reservoir, conduit, &c., when arranged for the daily delivery of 100 million gallons, and $12,000,000 when arranged for the delivery of 200 millions.*

Objections to the Gravity Plan.

1st. That necessarily, the work must be built much larger than required for the supply of the present population, while steam power can be increased from year to year, by building additional engines, buildings, laying pipes, &c.

2d. That the construction of such a lake as the Perkiomen, and drawing down its surface in summer 25 feet will cause sickness in the surrounding region.

3d. That some extraordinary flood may sweep away the dam, inundate the country, and leave the City without water.

In reply we would say, That the first objection has force, and a gravity works should not be constructed, unless demanded for the purpose of obtaining a purer and better water, or unless the time is near at hand, when the cost of gravity would be less than by other modes.

To the second objection, we reply that wherever such reservoirs have been built, in a similar description of country, no such effects have been produced, and in this case the character of the rocky and in some places gravelly soil, the steep slopes, and a moderate extent of shoal water, when the reservoir is drawn down, would not expose to decay sufficient vegetation to produce such apprehended sickness.

In regard to the next point, namely, the danger of the dam being carried off by some extraordinary flood, we have to say, that our plans and estimates include the cost of a dam of unusual strength, namely, of 68 feet width at top water line, to be made with slopes of two feet horizontal to

* See Mr. McAlpine's estimate appended.

one vertical, and faced with stone pavement, and with a puddle wall of large size in the middle, with solid rock beneath the base of the dam, extending up both banks, with a weir or spill-way 230 feet long excavated in the rock, with the dam 12 feet above the weir or comb of the spill-way, and 20 feet wide on top, built in the manner proposed, with the best materials, none being of a perishable character; and if built in such manner, we do not feel the least fear of its failure.

The surveys made under the direction of the Commission were necessarily hasty and experimental; and, in our opinion, thorough and careful surveys should be made of the location of the line of the conduit from the Perkiomen dam to the East Park Reservoir. We believe that the true interests of the City of Philadelphia would be promoted by such surveys, which, with careful estimates made in detail, and an accurate map, would enable members of Councils and persons interested in the subject, to study it understandingly.

In the appendix will be found a paper prepared by Wm. J. McAlpine, one of the members of the Commission, relating to the Perkiomen Reservoir and conduit plan; and containing various calculations and suggestions made by him.

Artesian Wells.

The question of a supply of water from deep wells, made by boring, and commonly called Artesian, has been somewhat discussed in Philadelphia, but there is no probability that an adequate supply for the general use of the City could be obtained in that manner, and the quality of the water obtained from such wells varies very much in different localities, depending upon the nature of the strata from which the water is procured; and this Commission cannot recommend any dependence upon such plans for the general City supply, attended, as they are, with great expense and extreme uncertainty, and being in every case more or less experimental.

GENERAL CITY DISTRIBUTION.

This may be most advantageously conformed to the topography of the City, by preserving the different elevations for distributing to the three plateaus of different heights, namely: 120 feet, 212 feet, and 365 feet; with the East Park Reservoir as a feeder for those below it. The reservoirs at the height of 120 feet, will supply, by far, the largest population. That at Belmont supplies the next largest, and the Roxborough Reservoir the least. The lowest of these systems will receive about 70 per cent. of the whole, the second about 20 per cent. and the third about 10 per cent.

With the Delaware Reservoir raised to the same height as the Spring Garden and Corinthian, namely 120 feet, and connected by mains with the East Park Reservoir, the distribution to the large plateau, below the height of 120 feet, will be very complete.

This is the most advantageous mode of utilizing the present reservoirs.

The present general system of distributing the water throughout the City, from the reservoirs, has been adapted to the local circumstances, and with the changes we have recommended, nearly all of which were suggested in the last Annual Report of the Chief Engineer of the Water Department, it will be very complete.

The distribution in West Philadelphia by only a twenty-inch main from the reservoir is insufficient, and ought to be enlarged. At the same time an arrangement should be made at the pumping works, so as to furnish the consumers on the east side of the Schuylkill with water from the Belmont Reservoir instead of direct from the pumps.

This arrangement would answer well until these pumps shall be required to supply over fifteen million gallons per day, when an additional main may be required from the pumps to the reservoir.

East Park Reservoir.

This structure will have its surface 135 feet above City datum, a depth of water of twenty-five feet, and a surface area of 79 acres, and will contain when full more than 700 million gallons of water.

Its location within the bounds of the Park frees it from the serious objection of obstructing streets and public highways, and its great capacity will make it especially useful as a subsiding and purifying reservoir, and as a security against scarcity of water in case of accident to the works, or of an extensive conflagration.

It can be used as a storage reservoir with great advantage, its water can be drawn into the existing distributing reservoirs of the City and thereby maintain the equability of the distribution.

Its construction can be cheapened about a quarter of a million of dollars by omitting brick pavement on the bottom and substituting a layer of clean gravel. We think that the bottom can be made tight by the proper use of the material found within the limits of the reservoir or in the vicinity.

We recommend its immediate completion.

Reservoir at Manayunk.

As before stated, the larger part of Manayunk lying at a low level is now supplied by pumping into the Roxborough Reservoir. This evidently involves too great a loss of money to be continued. If not remedied by the leasing of the water power at Flat Rock Dam, it should be done by the extension of a pipe from the East Park Reservoir, or the construction of another small reservoir, in the vicinity of Manayunk, at a point 135 feet, or else of 212 feet above City datum, to be supplied by an independent main from Roxborough pumping station. It would require about ten thousand feet of pipe, and a small reservoir costing about thirty thousand dollars ($30,000.) The decision in regard to the most advantageous height for such reservoir to be made after a careful examination as to the quantity of water likely to be consumed by the inhabitants, at different elevations.

In case the City should lease the water power of the Flat Rock Dam, it might be advisable to supply the above new reservoir if placed at 212 feet, and also the Roxborough Reservoir by this water power; and perhaps to place the machinery for that purpose near the Flat Rock Dam.

Pumping Works at Lardner's Point, and the Wentz Farm Reservoir.

In our general view of the City distribution we have concluded that three general reservoir systems, at elevations of 120, 212, and 365 feet shall be preserved.

The East Park Reservoir, at an elevation of 135 feet, may be considered as the feeder of the first system, situated at its western extremity. Another feeder, located at or near the Wentz Farm, would be highly advantageous, at its north-eastern extremity, to be succeeded by the erection of another reservoir at an elevation of 212 feet; thus preserving the three regular distribution districts. If, however, the purchase of the reservoir site, and contracts made, or other financial or legal reasons control the subject, the erection of a reservoir at Wentz Farm at a height of 164 feet, can be made very beneficial to Frankford and the high ground in that section of the City, and would immediately lessen the expense of water now supplied at too great cost from Roxborough and Belmont, on account of their greater elevation.

After a careful examination of the subject, we recommend the construction of Pumping Works at Lardner's Point, and the completion of a reservoir in accordance with the views just expressed, with two ten million engines, properly connected by mains with the Delaware Reservoir, and with the proposed new reservoir.

Extension of Inlet Pipe at Kensington Works.

As a speedy means of improving the quality of the water now supplied from the Delaware, we recommend the extension of the inlet pipe.

Reference to the Reports of Professors Booth and Garrett, and Table Furnished by Dr. Cresson, and to his Report to Water Department.

The Commission were desirous of obtaining the professional opinion of Professors Booth and Garrett, experienced chemists of Philadelphia, upon the water from the two rivers, and in regard to their probable future qualities for potation, these gentlemen having repeatedly analysed them during the past thirty-three years; and, at our request, they have made new analyses of several specimens of water which we had collected and sent to them for that purpose. The observations and conclusions of these gentlemen, as contained in their report, will be found in the Appendix (marked B). We regard them as highly interesting and satisfactory, and we ask for them the careful consideration of Councils.

We cannot avoid saying that we feel under great obligation to those gentlemen for the able report they have presented to us upon the above subject.

At the request of the Commission a number of specimens of water, taken during our examinations from different places on the Schuylkill and Delaware Rivers, were submitted to Charles M. Cresson, M. D., chemist, of Philadelphia, for analysis, he having kindly volunteered to analyse them, and report to us the results. A table (marked C) containing these analyses, carefully prepared by Dr. Cresson, will be found in the Appendix, and to which we ask the attention of Councils. We beg leave also to refer to his full report, entitled "Results of examinations of water from the River Schuylkill," printed in the last report of the Chief Engineer of the Water Department, in which his views respecting the pollution of the river, together with several important remedial suggestions, are given.

The Commission take this opportunity of tendering thanks to Dr. Cresson for the manner in which he has tabulated for our use the results of his professional labors in this connection.

In our judgment the reports above mentioned, taken in connection with the paper of one of our members, which also appears in the Appendix, contain a complete and almost exhaustive presentation of the important subject of the "Pollution of Rivers."

REMARKS UPON THE SCHUYLKILL AND DELAWARE RIVERS.

Schuylkill River.

Elsewhere in our report, and in the paper of one of our members, as well as in the report of Professors Booth and Garrett in the Appendix, some of the present characteristics of this stream are sufficiently explained; we would here make only a few additional remarks.

The Schuylkill cannot be regarded as a small stream, draining, as it does, one million one hundred and fifty thousand acres of territory, and having an average daily flow of over fifteen hundred million gallons.

If this flow continued the year round, the question of its contamination from the mines and from sewage, would have little importance. It is because of its minimum flow, falling, in an extreme case, to two hundred and forty-five million gallons per day, that the subject of its contamination has been deemed worthy of the most careful investigation.

It is well to recollect, however, that the Schuylkill is subject to heavy freshets of sufficient volume and velocity to sweep out at such times a large portion of injurious sediment which, in the intervals between the floods may have been deposited. A river which is capable of discharging a body of water, ranging from six to eleven feet in depth, over a weir eleven hundred and twelve feet long, possesses a conservative power which we should not fail to recognize, but this beneficial influence, valuable as it must be in connection with the healthfulness of the valley of the Schuylkill, and especially of the City of Philadelphia, through which this river passes, is not of itself adequate to the correction, during periods of drought, of such contaminations as are treated upon in the papers to which we have referred. At the same time, it may be very proper to consider that, during three-fourths of every year the flow of the Schuylkill, instead of being limited to only two hundred and forty-five million gallons daily, is three or four times that quantity.

Delaware River.

It may be assumed that at Easton, ninety-six miles by the river above Philadelphia, the water in the Delaware is as pure as the best river waters, and we know that in its course of sixty miles, thence to tide water at Trenton, it receives a number of pure water tributaries, probably adequate to a thorough dilution of all injurious matters from country drainage which now enter that part of the stream.

The Delaware continues to have a rapid current all the way to tide water. It may therefore with truth be claimed that the natural fresh water flow of the Delaware River meets the tidal waters above Philadelphia, essentially a pure stream, perfectly adapted to the supply of a great city.

The minimum flow of the Delaware at Trenton Falls, is not less than two thousand cubic feet per second, or 900,000 gallons per minute, which in a day amounts to 1,296 million gallons. In general it is very much more, and its average flow throughout the year is calculated at 4,582 million gallons, based on a drainage area of 8,000 square miles, and allowing only eighteen inches, or about forty per cent. of the rainfall to reach tide-water.

With a minimum flow of 1,296 million gallons per day, and an average of 4,582 million gallons, the natural flow of the Delaware acts as a vast conservative power to maintain the upper tidal flow of the river above the City of Philadelphia fresh and pure.

Here is a reservoir of water, thirty-six miles in length, with a width varying between one thousand and three thouand feet, forever moving seaward past the city. No accurate measurements were made by us, nor were they deemed necessary; but from what we know from the coast survey charts, which are reliable, and in a general way, we think it is probably within bounds to assume for an approximate calculation an average width of eighteen hundred, and an average depth of twelve feet throughout these thirty-six miles; which gives a cubical content of 30,792 million gallons. Taking this as a sufficiently near approximation, this would show that with the minimum flow of 1296 million gallons per day, it would take about twenty-four days to fill; or for the total quantity to pass through the thirty-six miles; and with the average flow of 4,582 million gallons, nearly seven days.

Impurities in City Reservoirs:

Subsidence.

In regard to such impurities as are held in solution, it is obvious that when once delivered into the distributing reservoirs, they pass into the circulation through the pipes to the consumers.

Other impurities may or may not enter the circulation. This will depend somewhat upon the arrangement of the reservoir, its area and depth, relatively to the quantity of water daily drawn from the particular reservoir.

If the reservoir be very small and shallow, and containing not more than a day's supply, for example, it is plain that there can be little opportunity for subsidence; but even in such a case, if the reservoir be kept full, or nearly full, the floating impurities might never enter the circulation.

In the case of a large reservoir, holding many days' supply, it is quite different. Time is then afforded for the heavier impurities to settle to the bottom; and if the water is admitted at one end and taken out at the other end of the reservoir, very little, if any, of the heavier particles can pass into the circulation; and we can see no reason why any of the superficial impurities, such as remain on or very near the surface, should ever be allowed to enter the circulation. Only such impurities as are held in solution, and perhaps to some extent, such as have about the same specific gravity as water, are likely to enter the distribution pipes.

Filtration.

It is a frequent remark, that when all other remedies against the evil effects of impure water fail, a resort should be had to filtration. This may be applied for drinking purposes, at the individual or local places of consumption, but is quite expensive in connection with the general distribution of a large city.

Filtration, as explained in the paper of Col. Adams, in the Appendix, does not remove poisonous organic matter which may be held in solution; though all, or nearly all visible impurities may be stopped by filtration. Even the surface impurities may thus be withdrawn from the water, by allowing the basin or vessel to empty itself, as is done in City filtering basins.

It is almost entirely a mechanical operation; there seems to be little, if any, opportunity for chemical action.

Hence, while the ordinary process of filtering on a large scale, removes many impurities, and some which subsidence would not, it cannot be relied upon to remove all injurious matter held in solution.

The remedy, to be effectual, must be preventive. The poisonous impurities must not be allowed to pass into the circulation of the river, unless it may be during strong freshets, when the whole quantity, compared with the immense volume of the stream, would be absolutely insignificant.

Aeration.

This is one of nature's processes for purifying water, not only of the land, but of the ocean, and when bodies of water are deprived of it, other processes are apt to set in. It is therefore desirable that nothing should be done to obstruct this beneficial action.

We have been informed that the cutting of ice, which was formerly allowed on the Fairmount pool, has been prohibited or discontinued.

We would especially recommend that the cutting of ice on the pool be resumed, as an important sanitary measure, on account of the aeration it will afford. If this were done systematically, it might remedy, at least to some extent, the disagreeable odor which we learn is sometimes noticed during the winter.

Saving of Water in Cities.

There are two elements at work in connection with the water supply of large cities; one demanding a liberal supply, almost regardless of cost, the other encouraging inventions for economising the use of water. These are not antagonistical, or need not be.

The city of Boston of late years has paid much attention to guard against waste, in the stoppage of leaks, and by the employment of meters; and it has been stated in the reports of the Water Department, with marked success, having reduced the daily consumption from about one hundred to about sixty gallons.

This method has also, to some extent, been introduced into the city of Brooklyn with beneficial results.

In New York, nothing of consequence has yet been done in that direction, owing, probably, to the circumstance that for more than thirty years the supply has been delivered by gravity through the Croton aqueduct, at an almost nominal cost, if the annual interest on the original outlay be left out. Even now, the quantity furnished in that city, is more than one hundred gallons per day per head of the population, which is now something over one million.

Philadelphia has been furnished with an abundant supply of water, at a very moderate cost, and there has been no reason to economise; but since it has become necessary to employ a large amount of steam-power, which is more costly, the subject of stopping waste is beginning to assume more importance.

One of the methods of securing an ample quantity for all proper uses is by stopping improper waste. That which is wantonly, or carelessly, or through bad management, wasted, may, under a perfected system, if saved, be counted as so much added to the regular supply; so that each consumer who pays for water has a direct interest in the general saving.

Not that the people should be restricted in the proper consumption of the water furnished; because abundance of good water is an important element in a sanitary view; but that all should favor saving arrangements in its use.

If, for example, twenty per cent. should, under ordinary management, be wasted, which, by the introduction of a more perfect system could be saved, it would be precisely equal to twenty per cent. saved to the citizens in the cost of pumping.

Although at present this question may not appeal very strongly to the people of Philadelphia, it is likely, at no distant day, to engage their earnest attention.

This Commission has not, as a body, felt called upon to enter critically into the discussion of particular plans, or to offer specific suggestions on this point; we have intended, in these few remarks, merely to ask attention to an important matter, which is likely to become of more consequence every year to those who pay the cost of the water supply.

Recommendations.

These may be considered in two parts; those relating to the more immediate requirements of the City, and those which belong mainly to the future. Among the former are:

1. The completion of the East Park Reservoir, and connecting it by 48-inch pumping mains with the works at Spring Garden and Fairmount, and by distributing mains of the same size with the Spring Garden, Corinthian, and Delaware Reservoirs.

2. The improvement of the machinery at Fairmount, and the building of two improved turbines.

3. The erection of a pumping engine of 10 million gallons capacity at the Spring Garden Works.

4. Re-arranging the pumping mains at the Belmont Works, and putting in a proper distributing main from Belmont Reservoir to supply the east side of the river.

5. The building of an intercepting sewer on the east side of Fairmount Pool, or of a conduit for purer water from Flat Rock Dam to the pumping works at Belmont, Spring Garden, and Fairmount.

6. The extension of the inlet pipe at the Kensington Works into deeper water.

7. The raising of the Delaware Reservoir six feet.

8. The establishment of a new pumping station at Lardner's Point, with a reservoir at or near Wentz Farm, with proper mains connecting the pumping works with the Delaware Reservoir, and with the new reservoir supplying Frankford, &c.

9. The consideration of the purchase and use of water power at Manayunk, and the construction of the proposed new works dependent thereon.

It is not expected that all of these will be finished in 1876; but enough may be accomplished to improve the quality and add to the quantity of the water supply during the Centennial year.

The completion of them all would both increase the quantity and improve the quality of the water supply of the city, to a very great extent.

Provision for Centennial Year.

To provide for the Centennial year we recommend the immediate completion of the alterations and improvements of the present wheels at Fairmount; the erection of a ten million engine at the Spring Garden Works, the extension of the inlet pipe at the Kensington Works; and the completion of the East Park Reservoir and its connecting supply and distributing mains.

And in view of the delay in building an intercepting sewer; the discharge from the breweries and the sewage in the vicinity of the Spring Garden Works should receive immediate attention.

In regard to the future, our investigations show, that there is only one of the proposed plans for bringing water from a distance which seems to be reasonably practicable, namely, the Perkiomen Reservoir and Conduit scheme, as presented in this report. The proper time for entering upon a work of such magnitude requiring so large an expenditure of money, will necessarily depend in some measure upon the action of Councils on the subject of the works we have recommended to their consideration, and also upon the success which may be met with in maintaining a satisfactory supply of good water by the means we have indicated.

Raising Fairmount and Flat Rock Dams.

It has been suggested by Mr. James F. Smith, Chief Engineer, in his paper contained in the appendix, that the dams at Fairmount and Flat Rock might be advantageously raised, and we commend this subject to the consideration of Councils.

Concluding Remarks.

The present water supply system of Philadelphia, is complicated, yet, as suggested by the present Chief Engineer in his report for 1874, it can be arranged to form a very complete system, by a comparatively small expenditure, as we have indicated.

The Commission have, from the nature of their duties, been called to dwell upon the subject of the quality of the water now supplied to the City of Philadelphia, as well as the quantity, and to refer pointedly to the danger arising from the pollution of waters used for drinking. We would not, however leave it to be inferred that we regard the water supplied to Philadelphia as unwholesome, but would earnestly press upon the consideration of Councils, the importance of maintaining its purity, and of being ready for the unusual demand which is certain to occur during the Centennial year.

In our introductory remarks we have referred to the favorable effect of thorough investigation, discussion, and interchange of individual views, whereby the opinions of the members of the Commission were brought into closer approximation; and we are enabled to present a report which contains an expression of the united views which have resulted in the foregoing recommendations, which are respectfully offered to the consideration of the City Councils.

Such differences of opinion as may rest in the minds of our members we believe to be of a nature which cannot impair the value of the facts stated or of the suggestions and recommendations.

We cannot close this report without offering our thanks to the gentlemen who have aided us in various ways, by furnishing us with information, and otherwise facilitating our investigations. Among these we would particularly mention Mr. Gowan, President of the Philadelphia and Reading Railroad Company, and Mr. Jones, Vice-President, and Mr. Smith, Chief Engineer of Canals, Mr. Clark, President of the Lehigh Coal and Navigation Company, Mr. Graff, Mr. Birkinbine, and Mr. Smedley, Chief Engineer and Surveyor of the City. We are also indebted to Mr. Welch, for valuable information, and to Mr. Emile Geyelin, for his efficient assistance when making measurements of the quantities of water delivered from the Fairmount pumps, and for estimates, &c. We desire also to thank the officers of the Franklin Institute for their kind attention in furnishing rooms in their building in which we have held our sessions, and for many favors extended to us.

Respectfully submitted,

W. MILNOR ROBERTS, *Chairman.*
WM. J McALPINE,
JULIUS W. ADAMS,
WM. E. MORRIS,
SOLOMON W. ROBERTS,
WM. H. McFADDEN, *Chief Engineer of the Water Department.*

Philadelphia, October 7, 1875.

APPENDIX A.

On the Pollution of Rivers, as Applicable to the Future Water Supply of the City of Philadelphia. A paper prepared at the request of the Commission, by

JULIUS W. ADAMS, C. E.

In examining the water resources of this City for the future, the first consideration which should have weight in the selection of a water for domestic uses, when the question was one of several sources equally copious, would be that of their relative purity (without which mere copiousness, or economy in its introduction, would be of little value) as, under no circumstances should the cost of supply for a populous City be weighed for a moment in the balance against purity; upon this, more than upon almost any other circumstance, will depend the health and comfort of the locality, and consequently, to a great extent its prosperity.

It will be unnecessary to enlarge upon the arguments in support of this view of the case, but we shall have frequent occasion to refer to the reports of the thorough investigations of the British Government into the health of towns, from which we shall see that the rise, prevalence and fatality of many contagious and even common diseases, have been traced directly to an impure water supply. We shall therefore first consider this question of purity, with such light as we are enabled to command, independently of any considerations as to cost.

The first question then is, what constitutes a pure water for practical purposes, for it is well known that all natural waters contain more or less of substances, which under certain relations may be considered as impurities, and the best we can hope for, is to select a water *relatively* pure.

The constituents of pure water to the unaided eye, are transparency, absence of positive taste and smell, and without particles in suspension, and without exhibiting any sediment upon standing; and yet a water may possess all of these in an eminent degree, and not be a safe water to drink, and hence we must have recourse to some other method to detect the hidden impurities, and also to determine whence the impurities have arisen, and to what extent they may be allowed to be present without danger. And hence, whilst the discrepancies in the result of analyses of waters by chemical experts of equal scientific attainment and experience, would, very naturally tend to weaken our faith in the value of such investigations, we must bear in mind that such analysis is our only guide to the hidden ingredients of a compound body, and however chemists may disagree in the inferences to be drawn from a given analysis, or in the nomenclature which they may individually see fit to employ, or in the detailed methods of their analysis, yet there are broad grounds upon which, with slight exceptions, they all agree, and it is within these limits that we shall confine our present investigation, referring for the facts and figures in the composition of drinking water, to the report of a late course of lectures delivered by Professor W. A. Corfield, M. D., before the School of Military Engineering, at Chatham, England, on the Water Supply of Cities and Towns.

Natural waters contain dissolved carbonic acid gas, which has the property of holding in solution quantities of certain salts, much greater than the water would otherwise retain in solution; and one of the most prominent of these is a salt of lime, dissolved in carbonic acid, forming the carbonate of lime; they contain, also, frequently sulphates of lime, soda, magnesia, iron, &c.; they also contain phosphates, chlorides, and nitrites, even rain water contains the latter, and salts of ammonia are found in almost all waters; we call in chemical analysis here to determine how much of either, or all of these, a water may contain, the source from which they have probably arisen, and the quantity which may, without injury, be allowed in a potable water. Some misapprehension exists as to the relative value of soft and hard water for domestic uses. It may be sufficient to state, under this head, that a moderate degree of hardness in water is not considered prejudicial to health, but merely in its economic value.

For washing and other domestic purposes, the use of hard water is attended with a waste in soap, tea, coffee, and chemicals to correct the defects growing out of the hardness, which, in the aggregate, assumes quite a formidable appearance.

Mr. Bateman estimates the saving to the people of Glasgow, in the introduction of the soft water of Loch Katrine, at £36,000 per annum, and states that the use of such a water in London, would save its inhabitants yearly a sum of no less than $2,000,000, in soap, soda, tea, coffee, and chemicals. The hardness of the London water averaging about 16° in every gallon of water used in washing, destroying or rendering valueless *one-third* of an ounce of soap.

On the other hand, Mr. Bateman shows, that in 65 towns in England, the death rate decreased nearly in the direct ratio of the increase of hardness of the water used, up to 16° of hardness. Observations elsewhere fail to confirm this view, and indeed there are so many other conditions that affect the mortality of large towns and cities, that no argument can be drawn from such statistics in favor of, or against a hard water.

It may not be amiss to consider in this place, and explain what is meant by a hard water, and how to remedy its defects.

Water containing certain salts in solution, notably those of lime, magnesia, and iron, do not dissolve the soap perfectly nor make a lather, as do soft waters, but it forms with these salts insoluble precipitates, and the amount of soap which is required in order to make a lather with the water, is taken as the test of the amount of these salts present, and which causes the hardness so called of the water; one degree of hardness expressing that a gallon of the water contains in solution, an amount of these salts, which would precipitate as much soap as would a grain of carbonate of lime in the gallon of water. It is common in analysis of water, to refer the results to parts in 100,000, and a water containing 1 pound of carbonate of lime, or its equivalent of other hardening salts in 100,000 pounds, is said to have one degree of hardness; each degree of hardness in this scale, indicates the destruction and waste of 12 pounds of hard soap by 100,000 pounds of water, when used for washing. On such a scale the London water for instance would be represented by 20, and as a grain per gallon is one part in 70,000 (imperial), if we multiply the degrees of hardness in this latter scale by 7, and divide by 10, we will have the degrees expressed in Clark's scale of degrees or $\frac{20\times7}{10}=14°$, the London water by Clark's scale. Up to 6° of hardness by Clark's scale, or $8\frac{1}{2}$ per 100,000, a water is considered soft. Hard water is made softer by boiling, the carbonic acid being driven off, and carbonate of lime precipitated. What is called the "permanent" hardness of water, is what remains of hardness after boiling, and is so far an important fact to know, as it is measurably due to salts which are injurious, such as sulphate of lime, chloride of calcium, and magnesian salts, and hence a water of "permanent hardness," is an objectionable water. The chlorides in water may possibly indicate sewage contamination, and are hence grounds for suspicion. Common salt (chloride of sodium) may come from infiltration from the sea, or a strata of common salt, but sewage contains it in considerable proportions, as it is found in urine, and all excretal matters. Pure natural water may contain about a grain of chlorine in a gallon, or one part in 100,000, but the average of sewage in water closeted towns, is ten parts in 100,000, and water which contains more than one grain in a gallon, or more than one in 100,000 of chlorine, may be suspected as being contaminated by sewage, more especially if the water has been exposed to known sources of such contamination. Making every allowance for the possibility of salt being present in the soil through which the water flows, the presence of chlorine in the proportion above stated, is a good test of the purity of a water.

Nitrates and Nitrites.

The presence of nitrates and nitrites in water indicates that it comes in most cases (if not in all) from the oxidation of organic matter in some form or other, and is characterized as "previous sewage contamination;" in rain water even small quantities of it appear, and its presence alone is not of itself a sufficient reason for rejecting a water, but it will be perceived, that while the nitrates or nitrites may not in themselves be injurious, yet they give reason to suspect that the waters containing them in solution have at some previous time been contaminated with organic matters to a large extent, which organic matters becoming oxidized, resulted in the production of nitrates and nitrites,—hence, if the water contains much of these, the probability is that if derived from a source liable to contamination from refuse matters, we are exposed to the possibility of their appearing at times in solution in their unoxidized form, in which shape they are highly objectionable.

The London drinking water contains 2 in 100,000 parts, while wells deriving their supply of water from sewage saturated soil, contain sometimes over 8 parts in 100,000. Unless the water under examination comes from a source which is beyond the suspicion of sewage contamination, the presence of nitrates and nitrites in large quantities, should lead to its rejection for domestic use.

Salts of Ammonia.

These are found in exceedingly small quantities in natural waters, but also come directly from sewage. The amount in a proper drinking water should not exceed from .001 to say .005 parts in 100,000. Sewage contains about 6 parts to 100,000, and any water containing by analysis salts of ammonia in greater quantity than is represented by the second place of decimals in parts of 100,000, may be relied on as impure water, charged with organic matters. These latter organic matters, whether present in suspension or solution, are in analysis represented in two different ways: In one. as so much organic carbon, and so much organic nitrogen,—the other, consists in the conversion of the organic nitrogen, or a considerable part of it, into ammonia, and then is estimated as so much ammonia.

The British Rivers Pollution Commissioners have given by the first method of analysis, two parts of organic carbon in 100,000, or three parts of organic nitrogen in 100,000, not as a standard for drinking water, but of a water that shall be considered as polluting any water course into which it is turned. The second method of analysis, known as "Wanklyn's Method," taking advantage of the known delicacy of the test of ammonia, represents the product obtained by that analysis as "albuminoid ammonia," and for a drinking water, it should not appear above the third place of decimals in parts of 100,000. If in the first place, or two parts in 100,000, it is decidedly bad water, and indicates a considerable amount of organic matter in a state of solution. The albumenoid ammonia represents about ten times its weight of dry organic matter, and about forty times its weight of moist organic matter; so that .05 of albumenoid ammonia in 100,000, represents about two parts of moist organic matter in the water.

Briefly then, in considering the analysis of waters, the presence of nitrates should condemn a water with much organic matter in it. The ammonia does the same, and the chlorides are especially to be regarded with suspicion, if you have not good reason to suppose that they come from some other source than one liable to sewage pollution.

The danger of organic matter consists in the fact that it is organic matter in a state of rapid putrifactive change, and that it may, and often does contain (especially if derived from excremental matter) the poison of specific diseases, which it is known may be disseminated in a drinking water to a population.

There are three obvious sources of water supply to this City: First by pumping from the Schuylkill River; Second by pumping from the Delaware River; and Third, some intermediate affluent of one of these rivers, delivering the water by gravity into the City.

The undoubted excellence of the natural Schuylkill water, has given it so high a reputation in years past, as to render it a very thankless task for any one to attempt to lower in the public eye that long received standard of excellence, but our duty would be illy performed, did we not call attention to the source of pollution now existing, and daily augmenting, tending to render the water, at no distant day, utterly unfit for domestic uses, and although it may be said that no pollution can threaten the water of this river, which proper legislation is not competent to prevent or remove, yet it must be considered whether it would be a wise policy to interfere by stringent legislative enactments with the free use of these waters for mechanical purposes, thereby restricting and hampering the further development of one of the principal sources of the material prosperity of this city, and also, largely of the State; were this the only source for pure water to be had for the City at a reasonable cost, the case would be different, but, as before remarked, it being but one of several sources equally pure in their origin, the effort to retain the water in a condition suited for domestic use in the City may prove neither a wise policy nor a successful one. In England, from necessity, the greatest efforts have been made to secure the purity of streams. In examining the English reports on the subject, no one can fail to see that the laws cannot be so enforced as to effect the desired result. The most stringent regulations are made by Parliament at the instance of "Rivers Pollution Commissions" and "Sewage of Towns Commissions," but the rivers continue dangerously foul in spite of them; the temptation to use the streams as sewers is stronger than the fear of the law which seeks to protect them.

Waiving any speculation on this point however, and coming to the facts, we gather from the late Reports of the Water Department, as well as from our own observation, that the foul refuse from the various manufactories on the river, the slaughter-houses and other sources of impurity incident to a dense population on its shores, is now poured into the river without stint, rendering it the common sewer for all settlements and industries on its banks; and on page 38 of the last Annual Report of the Water Department, we find it reported, as stated by Dr. Cresson, that "since February, 1872, the sewage in the Fairmount pool has been steadily increasing, until the water is occasionally charged with an amount of sewage exceeding that carried by the River Thames at London, and is totally unfit for use, and unless some precautions are taken to prevent the influx of this great amount of sewage of animal matter into the sources of supply, we may certainly expect to have our City visited by some epidemic scourge."

It is needless to multiply evidence to the effect that the water of the Fairmount pool, is, at times, from the amount of refuse, from the slaughter houses, breweries, and above all, the manufactories at Manayunk, not a proper water for domestic use. This is conceded by all who have examined it.

We propose to show that even were the Fairmount pool purged of the foulness now received below Manayunk, the same, or similar causes for pollution, with increased difficulties of prevention, are in exercise in the upper pools of the river, tending to its ultimate foulness at an early day, and hence that remedies for purifying the river, if made at all, should extend throughout the valley, or at least to such reaches of the river as are likely to become, in the future, more densely populated, or crowded with manufactories, than at present.

The Schuylkill, taking its rise in the mountainous coal-bearing regions of Schuylkill County, receives large accessions, in its descent from the mountainous district, for a distance of some 25 or 30 miles, when it enters a more highly cultivated country, and the slopes of the river become more gentle. Port Carbon, in the mining district, 108 miles from Philadelphia, is some 618 feet above tide, while Reading, which is 64 miles from Philadelphia, is 187 feet above tide. Near Reading several large tributaries enter the river, their waters largely impregnated with lime, the neutralizing effects of which will be noted subsequently.

The region drained by the river is estimated at something over 1,800 square miles, of which 1,200 square miles is below the mining region, a large portion of which is a highly cultivated, populous, and thriving region. Several cities and towns, numbering about 20, occupy closely its banks, and have many of them become centers of manufacturing interests, and are estimated to contain at present an industrious population of over 100,000, Reading alone containing nearly 40,000 people; and, in addition to the enormous coal mining operations of the upper Schuylkill, iron banks have been opened, and iron furnaces built upon its margin; cotton factories, carpet and dye works, woollen and hat manufactories, paper mills, tanneries, chemical and gas works, breweries, and indeed the advantages of the location are so obvious, that almost every branch of manufacture has found a convenient location on its banks, and some of them on a scale not exceeded by any in this country; nor should the recognized influence of railroads on the banks of rivers be lost sight of, in estimating the future probable distribution of the population and industries of this valley.

From the ninth United States census returns, it appears that the area draining into the River Schuylkill above Philadelphia County contained in 1870 a population of 300,000, and that the increase of the entire State of Pennsylvania for the previous ten years was at the rate of 21.3 per cent. From the proximity of the towns on the Schuylkill to Philadelphia, the readiness of communication between them and the metropolis, the character of the country, its manufactures and industries, Philadelphia itself cannot be expected to increase in wealth and population to the extent anticipated, unless this valley, teaming with all the elements of prosperity, beyond that of any similar area in the State, increases in even a greater ratio than the entire State itself. It will be a moderate estimate then to assume for the increase, 20 per cent. each for two decades, and 15 per cent. for each of the next two decades, or 70 per cent. in 40 years. This will give a population on the water shed of the Schuylkill, above Philadelphia County, of 510,000; adding to this the population of the City, estimated as draining into the Schuylkill, viz.: 18 square miles of City area, 450,000, and we have as the total population on the drainage area of the river 40 years hence, 960,000, or say a million. As wealth and luxury increase in the river towns, and a better knowledge of the laws of health prevail, sanitary improvements would be the first to demand attention, and a water supply would of necessity be accompanied or followed by a better system of drainage and sewerage of the several localities.

Indeed steps in this direction have already been taken, and Reading, Pottsville, Phœnixville, Norristown, and Conshohocken, representing a population of about 75,000, have their systems of water works, and in most of these towns, sewers to the river are either projected or being built, which in a short time will render the entire refuse from them tributary to the river, as will be the case from the entire population of the settlements on the immediate river banks. That is to say, of the anticipated population of the entire valley, that part of it which will occupy the immediate shores of the river and its tributaries, we may estimate as discharging all its refuse into its natural receptacle, the river—or in the future, the river will be the main sewer for at least 300,000 inhabitants above the county line of Philadelphia.

The sewage from a single individual yearly, undiluted with water, may be estimated at 1,028 pounds. The following table, compiled from observations of * Wolf and Lehman, will show the amount of undiluted sewage from a population of 300,000, divided in the usual proportion of men, women, and children.

* P. 27, Report of River Pollution Commission, 1868.

Aggregate weight in pounds averdupois of solid and liquid excrement, furnished yearly by 300,000 inhabitants, divided in the average proportion of men, women, and children.

Population.	Solid Fæces.	Organic Nitrogen	Phosphates	Urine.	Organic Nitrogen.	Phosphates.
300,000	21,818,832	321,552	452,592	282,354.167	2,530.416	835,680

We ordinarily estimate that in cities the refuse from stables, kitchens, laundries, slaughter houses, animals of all kinds, all refuse in fact save that from dwellings, equals at least that from the inhabitants. In addition to this, we have in the present case, the fertilizers from the cultivated land, and the decayed products of vegetation, which the action of the rains brings to the water courses, and the carrion thrown directly into the streams (which I am assured is no inconsiderable item), but neither of these latter admit of being estimated with any degree of accuracy, and are in consequence omitted, and we come to the various branches of manufactures which seek the immediate shores of the river for the more ready disposal of their refuse.

It has proved extremely difficult to obtain the extent of the polluting elements poured into the river from the various manufactories on its banks, and but little has been effected in this direction, beyond obtaining the number, names, and purposes of the various establishments, and we can scarcely hope that the list is by any means complete. Some assistance has been derived from a paper prepared, but not published, under the auspices of the Commissioners of Fairmount Park in 1868, giving the daily amounts of material consumed in the various manufactories located on the river within 10 miles of Fairmount Dam, and the amount of sewage discharged therefrom; and from this, and a list believed to be authentic, purporting to embrace all the manufacturing establishments of any note on the river, extending as far as

Pottsville, and Tamaqua on the Little Schuylkill, and other sources, we estimate that the refuse discharged into the river from the various manufactories enumerated between these limits, comprising 14 tanneries, 29 woolen mills, 15 paper mills, 5 hat factories, 7 gas works, 22 cotton mills, 11 dye and print works, 4 soap works, 8 breweries, 2 oil works and refineries, 2 shoddy and sack works, wood-paper, pulp, super phosphates, glue, morocco, wadding, distillery, boot and shoe, cement and copper works, being in all 115 establishments, amounts to 15,000,000 gallons daily. This is exclusive of any discharge from 57 collieries, and 76 anthracite furnaces, or from the numerous cess pools, slaughter houses, or cemeteries located on the banks, the drainage from which ultimately reaches the river in some form. We are unable to determine precisely the character of the pollutions from these sources, but from the paper prepared for the Park Commissioners, we are enabled to state that the materials consumed in the manufactories embraced in their examination in the neighborhood of Manayunk, comprise the following ingredients used in varying proportions: Oil, bleaching powders, soap, lime, soda ash, potash, and aqua ammonia, alum, blue-stone and copperas, iron liquor and nitrate of iron, nitrate of tin, cream of tartar and argill, acetate and nitrate of lead and litharge, bicromate and prussiate of potash, analine salts, glue, pyroligneous acid, oxalic acid, muriatic acid, oil of vitriol and aqua fortis, and various dye stuffs, as cochineal, lacdye, indigo, catechu, logwood, cudbear, fustic, sumac, quicitron bark, madder, &c. It is very true that all these ingredients are not carried off bodily in the waste; some of them are, however, and the compounds of all of them; nor are they all noxious, but they represent fairly the nature of the manufacturing operations on the river, from which we may anticipate in the future increase of these operations, an amount of material amply sufficient to render the purest water, if not deadly or unwholesome, at least an undesirable beverage.

Looking to the future population of the Schuylkill Valley, and the increase in manufactures to be anticipated on its banks, it is safe to predict for the latter, an increase of 100 per cent. in 40 years, and from the estimated population of nearly a million of souls in the valley, at least 300,000 as resident in the towns and villages in close proximity to, and discharging their refuse directly into the river and its tributaries above Manayunk; this would furnish daily, according to the table on page 68, 415 tons of undiluted human sewage, in addition to the same amount of animal and vegetable refuse, and over 15 millions of gallons of manufacturing refuse; and upon the supposition that the sewage from this latter refuse is $\frac{1}{100}$th of its bulk, and that the minimum flow of the river is 245 millions of gallons daily, this will amount to one pound of concentrated sewage to each 80 gallons of water. This is disregarding the contamination from manufactories or population at or below Manayunk.

It should be remarked in this connection, that of all kinds of refuse, human sewage is the one most to be feared. Similar in kind, but less in degree, are the washings of clothing, and the filthy rags supplied to paper mills. "Next in order, but of a different kind, are waste liquors, containing animal matters, especially such as are in a state of decomposition. First among these are tanneries and slaughter houses, whose waste liquors are said to possess from five to ten times the manurial power of average sewage.* Next are glue factories, wool screenings, shoddy and woolen mills and soap works, others are principally dirty or offensive; while dye and chemical stuffs, form the principal pollution of a large class of works, and enter secondarily into the waste products

*Report of Medical Commissioners on Sanitary Qualities of River Waters, Boston, 1874.

of many other industries; but it is plainly desirable on sanitary grounds, to avoid the admission to drinking water of *any* kind of filth or refuse matter. Let authorities differ as to what constitutes pollution, and as to the degree and kind of danger to be apprehended from a particular sort, they are in the main agreed, that the contamination which ordinarily occurs, may impair health and predispose to disease, even if they do not produce a direct and specific effect."

"Testimony can be multiplied to almost any extent in support of the position, that manufactory refuse renders water unfit to drink, and we should condemn the admission of all filth, without waiting for scientific reasons, or demonstrative proof. That which is in any way offensive to the sight, taste, or smell, or the sense of decency or propriety, has no more right to a part in the composition of our drinking water, than those substances which are actually proved to be deleterious to health."

"The effect of some forms of manufacturing refuse upon the lower animals has been noted. It is well established that tanneries, paper mills, and gas works, kill and drive off fish, notwithstanding certain species of animals seek out and thrive upon some forms of filth. The effect upon vegetable life on the other hand is no evidence of the purity or impurity of a water supply. Sewage in some situations may cause a rank growth, while in others it kills. Nor is the neutralizing effect of the discharges from chemical works, nor their accidental destruction of the low forms of organic life associated with putrifactive changes, to be at all depended upon. Experiments reported upon at a meeting of the Association of Medical Officers of Health, London (Lancet, 1872), show that chloride of lime or bleaching powder, instead of stopping, actually promoted the decomposition of the albumen liquid. Vibrios were formed in great abundance, but no fungi—acids promoted the formation of fungi, particularly the sulphuric and acetic. Alkalies promoted the formation of vibrios and prevented the growth of fungi. Soda produced little or no effect, and ammonia and lime promoted the putresence and had very little effect on the microscopic life."

According to the reports of the Water Department of Phila. the impurity in the form of sulphuric acid, from the drainage of the coal mines amounts, at Schuylkill Haven, to near 10 grains in a gallon, an amount destructive to all animal life in the water above Reading. It seems however, that near the latter place, three creeks, the Ontelaunee, about 6 miles above, the Tulpehocken and Wyoming creek, at Reading, drain magnesian limestone regions, and thus tend to neutralize the effect of the sulphuric acid by forming sulphate of lime and magnesia, at Reading, reducing the amount of the acid per gallon to 2.65 grains, and below Valley Creek, at Valley Forge, the amount is said to be reduced to 1.5 grains per gallon, or about the same as at Fairmount Dam. The analysis of the water at Fairmount in the years 1842, 1854, and 1865, gave respectively 302, 1.417, and 1.508 grains to the gallon, whilst the lime remained about the same; the magnesia also increased steadily from .230 to .835 in the same interval.

While we are unable to indicate the precise degree of impurity resulting from these ingredients in the water, we perceive they have always been on the increase, at a less rate than formerly, but still increasing. A fraction of a grain more per gallon of sulphuric acid (giving a total of 2 grains) we know would be harmful, nor is sulphate of magnesia (Epsom salts) desirable in ordinary drinking water. The continuance of the present proportion of sulphuric acid, or its diminution is looked for by the advocates for the use of the Schuylkill water, in the probable less amount of coal mined in the valley in years to come, than formerly; but though deep mining is not as profitable as surface mining, yet the limited extent of the anthracite coal fields, and the increased demand for their products, will lead to the application of improved machinery and processes for the extraction of the coal; and until the last ton is mined (it may be a hundred years hence) in the Schuylkill coal basins, these will continue to yield coal, and the drainage of the mines will continue as at present, to furnish sulphuric acid in possibly decreasing quantities; at all events, in the changes which the future will inevitably bring about in the artificial condition of the Schuylkill River, consequent on increase of population and industries on its banks, we cannot predict that the happy balance which is said to obtain now in the quantities and qualities of the polluting elements in the waters, whether from the mines or the manufactories, and which possibly tend now in a certain degree to neutralize each others noxiousness, will always preserve that fixed relation to each other so essential to their harmlessness in the drinking water of a great city. I give no technical chemical name to the pollution. To analyze a water 40 years in advance of its existence, would be absurd. I have, therefore, contented myself with indicating in general terms my estimate of the extent of the pollution which may be anticipated at that day. To seek for the precise scientific term by which chemists would characterize this pollution is scarcely called for, when we have the fact that over 500,000 thousand tons of the most active putrescible agent known, may be estimated as discharged yearly into the stream from which it has been proposed to supply the City of Philadelphia with drinking water in the future.

J. Simons, F. R. S. and medical officer to the Privy Council in his evidence on the water supply of London, in reference to the pollution of the River Thames, says, and it is applicable here: "Nothing which chemists in the present state of their science can report (negatively) as to their findings, will alter the fact of that filthy admixture, and I know that that fact represents a certain amount of danger to the population that receive the water." Various remedies have been proposed to meet the present difficulties of the case, and to restore and maintain the river in its original purity. All assume however, that the river is not exposed to injurious contamination beyond the limits of the County of Philadelphia; and all are based upon what we consider the following fallacies.

First. That the aeration of water by its motion over weirs or through long channel-ways, favors the oxidation of the organic matter of sewage held either in suspension or in solution, to the degree of rendering them wholly innoxious as poisons, thus destroying or rendering harmless the germs (whatever they may be) of typhoid fever, cholera, or other diseases.

Second. That either the palatability, or the apparently harmless use for an indefinite time of a water, or the results of its chemical analysis, are either, or all of them, safe guides to the selection of a water for domestic use.

Upon the unsoundness of the veiws entertained by some chemical experts, but which we have characterised above as fallacies, depends the correctness of our estimate of the future impurity to be apprehended in the water of the Schuylkill; and our opinion is based upon the results of the labors of the several commissions, appointed from time to time by the British Government, to enquire into the present and future water supply of London, and the subject of the pollution of rivers; and we feel constrained to quote freely from these papers, as the most convincing evidence we can offer on the question at issue.

This question of the pollution of rivers, has for obvious reasons, until very recently attracted very little attention, in our comparatively sparsely settled country, and the investigations of our men of science into the subject, have been for the most part very limited in extent, and entirely incidental in their character, and hence their opinions on the subject can scarcely claim the consideration which we are led to accord to those emanating from men of equal or greater celebrity elsewhere, when investigating a subject to which popular opinion, as well as legislative enactment, has attached a national importance.

From the River Pollution Commission ordered by the British Parliament in 1868, Sir Wm. T. Denison, and Drs. Frankland and Morton being commissioners, we quote as follows, as to the value of the aeration of river water:

"It has often been stated, but so far as we know without any proof, that the organic matter contained in sewage and other similar polluting materials is rapidly oxidized during the flow of a river into which such materials are discharged. Thus it has been asserted (Report of Royal Commission on Water Supply of London, p. LXXIX), that if sewage be mixed with 20 times its volume of river water, the organic matter which it contains will be oxidized and completely disappear whilst the river is flowing, 'a dozen miles or so.' We thought it very undesirable that a subject of such vital importance to our inquiry should any longer rest upon mere opinion, and we therefore determined to submit it to careful experimental investigation."

After citing the experiments, they add:

"It is thus evident that so far from sewage mixed with 20 times its volume of water being oxidized during a flow of 10 or 12 miles, scarcely two-thirds of it would be so destroyed in a flow of 168 miles, at the rate of one mile per hour, or after the lapse of a week. But even this result is arrived at by a series of assumptions which are all greatly in favor of the efficiency of the oxidizing process.

"Thus, for instance, it is assumed that the 62'3 per cent. of sewage is thoroughly oxidized and converted into inoffensive inorganic matter, but the experiments showed that, in fact, no sewage whatever was so converted or destroyed, even after the lapse of a week, since the amount of carbonic acid dissolved in the water remained constant during the whole period of the experiment, whilst if the sewage had been converted into inorganic compounds, the carbonic acid, as one of these compounds, must have increased in quantity. Thus whether we examine the organic pollution of a river at different points of its flow, or the rate of disappearance of the organic matter of sewage when the latter is mixed with fresh water and violently agitated in contact with air, or finally the rate at which dissolved oxygen disappears, in water polluted with 5 per cent. of sewage, we are led in each case to the inevitable conclusion, that the oxidization of the organic matter in sewage proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water, and that it is impossible to say how far such water must flow before the sewage matter becomes thoroughly oxidized. It will be safe to infer, however, from the above results, that there is no river in the United Kingom long enough to effect the destruction of sewage by oxidation."

These results confirm the opinion arrived at from theoretical considerations, and expressed by Sir Benjamin Brodie, in his evidence given before the former River Pollution Commission (first report, river Thames, vol. ii., Minutes of Evidence, page 49); his evidence was to the following effect:

"I should say it was simply impossible that the oxidizing power acting on sewage running in mixture with water over a distance of any length is sufficient to remove its noxious quality. I presume that the sewage could only come in contact with oxygen from the oxygen contained in the water, and also from the oxygen on the surface of the water, and we are aware that ordinary oxygen does not exercise any rapidly oxidizing power on organic matter. I believe that an infinitesimally small quantity of decayed matter is able to produce an injurious effect upon health. Therefore, if a large proportion of organic matter were removed by the process of oxidation, the quantity left might be quite sufficient to be injurious to health.

"With regard to the oxidation, we know that to destroy organic matter, the most powerful oxidizing agents are required; we must boil it with nitric acid and chloric acid and the most perfect chemical agents. To think to get rid of organic matter by exposure to the air for a short time is absurd."

*"Although, however, the flow of a river has thus but little effect in purifying the water by the oxidation of the dissolved organic matters, it has a most material influence in the removal by subsidence of a large proportion of the suspended impurities, both organic and mineral, especially if the flow be sluggish in places. In passing through still pools, the turbid stream lets fall its load of grosser mechanically suspended particles, and thus the water becomes clearer although the dissolved impurities remains nearly as great as ever. It is doubtless this clarification by subsidence which has led to the very general but erroneous belief in the rapid self-purifying power of running water.

"It must be remembered, however, that the mud so thrown is only deposited, not removed or rendered innocuous. During floods it is stirred up and again becomes very offensive; and when the temperature of the water rises in summer, the sediment enters into active putrifaction, evolving nauseously smelling gases, which buoy up large flakes of the mud, causing them to rise to the surface, and rendering the river

* Rivers Pollution Commission. Commissioners' Report.

offensive to sight and smell, if not actually injurious to the health of the neighboring inhabitants. We have submitted to analysis several samples of such mud, and find that they contain a large proportion of putrescible organic matter."

It should be recollected, in this connection, that the numerous dams (31) on the Schuylkill are favorable to the very state of things above referred to, in the deposition of sewage in the still water of the pools, not so palpable at present in the pools above Flat Rock, but the increase in manufactures, and the denser settlements on its immediate banks, which in the nature of things, is sure to take place, will bring it about. We quote from the evidence of Dr. Frankland, Professor of Chemistry in the Royal Institution, and the Royal School of Mines, England.

* "In the first place, when water is once contaminated with sewage, there is no process to which it is afterwards subjected which will effectually remove all that sewage contamination from the water. Filtration will not do it in certain cases, at all events. I have proved that the excrements of cholera patients cannot be filtered out of water, that after a degree of filtration which I believe is never attained by the water companies, and rarely obtained perhaps by the passage over soils in irrigation, this water still remains opalesant from the rice-water evacuations with which it is mixed.

"I believe that the noxious parts in sewage is that which is held in mechanical suspension, not held in solution. I would not say it is impossible to remove it, but no system of filtration will secure its removal. There are only two processes by which it can be effectually removed, the one is by boiling for a long time, and the other is by distillation; and therefore it is that I say that inasmuch as those two processes are impracticable on a large scale, in my opinion, water that has once been contaminated by sewage, ought not afterwards

* Royal Commission on Water Supply.

to be used for domestic purposes, and inasmuch as it is generally believed that the noxious matter of sewage exists there in the form of minute germs which are probably smaller than blood globules, I do not believe that even filtration through a stratum of chalk could be relied upon to free the water perfectly from such germs.

*"The sewage would be, during its course, to a certain extent, oxidized and destroyed, and resolved into other compounds, but how shall we say that all the sewage is resolved and destroyed, so that the water should be safe? To do that, we must be able to apply some extremely sensitive test to the water, which would enable us to ascertain the presence or the absence of sewage in it, and I want to know what the test is which we are so to apply.

"There are causes operating, as we all know, to destroy the sewage which, to a certain extent, will effect that end, but the question as I understand it is, whether those causes are really adequate to destroy the sewage, not partially, but absolutely and entirely, during a given course of the river.

"I think what is asserted by Dr. Frankland is true, that there are no known causes in operation on which we can adequately rely to remove the sewage from the water. That causes are in operation which partially remove that sewage and diminish its injurious effects, is true, but the question is whether those causes are adequate to produce a complete result; that is to say, whether they will take out of the water all the injurious matter which is contained in it, so as to render it fit for drinking. I do not think it possible in the present state of our knowledge to pronounce an absolute opinion upon that point. But if you ask whether it is wise to drink water into which you have put sewage, knowing that you have no means of getting that sewage out of it,

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* Sir Benj. Brodie. Evidence before Water Supply Commission.

that is a question which any one can answer for himself, assuming always the injurious character of sewage. I am not now pronouncing any opinion upon that point, or saying in what degree sewage is injurious; it does not appear to me to be a chemical question; I think that is a question of very great importance, but which is more likely to be solved by other agencies than by chemical experiments. Medical statistics will tell you more about the injurious or non-injurious character of sewage water than any analysis would do. It does not seem to me that we have, as I before said, any accurate chemical measure of the sewage in the water; at all events I do not know what that measure is. I have read the evidence which has been given by Dr. Frankland and one or two other witnesses also before this Commission, but I still hold to my opinion that we have no accurate measure of the sewage matter in the water, or even of the previous sewage in the water.

"Another most important thing is this: that really there is no reason whatever to believe that the injurious character, either of sewage or of the gases from a drain, depends fundamentally upon the quantity of that sewage or of that gas. In all probability it far more depends upon the quality of the sewage, namely, what it consists of. Now, what is the nature of the poisonous matter in the atmosphere or in the sewage? We do not know that at all.

"Therefore how can you possibly say when that poisonous matter is got rid of from the water or from the air. It is a question that with the means at our disposal, it is absolutely impossible to answer; and I say, as I said before, that I think you have a much better chance of getting at these relations, through accurate statistics properly applied, than you have through chemical analysis, because chemical analysis is one of the poorest things possible to reach those delicate quantities. You cannot get at those small quantities at all; chemical analysis must be limited by our power of weighing and measuring. We can only do those two things. We can weigh and we can measure, and we can do that with certain accuracy, and there we stop; but that accuracy is not capable of being multiplied *ad infinitum*. It may go on to a certain point, but we cannot go beyond that point. I think it is impossible absolutely to answer those questions, for we have not the data; but the question arises, as I said before, whether a prudent person likes to drink water which contains a certain quantity of nitrates and nitrites, or that when analysis is found to contain a certain quantity of organic carbon and nitrogen, water into which you have deliberately put cartloads of sewage at some time or other in its course.

"What I think is much more important still is another point, namely, the great dilution of the material, and I should rely upon the dilution quite as much and more than upon the destruction of the injurious matter. I say that partly from experience, and partly because I have had occasion myself very frequently to observe the vast importance in chemical changes of what people so frequently pass by as inappreciable quantities of matter. Indeed, I have occasion to see more and more every day that minute portions of matter, which previously were not suspected at all to exist, exercise important influences on chemical transformations."

"The injurious character of a water" impregnated with sewage matter, might not be discovered for years. You might long go on using it for years, and it might not be discovered, and you might have some outbreak of disease in the place, which nevertheless might be connected with the use of that sewage water.

"I think that chemical analysis is yet not sufficiently advanced, to pronounce a decision upon the matter, and that you have a better chance of getting at the real connection, between the injurious matters in the water, and diseases generated by those matters, through statistical observations, carried on upon a larger scale, than through chemical analysis. Statistics elicit relations of cause and effect, on which you cannot deliberately experiment.

* "The presence of organic nitrogen may be derived from substances which are quite harmless, or it may be derived from substances which are very injurious, and we have no means of distinguishing between the two. Nitrogen is always present in such combinations, not as nitrates, and not as ammonia, but the presence of nitrates is always a suspicious circumstance in water, and the greater the quantity of nitrates, the more suspicious is the nature of the water, and the more reluctant one would be to use such a water, as a source of supply.

"Whenever chlorine is high in the water, it is necessary to look for nitrates derived from sewage, and as a rule, it is so constant, that there is scarcely any exception. When we find more than the average quantity of chlorine in a well water, nitrates are found also, and if the water in a district is pretty well known, that is to say, if the amount of chlorine in water from any district is pretty well known, and specimens of the water should indicate rather more chlorides than usual, you may conclude with almost certainty that it is from sewage.

† "In the coal districts, however, and in saliferous portions of the new red sand stone districts, wells do not often furnish drinkable water, and then the dependence fall upon rivulets and streams, which when taken near their sources, where they contain only the drainage water of upland pas-

* Dr. Miller, Prof. of Chemistry. Evidence before Water Supply Commission.

† Report of Commissioners, Rivers Pollution Commission, 1868.

tures, afford a perfectly satisfactory supply. Lower down they necessarily contain the drainage of houses, villages, and cultivated fields, and their water cannot then be taken without risk, for no process has yet been devised of cleansing surface water once contaminated with sewage, so as to make it safe for drinking. It is therefore advisable to adopt as generally as possible the mode of collecting into reservoirs for household purposes the water from the high lands along the edge of the great valleys, or from such other collecting grounds as may be most convenient.

"The previous animal contamination of water, as deduced from chemical analysis, must therefore always be regarded as a minimum quantity: it does not represent the comparative freedom of different samples of water from anterior pollution, but whenever analysis shows this excess of nitrogen, in the shape of nitrites, nitrates, and ammonia, the water stands convicted of previous contamination to the extent so indicated.

The importance of the history of water as regards the anterior pollution with organic matters of animal origin, does not arise from the presence of the inorganic residues (nitrates, nitrites, and ammonia) of the original polluting matters, for they are in themselves innocuous; but from the risk lest some portion of the noxious constituents of the original animal matters should have escaped the decomposition which has resolved the remainder into innocuous mineral compounds. And the danger is more to be feared because it is quite impossible by chemic analysis, or indeed by any other process of investigation short of administration of the water to human beings, to discover whether or not such noxious substances are still left in the water. We cannot but regard this risk as considerable, whatever may be the nature of the noxious ingredients in excrementitious matters, but if we are to accept the theory which is now prevalent amongst physiologists who have closely studied the subject of the spread of epidemic and infectious diseases, that these diseases are propagated by minute zymotic germs, the danger becomes augmented on account of the great resistance which such organic and living germs oppose to the oxidizing agencies which gradually decompose and destroy dead organic matter. That this is no imaginary danger is evident from the numerous outbreaks of typhoid fever and cholera which have been distinctly traced to the drinking of water previously polluted by excrementitious matters, but in which chemical analysis failed to detect any noxious ingredient. Thus Dr. R. Thomas Thorne, the medical officer deputed to examine into the case of an outbreak of the typhoid fever in the year 1867, in the village of Terling, reports: (Tenth report of medical officer of the Privy Council, 1867) that the outbreak was caused by the drinking of water from certain wells; chemical analyses, however, did not discover any noxious substance in the water, but the analytical results give for three of the wells a previous sewage or animal contamination.

"In September, 1867, an outbreak of typhoid fever occurred at Guilford, and Dr. Buchanan, an inspector of the Medical Department of the Privy Council Office, was sent to investigate the cause. He reported that a new well had been sunk to supply the higher part of the town, and that water from this well was supplied to about 330 houses for one day only, the 17th of August. On the 28th of August there were several cases of typhoid fever in these houses, although they are all situated in the highest and healthiest district in the town. The number daily increased, and there were, in all, about 500 cases and 21 deaths. With three exceptions, all the persons attacked in August and September had drank the water exceptionally supplied for one day only, as just stated.

It was subsequently found that a sewer ran within 10 feet of the well, and that the sewage leaked through the brickwork and saturated the soil just above the spring which supplied the well. The water was afterwards analyzed, and no ingredients were found that could be pronounced noxious; the results, however, showed that each 100,000 lbs. of it had been previously polluted with a quantity of animal matter equivalent to that found in 7,330 lbs. of average London sewage."

"Similar outbreaks of typhoid fever in many other places have been ascribed, by the medical officers deputed to investigate them, to the excremental pollution of drinking water. In every case analysis showed large anterior animal pollution, but in no instance was any deleterious substance found in the water; indeed it is obviously impossible for the chemist to detect the fatal ingredient until the physiologist has discovered what ingredient it is, in excremental matters, which at certain times produces such disastrous results. On this account the chemical examination, even of the actual excrements of typhoid patients, has hitherto failed to detect anything to which positive injury to health could be ascribed, and it is, therefore, obviously impossible that any such constituent can be found, after the excrements have been diffused through many thousand times their bulk of water.

In this instance, before the Royal Commission on Water Supply, Mr. Simon, F. R. S., the medical officer of Her Majesty's Privy Council, thus expresses his opinion on the subject (Minutes of Evidence, page 167):

"There are dangerous qualities of water supply, with regard to which, so far as I know, chemists are totally unable to measure, even to demonstrate the fatal influences that a water may have. A water may be, for instance, capable of spreading the cholera, but chemists be unable to identify the particular contamination which produces that effect. It is, I think, a matter of absolute demonstration, that, in the old epidemics, when the south side of London suffered so dreadfully from cholera, the great cause of the immense mortality there was a badness of the water supply then distributed in those districts of London. In the interval between the 1849 epidemic and the 1854 epidemic one of the two companies which supply the south side of London had amended its source of supply; it had gone higher up the river, and we at once lost a great part of the mortality on that side of the river. I may refer on this subject to a special report which I made in 1856 to the then General Board of Health, and which was laid before Parliament, on the last two cholera epidemics in London as affected by the consumption of impure water. I have just said that in 1853–'4, after the one company had improved the quality of its supply, the southern district of London showed a greatly diminished liability to cholera. But it was found that this great difference did not prevail uniformly through the south side of London, but was confined to those houses which were supplied by the improved water supply. There was still great mortality on the south side of the river; but this belonged exclusively to the houses which were still supplied with impure water. The details of this gigantic crucial experiment, performed on half a million of people, are given in the report to which I have referred.

"Now we come to another epidemic period.

"And now, fortunately, both the companies which supply the south side of London have ceased to give foul water, subject to some qualifications which I will state presently. They both give fairly good water, and now in consequence the cholera mortality in those parts of London has been, comparatively speaking, insignificant. But as is now a matter of notoriety, within the area of another water company of London, the population last year suffered very dreadfully from cholera. I refer to certain eastern parts of London.

Cholera in high development was confined to those parts of London, and those parts of London were in the area of one water company, and what makes this case the more remarkable is that not the whole area of that water company suffered; the water company gave two waters, and the high cholera mortality was apparently restricted to those parts of London which received one of these two supplies, so to speak, to half the district of the East London Water Company. The source from which the company supplied this half of its district was a source peculiarly exposed to contamination from a foul part of the river Lea. The contamination was sewage. Speaking broadly for the whole metropolis the area of intense cholera in 1866 was almost exactly the area of this particular water supply, nearly if not absolutely filling it, and scarcely, if at all, reaching beyond it. I think the rule ought to be that no sewage should go into any water that can be used for drinking purposes. I think even that allowance should be made for the proper decent taste of the people. Water into which sewage has been discharged is in relation to the matter now under consideration, an experiment on the health of the population, and I do not think that that experiment ought to be tried. I think the drinking of such water is dangerous; it is not practicable to define the exact line at which danger in a particular case begins. Everybody knows that water with certain obvious pollutions by sewage is fatal to health, and I do not know where to draw the line in practice between such cases and those which are, practically speaking, unimportant.

*"Although the water of the Thames has been submitted to analyses by different chemists, on many hundred occasions, no constituent which could be pronounced noxious, has been detected, but the history of the water traced in the inorganic

* Report of Commissioners, Rivers Pollution Commission, 1868.

constituents above referred to, always reveals that which is indeed well known to be the fact—its previous contamination with sewage or animal matters.

"Further and abundant evidence to the same effect might be adduced, but we have confined ourselves to that of medical officials in Your Majesty's service, whose special duty it is to inquire into the causes of epidemic disease.

"This evidence, taken in connection with our own investigations, appears to us conclusively to prove, first, that there is, at certain times, in human excreta, some material capable of producing disease of a very fatal character in human subjects; second, that this morbific matter can be detected only by its specific action upon the human subject, and cannot be distinguished, either by chemical or microscopical analyses, even in the concentrated excreta, much less in water mixed with the excreta; third, that inasmuch as the organic matters of sewage are oxidized and destroyed with extreme slowness in running water, there is great probability that the morbific matter will escape destruction and be conveyed to great distances in rivers and streams."

The State of Massachusetts recognizing the importance of this subject of the pollution of rivers, entrusted it for examination and report to the State Board of Health, and in their report for the year 1874, extracts from which follow, the views presented above will be found fully sustained.

"From the Fifth Annual Report of the State Board of Health of Massachusetts, January, 1874.

On Rivers as a Source of Water Supply.

"We are naturally led to consider the bearing of the facts observed on the question of the use of rivers as a source of supply of water for domestic purposes. The matter was, to some extent, discussed in the report made to the Board last year, and I desire to repeat and emphasize the statements made at that time. The order of the Legislature, in accordance with which this investigation was begun, alluded to the 'joint use of water courses for sewers and as sources of supply for domestic use.' I believe that all such joint use is to be deprecated, and because of the very great difficulty, I might say impossibility, of preventing the use of running streams as sewers, to a certain extent, their use as sources of domestic supply, at least at such portion of their course as lies below thickly settled and manufacturing towns, is not to be advised.

"A river may, considered by itself, afford a most excellent, a perfectly unobjectionable, supply of water. Its sources may be clear and pure mountain streams; it may flow over a rocky or gravelly bed, uncontaminated by refuse from the habitations and factories of men, and free, or nearly so, from vegetable matter; it may be so situated that no liquid refuse finds its way to it, without being first purified by filtration through a sufficient amount of natural soil. In this case no objection can be made to using the water for all domestic purposes. On the other hand, a pond or lake may be, in itself, a very objectionable source of supply, especially if so situated as to receive direct drainage, or if fed by streams which are used as sewers. It is an indispensable condition in the choice of any stream or lake as a source of water supply, that the source should not only be free from actual present contamination, but should also be so situated as to render it possible to protect it from contamination in the future.

"It is very true that a large amount of refuse material is of such a character as to be, except in excessive quantities, of no appreciable influence on the human system; the addition of the inorganic compounds of lime, soda, potash, &c., would have no deleterious effect; in fact, although the lime compounds increase the hardness of water and make it less desirable for washing, the presence of a moderate amount of mineral substances makes the water more palatable, and very probably also more wholesome.

"Then in the case of many waste liquors which appear to be very offensive, the matter which really could be regarded as injurious is comparatively small in amount. If we consider the character of the substances discharged by different manufacturing establishments, we shall find them very different; some of them are such as to be universally regarded as unfit to admit to any stream, those for instance containing lead, arsenic, &c.; others, such as salts of iron, are scarcely regarded as injurious; thus the discharge of sulphate of iron (copperas), into a stream already polluted with sewage matter, might within certain limits be of positive advantage (see last report of the Board of Health, pages 97, 98). Again, in the case of some of the vegetable dye-stuffs, the weak, spent dye liquors, although they communicate a very foul appearance to the water for some distance, yet contain a comparatively small amount of solid matter, and if discharged into a stream of considerable size, as soon as disseminated through it, are diluted to a very great extent.

"Much depends, of course, upon the size of the stream into which the refuse is thrown. Thus, while into the Merrimack, at Lowell, even during the summer, it would be necessary to throw more than 100 tons of solid matter daily in order to increase the amount in the water by one grain to the gallon, another and smaller* stream might be hopelessly fouled by a single factory.

Different in character, however, from much of the refuse of manufacturing establishments, is the sewage coming from our dwellings, or the sewage (in its more restricted sense, of

* The Merrimack is estimated to deliver at low summer flow 2,000 cubic feet per second, being five times the summer flow of the Schuylkill, and about equal to that of the Delaware River.

excremental matter from animal sources) which comes from our manufactories. In fact, this foul material coming from establishments employing a large number of operatives is likely, in many cases, to have a more injurious effect upon the stream into which it is thrown than the refuse from the manufacturing operations. There are, however, some branches of industry which discharge refuse material offensive and dangerous to health. Such material is discharged from tanneries, wool-pulling, and hide-dressing establishments, slaughter-houses, and rendering-houses. Too much stress cannot be laid upon the importance of preventing the discharge of such refuse, and of sewage in its more restricted sense, into any stream or pond used, or likely to be used, as a source of water supply.

"The importance of this matter is underrated for two reasons: first, because of the oft-repeated assertion, made on the authority of Dr. Letheby, that "if sewage-matter be mixed with twenty times its bulk of ordinary river-water, and flow a dozen miles, there is not a particle of that sewage to be discovered by chemical means." Secondly, because of the feeling that to be in any way prejudicial to health, a water must contain enough animal matter to be recognized readily by chemical tests—enough, in fact, to be expressed in figures.

"The first of these opinions has been disproved by the experiments of the Rivers Commission in England, who have shown that not only is a flow of twelve miles insufficient to destroy the organic matter of sewage when mixed with water in the above proportion, but also a flow of one hundred and sixty miles is far from sufficing for that purpose. When sewage is mixed with water, some of its constituents begin to decompose very soon. The urea, for example, is quickly converted into carbonate of ammonium; others of the constituents, however, are less ready to begin to decompose, and when decomposition does set in, although some of the substances may undergo chemical change, there still remain organic nitrogenous compounds in the mixture, and these substances are swept along by the rivers, even to the sea.

"The carcass of a dead animal thrown into a river or into a pond, and confined there so as not to be borne off bodily, gradually wastes away, and in a longer or shorter time, the main part of the carcass has disappeared. What has become of it? A part has been converted into gaseous products of decomposition, as the offensive odors observed during the decay will testify; but another portion has been carried off by the stream as soluble nitrogenous organic matter. This nitrogenous matter would be detected a short distance away, with greater or less ease, according to the volume of water present, and in a stream of large size, or in a lake, at no very great distance from the source of contamination it would be impossible to discover any offensive matter. There is a limit to the delicacy of our tests; there is a point beyond which, at the present, we are not able to go. At the present time, a chemical analysis *alone* is not sufficient to determine the desirability of a given water-supply. The rice-water evacuations of a cholera patient, diluted with no very large amount of water, would form a liquid in which chemical tests would fail to indicate the presence of anything which could be pronounced injurious, and yet there is no destruction of the poisonous material; it is still in the liquid, although not to be recognized, and such water is now regarded by physicians as the most direct and certain vehicle for the transmission of Asiatic cholera.

"The second opinion is, that sewage, if diluted to a very considerable extent, becomes innocuous; this opinion, which involves questions belonging to the physician rather than to the chemist, is very likely to be carried too far. I do not know that we have any proof that perfectly fresh sewage (the term being used in its more restricted sense) coming from healthy persons, when mixed with water, is injurious if drank; it would probably not be asserted that such a mixture was actually good to drink,—it would certainly be opposed to our instinctive ideas.

"It is true that fish are not destroyed by even a considerable discharge of fresh sewage into a stream. We do know, however, that sewage which has begun to undergo decomposition is unwholesome; such decomposing sewage has been observed to destroy and drive away the fish from the stream in the immediate neighborhood of the point of discharge, and there are a great number of instances on record where cases of sickness have been traced directly to the fact that the water used for drinking was rendered foul by the decomposing excremental matter which found its way into the source of supply; and drinking-water, polluted by even an infinitesimal amount of excremental matter coming from those suffering from typhoid fever, is now very generally held to be capable of propagating that disease.

"It has already been stated that sewage matter itself is not completely destroyed when it is introduced into a running stream, and is borne along even for many miles; we must suppose, and indeed have every reason to believe, that in the case of sewage which when *fresh*, is capable of communicating disease, the destruction of the peculiar organized matter which has the specific effect must be more slow even than the unorganized effete matter which forms the mass of the dissolved and suspended solid matter of ordinary sewage. In the case of certain diseases, which have been shown by experiment to owe their origin to the presence of distinct and recognizable living organisms, it has been found that these organisms retain their vitality in spite of very varied conditions, and through very considerable changes of temperature.

"One would not assert that the drainage from a single house would contaminate the water of a large river like the Merrimack, so as to make it unfit for domestic use, yet we must beware how we depreciate the effect of sewage-matter, even in a large stream. While, with a small amount of sewage, the chances are as favorable as possible for the action of atmospheric influences, and the chances of taking up any undecomposed particle of material, capable of propagating disease, are rendered proportionally small owing to the great dilution, it is to be borne in mind that the action of such matter on the system is not regarded as *cumulative.* A minute quantity may do much harm, because it is now generally believed that it may hold the specific thing which propagates specific diseases. In the case of certain organic poisons which affect the system through the blood, the experiments of M. Chauveau and of Dr. Burdon Sanderson on vaccine matter render it well nigh certain that no amount of dilution can destroy the power of infection which these poisons possess. From these experiments it appears that if innoculation be performed with vaccine lymph after it has been very much diluted, the chance of the formation of pustules is rendered less, but when the vaccination is successful, the pustule formed presents its normal features and passes through the usual stages of development.

"It has been objected that it would be impossible to obtain water perfectly pure, and that it is very questionable whether perfectly pure water would really be as wholesome as water containing a certain amount of foreign substances (see note on pp. 110, 111). It may be very true that we cannot procure absolutely pure water; we may not even be able to procure water absolutely free from such substances as we regard as injurious; but there are some causes of contamination which must, at any cost, be avoided, and in other respects the water must be obtained as nearly as possible of the ideal excellence. We know that there are many persons who live and seem to get along very well in utter disregard of the laws of health as far as personal cleanliness, diet, pure air and many other things are concerned; but because many thus live for a time without experiencing evident inconvenience, does any one argue that purity of air, a healthful diet and cleanliness of person are not to be recommended and sought after? The effect upon the community of the bolting of indigestible food must be immense, but comparatively few are the acknowledged cases of injurious effects. We are able, however, in many cases, to show, even in these matters, that the apparent strength and immunity from discomfort is due to a constitution naturally strong, and the draught upon the vital energy may be seen, if not in the persons themselves in later years, at least in their children.

"In fact, to isolate the effects of various habits, which, from a hygienic stand-point, are decidedly bad, is a problem which, in many cases, it is impossible to solve, and yet that disease does come from the use of an inferior water supply, is abundantly proved by many instances which are on record, where a disease such as diarrhœa, dysentery, cholera or typhoid fever, which had affected an entire community, has been checked by a change in the source of drinking-water; and on a still larger scale there are instances where the benefits derived from the change to a better water-supply have been marked by a decreased death-rate. In such cases, it is difficult to point to the exact thing which has produced the bad effects, but in some cases the presence of a comparatively large amount of organic matter, derived from animal sources, has been the only circumstance to which chemical examination could point as a probable cause.

"It is also, as has already been said, well established that particular forms of disease may be and are transmitted by drainage into wells and other sources of water-supply, and it is impossible to say how little foul matter is needed to work evil effects. A case, or several cases, of typhoid fever in a family, leads to the discovery that the well from which the drinking water is taken, is in underground but direct communication with the vault or cesspool; but the effect upon the system during the time when the well was deteriorating, during the time that the sewage material was gradually wearing a channel to the well, the point of time when the well *began to be* impure, these things were not, could not be noticed."

With reference to the probable ultimate pollution of the Delaware River, little need be said. The analysis of the water opposite and above the city, has shown the presence of organic matter, attributable to the sewage from the City, and the mingling of the tide water, yet the precaution suggested in the Report of the Commission, will suffice to preserve the water in at least its present degree of purity, for years to come, or until a scheme of works, dispensing with the use of water taken from the Delaware River within the influence of the continued sewage discharge and tidal action, can be perfected. If it be determined to take the water above the influence of the tide, or the Trenton dam, the water of the Delaware River may be relied upon for an indefinite period in the future, as well suited for domestic use.

This river drains an extent of over 8,000 square miles of mountainous country, the centres of industries of which are well marked, and presumable not likely to increase in number or character, while the upper reaches of the river, or a large portion of it, will always continue as now, to drain a sparsely inhabited region, destitute of any source of pollution to the pure water derived from its rapid water shed. The minimum discharge of the river is so great as to neutralize, by its extreme dilution, any polluting element likely to arise above the point where it is taken for the City use.

This increased volume is shown in the comparative discharges of the rivers Schuylkill and Delaware, the former being at its least flow 378 cubic feet per second, while the latter is estimated at 2,000 cubic feet per second.

It will be perceived, by the tables of analysis, that organic matter, presumably from sewage, is found to the extent of over half a grain per gallon as far up as Trenton, showing, that for a *permanent* future supply, the water, if taken from this river, should be taken from above the dam at that place.

As the City of Philadelphia extends northward, the increasing population on the banks of the river will tend to pollute its waters more and more, and this, combined with the tidal action, will result in the extension of the pollution far beyond the limits of the City, and render the river within its influence an improper source of supply for a great City.

In support of this view, we would observe: First. That although the rise of tide opposite the City is some six feet, the sea water flow does not reach the City by many miles; the water opposite the City being for all purposes entirely fresh, and its rise on the flood is due to the action of the tidal wave below, in backing up the fresh water of the river. When the ebb-tide makes below, and the sea water flows out, the fresh water above falls proportionally. The flood is said to run about five hours, and the ebb about seven hours. This is so only in appearance; in reality the flow of the tide is about the same in duration in each direction. The additional two hours run on the ebb is the result of the extra head of the river water, produced by the back action of the tidal flow on the flood. Second. The action of a float upon or near the surface of the water is no indication of the movement back and forth of the sewage held in suspension. Portions of the fresh sewage, it is true, will float, but after maceration the sewage has a specific gravity of about 1.325, and will sink in still water, or very slow currents, at the rate of about one foot per minute, but in a current of 170 feet a second, it will not sink, but remain in suspension.

The flow of the tides here are said to be at the rate of 3 miles per hour in each direction. This, of course, must refer to the mid-tide flow, for the commencement and termination of each tidal flow must be gradual previous to the still water which occurs for a greater or less interval between the tides, when, as in this case, the tide does not come in with a "bore." Hence such portion of the tide as runs with a greater velocity than 2 miles per hour, will carry the suspended sewage with it, to be gradually deposited wherever the flow is less than 2 miles per hour. It would seem that the sewage carried up by the flood, would, on account of the greater duration of the ebb flow, always be returned below the point at which it started, but if the flood runs up with a greater velocity than the ebb during any portion of its flow, and that velocity exceeds 2 miles per hour, the sewage will be carried up stream, a portion deposited during still water near the shores and in the eddies, and such portions only as happened to be in the deeper channel way, would be returned by the ebb tide, providing that the velocity of the latter was above 2 miles per hour, otherwise it would gradually be precipitated to the bottom. Hence it is that the sewage of the City, estimated at present at over 20 millions of gallons daily, if discharged during the prevalence of flood tide instead of being swept sea-ward, is deposited near the shores and in eddies, and for a long distance above the outlet of the sewers into the river, how far, it is impossible to determine, unless by a series of observations instituted for the purpose. I have estimated, however, that its presence may be anticipated for at least 15 miles above the City limits.

From the Report of the River Pollution Commission, referred to above, as also from the extracts of the evidence delivered on the water supply question of London, as well as the Report of the State Board of Health of Massachusetts, but one conclusion can be reached, when we consider the character and professional standing of the individuals whose evidence we have quoted, notwithstanding that adverse opinions are given in the evidence of other experts; and that is, that with our present knowledge of the subject, we cannot but *distrust* the purity of any water for drinking purposes, when once polluted in the manner and to the degree we have estimated as likely to arise in the case of the River Schuylkill, and further; that no chemical analysis can be relied upon to determine its fitness for domestic use, after such pollution by human sewage.

Grounds for *distrust* in determining the purity of a water, are grounds for its rejection, especially when brought into comparison with a water from a source of undoubted purity.

Accompanying this are some tables of analyses of the waters, both of the Delaware and the Schuylkill, but as the scope of our investigation refers to the probable *future* condition of the river, and does not dwell upon their present condition, we cannot of course presume to indicate what in chemical language would be the composition of their waters. We have estimated the probable amount of impurity of various kinds likely to be thrown into the Schuylkill, and quote the arguments and the evidence which in our opinion establish the position, that once fouled to the degree we have supposed, the water can no longer be properly recommended as a drinking water for the City; hence the scientific name for the different species of pollution at present existing, or the laboratory experiments by which it is shown that *no* serious pollution exists; we do not consider as controlling elements in the investigation in which we are engaged, but the tables of analyses prepared by the experts for the use of this Commission are of great scientific interest, as probably showing all that chemistry can indicate bearing upon the healthfulness or otherwise of these waters.

In quoting so freely as we have done, it is to be hoped that due acknowledgment has been rendered in all cases, of the source from whence the material has been derived.

APPENDIX B.

REPORT OF MESSRS. BOOTH AND GARRETT, TO THE COMMISSION ON THE WATER SUPPLY OF PHILADELPHIA, ON THEIR CHEMICAL EXAMINATION OF THE WATERS OF THE SCHUYLKILL AND DELAWARE RIVERS.

GENTLEMEN :—We respectfully offer you the results of our examination of the waters of the Schuylkill and Delaware Rivers, and our inferences therefrom, relating to their present and future use in Philadelphia.

The waters contain mineral and organic matter dissolved in them, and as these demand special and separate considerations, we shall first treat of the mineral constituents, as perhaps of least importance.

I. MINERAL CONSTITUENTS OF WATERS.

We offer the following table of analyses of the waters of the Schuylkill conducted in our laboratory at four different periods of time, viz.: by Booth & Boyé in 1842, by Booth & Garrett in 1854, 1862 and 1875. The table shows the number of grains of each constituent in 1000 gallons of water taken at Fairmount, the gallon being that of the United States, measuring 231 cubic inches, and weighing 58,372 175-1000 grains of distilled water.

The organic matter, carbonic acid, and combined water of some of the salts, are summed up in the last item, as the difference between the sum of the other constituents and the sum total of solid matter, found by directly weighing the solid matter left by evaporation.

Solid contents of Schuylkill water at Fairmount, as determined at four different times during 33 years.

Grains in 1,000 Gallons.

	B. & B. 1842.	B. & G. 1854.	B. & G. 1862.	B. & G. 1875.
Lime	1,226	1,404	1,457	1,821
Magnesia	230	696	835	802
Soda	455	348	131	568
Sulphuric acid	302	1,417	1,508	2,445
Alumina and Oxide of Iron	77	68	75	traces.
Chlorine	86	168	139	155
Silica and insoluble matter	385	undet'rm	339	348
Organic matter, carbonic acid, water of hydration, &c	1,650	2,008	2,556	1,999
Total solid matter per 1,000 gallons determined direct	4,421	6,109	7,040	8,138

There is a striking increase in the solid matter in the water from (4,421 grains) 10 ounces in 1842 to (8,138 grains) 18 ounces in 1875, gradually rising as shown in the totals of 1854 and 1862.

The change appears to be chiefly in the increase of sulphuric acid, lime, and magnesia, as shown in the following table of the number of grains in 1,000 gallons of water in the several years.

YEAR.	1842.	1854.	1862.	1875.
Grains in 1,000 gallons..................	1,758	3,517	3,800	5,068

The question at once arises, is it likely to increase in a similar ratio?

In the first place the quantity is not great at present, for the average number of grains of solid matter in the 1,000 gallons, of 12 artesian wells in London, and of 12 analyses of the waters of the Thames and New River supplied to London (England) shows the Fairmount water in 1875 to contain three times as much as the former, but the Thames two-and-a-half times as much as Fairmount, thus:

Grains of Solid Matter in 1,000 Gallons.

Artesian Wells (London).	Thames (London).	Schuylkill (Phila'da).
2,451	19,438	8,138

While, therefore, the amount is comparatively moderate, yet if it increased in the same ratio in another 33 years, it would amount to 14,980 grains in A. D. 1908, and to 33,884 grains in 1,000 gallons in A. D. 1941, or in two generations from the present time. Such impure water would be rather objectionable; but will it increase as rapidly as indicated above?

The cause of increase will reply. All good tasting springs of water have been employed as types of purity by all mankind from the beginning of time, and yet they almost all contain small quantities of mineral impurity, so-called, but falsely, for such small quantities are normal, not exceptional. That mineral matter is not impurity when it is an invariable part or component of the very type of purity. The quantity of mineral matter in well-tasting spring waters varies from a fraction of a grain (extremely rare) to several grains per gallon, or in 1,000 gallons from 500 up to 5,000 grains, the average probably being 3,000. Now, springs are the sources of brooks, which unite into creeks, and these by their confluence make rivers. We examined a large body of water whose fountains were not remote, in a dam supplying Pottsville, and found in it from 1,100 to 1,500 grains in 1,000 gallons.

We may assume then that the sources of the Schuylkill in the coal region (and elsewhere) are of the usual purity of springs, and that in their downward flow, decaying organic life, both vegetable and animal, is added, and small quantities of mineral substances in solution from the fewer exceptional mineral springs. Such is the normal condition of a river, and such was that of the Schuylkill. But the opening of the coal mines, and the extraction of coal, have materially modified the water. Iron pyrites (composed of sulphur and iron) is a normal impurity in coal, and when exposed to the air with or without roasting, becomes changed by oxidation into sulphate of iron, soluble in water. So large is the quantity introduced into the river at Pottsville that a body of the water has a greenish tint, like copperas, and the fish are destroyed; many of the waters flowing out of coal mines, contain so much sulphuric acid from the same source, that iron boilers are seriously corroded. The water at Schuylkill Haven has a decided acid reaction, and our analysis shows that it contains a considerable excess of sulphuric acid over the bases dissolved in it.

The following table shows clearly the changes of the mineral contents in the river, taken from our analyses in 1862, of water taken at several points from Schuylkill Haven to

Philadelphia; the increased substances, lime, magnesia, and sulphuric acid, alone being presented:

Grains of solid matter in 1,000 gallons of water in 1862.

Schuy'l Haven.	Reading.	Valley Forge.	Flat Rock.	Fairmount.
11,032	5,446	3,447	3,428	3,800

The free sulphuric acid, alumina, and oxide of iron, at Schuylkill Haven, disappear at Philadelphia, but after the water leaves the former place, it encounters a large amount of limestone, whereby lime and magnesia replace the alumina and oxide of iron, and altogether satisfy the sulphuric acid, making neutral sulphates. Hence the considerable and successive increase in sulphates of lime and magnesia from 1842 to 1875. As coal is extracted, iron pyrites is also extracted; it is changed to sulphate of iron; limestone changes the sulphate of iron into sulphates of lime and magnesia, while the oxide of iron is dropped, and may be seen coating dams on the river in and below the coal region. Since pyrites is the normal companion of coal, the increased openings for coal will increase the quantity of sulphates of lime and magnesia in the water, as is shown in the small table, of the past history of the river, following the large table of analyses.

If such be the cause of the increase in the mineral matter of the Schuylkill, will not increasing development of coal in the valley of the Schuylkill increase that matter?

We answer yes; but we do not think that it will be developed in the same ratio for two coming generations as it has been in the last 33 years; because much coal has been taken out, and the increasing depths and expense of mining will diminish the ratio, or rather prevent the increase in the same ratio of mining coal in the Schuylkill basin, while other cheaper sources tempt in neighboring basins.

While therefore we may fairly anticipate an increase in the mineral matter of the Schuylkill in future, yet we regard its very objectionable increase too remote to cause the least anxiety at present. Moreover, the diminution in the quantity of mineral matter per gallon, or per 1,000 gallons, as exhibited in the above small table, in the 100 miles of the river from the coal region to Philadelphia, shows, either that something abstracts a large amount of mineral matter from the water, or that it is so largely diluted with purer waters, as to exhibit at Philadelphia a water of comparative excellence in mineral matters, as compared with the waters of London and many other cities.

The mineral matters of the Delaware River are discussed shortly. The Delaware has not now one-half as much as the Schuylkill, and is not likely to increase in the same ratio, because a small proportion of it only heads in the Coal Region, and we know of no other general source of mineral matter likely to increase it.

One general conclusion may be drawn by a comparison of the two rivers, that the Delaware is superior to the Schuylkill for manufacturing purposes, where quality of water is an element of calculation. The increased hardness of the Schuylkill, perceptible to a sensitive touch, and rendered visible by a coagulated precipitate of lime soap, when washing, is still too small to take account of in washing-soap in manufactures; nevertheless in every 1,000 gallons used, the amount of soap rendered useless is appreciable.

There is one point of superiority, in the considerable content of sulphates in Schuylkill water, which should not be passed over; viz., that in flowing through lead pipe an extremely hard and adhesive white coat of sulphate is formed on the interior surface, whereby all further apprehension of the solution of lead in water is prevented. Hence the cheap and convenient lead pipe is universally employed in Philadelphia, and with perfect safety from injury by lead.

II. Organic Constituents.

Nearly all the natural waters on the surface of the globe contain organic matter in solution; even the springs, which are typical of purity, and have ever been regarded as sources of refreshment and health. On the other hand marsh water, stagnant pools, and in general, waters containing microscopic organisms which are observed to accompany putrefaction, are generally admitted by the same human experience to be prejudicial to health. Further, the long continued experience of City life in various parts of the world has shown that water contaminated with animal refuse, such as the sewage of large cities, is fatal to health.

It is further known that it is not so much the quantity, as the nature or condition of the dissolved organic matter, that determines the goodness or badness of a water used as a beverage. Ten grains of dry, putrescible sewage matter in a gallon might prove deleterious, while one hundred grains or more of tea or coffee in a gallon are most welcome, refreshing and healthful. The quantity of organic matter in spring water varies from a small fraction of a grain to one and a half or even two grains, and is innocent, nay, possibly beneficial. The larger amount and of a different kind in sewage is injurious. These few statements on organic matters in waters comprise the bulk of our knowledge, nor can we draw a sharp line between waters that are injurious or beneficial from their content of organic matter.

While the springs, the sources of rivers, are more or less pure, mostly types of purity, although containing a little organic matter, yet as the brooks, creeks, streams and rivers flow in the lower parts of valleys, the rains wash down to them the products of decomposition of the vegetable matters of the forest and field, and of the animal refuse of insect, bird, beast, and human life. Hence, the river is usually an inferior type of purity than the spring; it contains more organic matter. And yet river water has been used from the earliest times without the slightest injurious effect, but with all the refreshing and beneficial influences of spring-waters, except their coolness. Where, however, rivers receive a large amount of putrescent and sewage matters, they have been alleged to be, and probably are, baleful, disagreeable even to the taste and smell, and a fruitful source or irritator of disease. The proportion, as well as nature, of sewage matter is, therefore, the test of the quality of river water; for all rivers have contained a portion, and may be healthful, while those passing through cities, being surcharged, are injurious.

Although we are yet in our infancy on the question of the exact nature and quantity of sewage, injurious to man, in his drinking water, yet we shall make a few remarks on the subject, such as we feel authorized to do by the present state of our knowledge.

When nitrogenous, organic matter undergoes decomposition, ammonia is one of its most frequent products, and when oxidation of such matter occurs, nitrous and nitric acids are a further product of decomposition. Neither ammonia nor nitric acid can be said to be detrimental to health, in the small proportion they are or may be contained in waters. But the presence of ammonia, especially, leads us to infer the more immediate presence of putrescible (nitrogenous, organic) matter, just preceding it; while nitric acid seems to show that organic matter was present longer antecedent. Hence, it is usual to determine the amount of ammonia present in a water, in order to infer something of sewage. Nitric acid is less frequently determined because it shows that the sewage, if any, was in a fair way to be destroyed by oxidation. There remains, however, still in sewage water organic matter, nitrogenous, but not ammonia nor nitric acid; but which, by decomposition by putrescence, would yield ammonia. Hence, it is common to decompose this matter in a chemical analyses, so as to determine the amount of ammonia that it yields as a sort of measure of the quantity of organic matter in a water. Because albumen will yield about ten times as much organic matter as the ammonia obtained from it, some chemists have so stated their analysis, and the ammonia determined is called albuminoid ammonia. While this conclusion is doubtful, yet because albuminous matters are among the most abundant, and typical of others, we are willing to accept the name albuminoid ammonia. We consider its amount in a water to indicate with a little probability, but by no means with certainty, the quality of a water. We may as well confess that chemists are very uncertain as to the nature of the organic matter which causes the unhealthiness of a water. We use the term, and hold the view that it is the best we know at present.

We now present a tabular view of the ammonia ready formed, and of the albuminoid ammonia, which we have recently determined in waters around Philadelphia. We append the average of 20 analyses of Thames River (London) waters in actual use.

Table of Free and Albuminoid Ammonia.

	Grains in 1,000 Gallons.	
	Free Ammonia.	Albuminoid Ammonia.
Fairmount	1.17	1.76
Belmont	5.85	5.11
Flat Rock	7.31	5.12
Perkiomen	1.46	7.31
Spring Garden	17.50	8.75
Delaware Basin	25.74	11.70
Bryn Mawr Artesian Well	None.	1.75
Thames River, London	1.00	5.31

On the above we remark that there must have been some special contamination of the water as drawn at the Spring Garden Works, and therefore we place it last of the Schuylkill waters and in our discussion we leave it out of view. *Note.*—This inference has since been confirmed by Chief Engineer, Dr. McFadden. The large comparative quantity in the Delaware Basin is too striking to need comment; it shows the impure source of the water pumped into the basin, and certainly gives an unfair and false view of the organic impurity of the Delaware River. The average quantity in the Schuylkill water does not exceed 5 grains of albuminoid ammonia in 1,000 gallons, which is the same as the average of the potable Thames River water.

But whatever the quantity of free and albuminoid ammonia in the Schuylkill, near Philadelphia, the most striking and important fact is, that this water, just as it enters into the forebay at Fairmount, in the very condition in which it is to be forced up into the basin for use through Philadelphia, contains the least free and albuminoid ammonia of all the other river waters. In the albuminoid ammonia, which is the measure of sewage at present, it is more than three times as good as any of the others, including the average Thames waters, above London. It contains less than one-third part of the sewage of the others, and strange as it may appear, it contains exactly as much as the so-called sewage of the Bryn Mawr artesian well water pumped up from the depth of 400 feet. We feel bound to enter here our energetic protest against the application of the term "sewage," which has a definite and well known application to the foul waters issuing from a City, to the organic matter of Spring water. It is faulting Providence for the abundant supply of the source of health and refreshment.

Let us consider this fact one moment. The Fairmount water contains just as much sewage (so called by chemical test), as an excellent spring taken from a place remote from, and beyond the depth of, any present surface sewage. If we used such a water as the Bryn Mawr, we would not be led, either by its taste or any noticeable effect, well, to say that it contains sewage; for it would be a vile slander; why then should we declare a water impure with sewage, that contains no more than that, either to the taste, or by the chemist's test? Look at it still closer; suppose the $1\frac{3}{4}$ grains in 1,000 gallons of Fairmount water to be real sewage, what is the amount of the organic matter which that represents in a full tumbler of water? From the albuminoid ammonia in 1,000 gallons, we find there would be in a tumbler of Fairmount water 0.001 of a grain of *possibly* injurious organic matter. Whoever has seen the one thousandth ($\frac{1}{1000}$) part of a grain in delicate assaying weights, can imagine what a terrible trifle people drink in a tumbler of water. If we are refreshed by a glass of spring water with its .001 ($\frac{1}{1000}$) grain of terror, perhaps we may content ourselves with a similar draft of Fairmount water, in which the same terror lies hid, especially if cooled with a little Fairmount ice.

We use the expression Fairmount ice advisedly, for it brings us to an important question, the aeration of water. We have alluded above, to the oxidation of some nitrogenous matter into nitric acid, an effect well known to the chemist. In the artificial nitre beds, such organic matter is thus resolved, in presence of a base, into nitrate of potash (nitre, saltpetre). Now a nitrate is not injurious, unless perhaps in gunpowder, but certainly not if a grain of it were in every gallon we drink. We tested the Fairmount for the nitrogen it contained in the form of nitrous or nitric acid, and found it to be 24.1 grains in 1,000 gallons. This is equal to less than one-fifth ($\frac{1}{5}$) of a grain of saltpetre in one gallon, no more than is contained in many spring waters. This result is extremely interesting; for although the $\frac{1}{8}$ grain per gallon of saltpetre, or its equivalent of pure nitric acid of 40° Beaumé, is an unimportant item in drinkable waters, yet the aggregate quantity contained in the water of the river, based on that quantity per gallon, is about thirty pounds in every million of gallons of the Schuylkill. While this proportion precludes its origin from wastage in Chemical Works, it shows the very large amount of nitrogenous organic matter that has been oxidized by a thorough aeration of the water,—of matter that might, perhaps, have been injurious, changed into an innocent substance—as the River and its branches silently flow towards their common goal, the Ocean.

We are led from these considerations to suggest, as a matter of some value, the desirability of thoroughly aerating potable water. That offensive organic matter does enter the Schuylkill is certain, and its presence becomes known to a sensitive organ of smell in the winter. You have suggested this, and the remedy also; i. e. to allow ice to be cut freely in the winter season, so as to expose the water to aeration, and thereby to improve the quality of the water. If this were done, we think that every citizen of Philadelphia might be thankful if he could always enjoy as healthful and refreshing a beverage as Fairmount water, cooled in summer by Fairmount ice.

It is hardly worth while to draw your attention to the albuminoid ammonia, which we found in Perkiomen water, that it exceeds that in Fairmount water slightly. This single examination of the Perkiomen does not do justice to that affluent of the Schuylkill, but we do not suppose, from examinations formerly made, that it will surpass the latter in quality, if it should be found to equal it.

Having now shown that the Schuylkill water is about as good a water as we might wish to find for a large city, in its mineral and organic content, and that its mineral content, which is not injurious to health, will not increase as rapidly as heretofore, may we be permitted to draw a conclusion, as in our opinion, the best course to pursue for the present and for a rather long future.

Since the present water is good enough, we may keep it so and even improve it, by a system of sewerage gradually extended up both sides of the river, especially the left bank, above the influence of Manayunk, and by procuring sufficient legislative power to control the escape of sewage, or possibly injurious manufacturing residues. The long line of many miles would tend greatly to the purification of the water by aeration, deposition, or abstraction of possibly injurious substances from the water, by the time it reached within using distance of the City.

We have touched but little upon the Delaware water, because our examination and reflection on the Schuylkill water satisfied us, that the latter is better adapted to use as a beverage. The Delaware contains more organic matter per gallon than the Schuylkill, and since organic matter is generally agreed to be the more likely to prove injurious for drinking water, we have devoted less time to our great river. We have done the Delaware ample justice in stating that we regard it superior to the Schuylkill for manufacturing purposes. Its excellence for shipping is well established, but when so used, it has to undergo a putrefactive process on shipboard, whereby organic matter is partly destroyed and partly precipitated in the containing tanks. After this it will keep, we believe, for years. In a City, however, we need the water for immediate use, and cannot wait for purefication by putrefaction.

The period may arrive, although we believe it far distant, when a greatly increased population, lining the banks of the Schuylkill, may throw such an amount of sewage or putrescible matter into the river as to render its removal imprac-

Results of the Examination of Waters,

Sample Marked.	Amount of Sample.	Analysis No.	Date of Selection of Sample.	AMMONIA. Free.	Albumenoid.	From Nitrates.	Sewage.	
				POUNDS IN 1,000,000 U				
'1'	1 U. S. G.	1585	July 10, 1875.	548.85	145.71	....	1,457	low St. Wharf.
'2'	1 "	1586	" " "	118.51	43.90	....	439	
'3'	1 "	1587	" " "	41.96	50.51	....	50	
'4'	1 "	1588	" " "	145.71	82.28	....	82	
'5'	1 "	1589	" " "	29.14	23.31	....	23	
'6'	1 "	1590	" " "	7.77	38.42	....	38	
'7'	1 "	1591	" " "	6.07	8.74	....	8	
'A'	1 "	1597	" 13, "	2.42	3.64	11.65	3	
'B'	1 "	1598	" " "	16.15	40.31	....	40	
'C'	1 "	1599	" " "	3.64	24.28	....	24	
'D'	1 "	1600	" " "	14.57	31.52	....	31	
'E'	1 "	1601	" " "	38.85	70.43	....	70	Garden).
'G'	1 "	1602	" " "	206.42	87.42	....	87	ge.
'H'	1 "	1603	" " "	12.14	4.85	10.68	4	
'J'	1 "	1604	" 16, "	4.85	4.85	9.71	4	
'O'	1 "	1605	" 17, "	2.42	4.85	14.57	4	
'P'	1 "	1606	" " "	None	Trace	143.28*	Trac	
'Q'	1 "	1607	" " "	2.42	3.64	None	3	
'A_2'	1 "	1608	" 23, "	0.12	1.21	9.71	1	
'B_2'	1 "	1609	" " "	0.24	3.64	29.14	3	
'K'	1-5 "	1610	" 24, "	12.82	15.05	....	15	
'L'	1-5 "	1611	" " "	19.43	14.57	....	14	
'M'	1-5 "	1612	" " "	Trace	22.44	....	22	
'N'	1-5 "	1613	" " "	12.14	35.84	....	35	

* The large amount of Nitrates found in this water can possi or from certain cretaceous strata, or from the drainage of Cemeteries or Che

The amount of Sewage found in the greater number of the sa —"Q"— "J"—"H"—"O"—"A"—"P," which are noted in the order of th metals. None of these waters can be rated as of first quality, nor are they equ ated.

Dr. Cresson explains the term *Sewage*, in the above Table, to m ticable by sewers, aeration, or any other method which we can at present conceive, and then its unfitness for domestic use may oblige us to have recourse to the Delaware River, whose larger volume of water is not likely to be injured beyond remedy by any amount of population which may hereafter swarm on its shores.

Respectfully yours,

BOOTH & GARRETT.

APPENDIX D.

To W. Milnor Roberts, Esq.,

Ch'n of Commission on the Water Supply of Philadelphia.

Sir:—In the year 1872, I presented a report to Franklin B. Gowen, Esq., President of the Philadelphia and Reading Railroad Company, in reference to the means of increasing the quantity of water in the Fairmount Dam for the supply of the City of Philadelphia, and the delivery of purer water than could be obtained from that pool for the supply of the pumps, at the several pumping stations upon it.

The information contained in that report, so far as it is applicable to your present inquiry, and the plan that I proposed for its accomplishment, are by the kind permission of President Gowen, allowed to be used by me in this communication.

In my annual report as Chief Engineer of Canals, made to President Gowen December 16, 1874, I referred to the minimum flow of the River Schuylkill, and stated that at its lowest stage it will supply 245,000,000 gallons of water per day of 24 hours.

On the 29th of August, 1816, a measurement was made at "the narrows," now Flat Rock, near Manayunk, by a committee of the Schuylkill Navigation Company, when the water was said to have been as low as at any time for the then previous twenty years; in their report this committee state that "they found the passage, clear of eddies, at each shore, to be 60 feet and the depth 4 feet 9 inches, giving a section of 285 feet, and running in a minute 163 feet, giving 46,455 cubic feet passing in a minute."

This quantity is equal, in round numbers, to 500,000,000 gallons per 24 hours. At the time this measurement was made, the valley of the Schuylkill had not been denuded of its primitive forests, and the minimum flow must have been much larger than at present, but whether this measurement was made with the care and particularity with which such measurements are now made, cannot now be known. About the year 1825, the minimum flow was estimated to be 440,000,000 gallons per day, and in later years, 400,000,000 gallons per day has been the usual estimate.

Owing to the occupation of the river by the Navigation Works, the precise volume of the minimum flow cannot very readily be ascertained; Flat Rock Dam and the Canal outletting into Fairmount Pool, at Manayunk, may be regarded as the most favorable points of observation.

The quantity I have just above stated as the minimum flow of the river is the result of observations and measurements made by Edwin F. Smith, C. E., Resident Engineer of Canals of the Philadelphia and Reading Railroad Company, and in order that you may be enabled to judge of the accuracy of this result, I would ask attention to the following statement made by him:

"I submit herewith an explanation of the manner in which the daily minimum flow of the River Schuylkill, at Flat Rock, was measured by me in September, 1874.

"The usual method of ascertaining the flow by contracting the river in its passage over one of the dams of the navigation, so as to allow all the water to pass over a weir plank of the shape adapted to the formula, could not be resorted to for the reason that all the pools between Port Kennedy and Philadelphia are subject to the disturbing influence of the mills using water for power.

The quantity of water used from the Flat Rock pool, for power by the mills at Manayunk, is so large that when the river is at an extreme low stage, it is necessary to stop the mills a portion of each 24 hours in order to save water to meet the requirements of the navigation.

During the drought of 1874, the period of extreme low water was from September 2d to September 16th, fifteen days, and the cotton and woolen mills which run 60 hours per week, were allowed to make full time, whilst the paper mills, which run day and night, except Sunday, were run 15 hours out of 24. By this arrangement the water in Flat Rock pool was kept at its proper height for the navigation, and by means of temporary strips on the comb of the dam, no water was allowed to flow over except on Sunday, Sept. 6th and 13th, at which times the mills were not running.

"It may be well to state that the river was at as low a stage during the time mentioned as at any time during the droughts of July 8th to September 25th, 1869.

"The following are the quantities in detail:

No. 1. Dexter Mills, 1041.2 cubic feet per m. × 600m = - - - - - - - - -	624,720	cubic feet.
" 2. Economy Mills, 895.0 cubic feet per m. × 600m = - - - - - - - - -	537,000	"
" 3. Schuylkill Mills, 4415.0 cubic feet per m. × 600m = - - - - - - - - -	2,749,000	"
" 4. Inquirer Paper Mills, 3836.0 cubic feet per m. × 900m = - - - - - - -	3,452,400	"
" 5. Ripka Mills, 7810.5 cubic feet per m. × 600m = - - - - - - - - -	4,686,300	"
" 6. Eagle Mills—not in operation.		
" 7. Arcola Mills, 2328.7 cubic feet per m. × 600m = - - - - - - - - -	1,397,220	"
Carried forward, - - -	13,446,640	"

Brought forward, - -	13,446,640 cubic feet:
No. 8. Wabash Mills, 490.0 cubic feet per m. × 600^m = - - - - - - - - -	294,000 "
" 9. Brown Roofing Paper Mills, 918.0 cubic feet per m. × 900^m = - - - - - -	826,200 "
" 10. Schofield Mills, 1260.0 cubic feet per m. × 600^m = - - - - - - - - -	756,000 "
" 11. Mt. Vernon Flour Mills, 762.0 cubic feet per m. × 600^m = - - - - - - - -	457,200 "
" 12. Flat Rock Paper Mills, 6852.6 cubic feet per m. × 900^m = - - - - - - - -	6,167,340 "
No. 13. American Wood Pulp Works, 5525.0 cubic feet per. m. × 900^m = - - - - -	4,972,500 "
	26,919,880 cubic feet.
Water consumed at Manayunk Out-let Dock from September 2d to 16th, 1874, to lock 234 boats ∴ 18 lockages per day = - - - - -	875,460 cubic feet.
Leakage of Flat Rock Dam, out-let lock, mill fore-bays, and canal, estimated 3500 cubic feet per m. × 1440^m = - - - - - - -	5,020,000 "
	32,815,340 cubic feet.

32,815,340 cubic feet × 7.48 = 245,458,743.20 gallons per 24 hours.

"The measurement of the water consumed by turbine wheels, is based upon results obtained from time to time at each mill with a weir constructed to meet the requirements of Francis' Formula

$$Q=3.33\,(l-0.1 \times n \times h)\,h^{\frac{3}{2}}$$

with the proper correction for velocity, &c.

"For over-shot wheels the coefficient of discharge of the aperture in use was determined for each case, by testing a model of the aperture, made to quarter size, in a cut stone, water-tight measuring lock, fitted up for the purpose at Birdsboro, on the Schuylkill Canal. The coefficients were found to vary from 0.70 to 0.908.

"Then taking the case of Mill No. 1, Dexter Mills, we have, area of aperture = 9′ 11⅛″×1⅝″=165□ in.

Depth of head water measured from the centre of aperture to the surface of water in fore-bay = 51.948 inches.

"Reduced to the standard head, 36 inches, we have $\sqrt{36}$: $\sqrt{51.948}$: : 165□ and 6 : 7.2 : : 165□ : 198□ in. D= $\sqrt{2gh} \times A \times cd$, = 27.8 × 6 × 1.98 × 0.908, = 29,988.5712 cu. in. per second, = 1041.2 cu. ft. per min.

"It will be observed that the quantities discharged per minute do not, in all cases, agree with those given in the table marked D; this is because of changes in power that have been made since December 1st, 1874."

Names of Lessees of Water Power at Manayunk, with the quantity of Water used, Horse Power, and Rental, June 1, 1875.

Nos.	MILLS, ETC.	PROPRIETORS.	DIAMETER.	Discharge in Cubic Feet per Min.	Total Head and Fall acting on Turbines, in Feet.	Actual Horse Power.	An'al Rental paid to the P. & R. R. R. Co.
1	Dexter Mills (Dye Works)................	Heft & Ogle......................	1 Overshot, 18 ft., diam...	801.90	....	19.08	450 00
2	Economy Mills (Woolen)..................	Sevill Schofield........	1 Swain Turbine, 24 in....	895.00	23.00	31.10	1,326 00
3	Schuylkill Mills (Cotton)................	A. Campbell & Co......	1 Leffel Turbine, 48 in....	1,539.00	22.50	45.78	1,218 75
4	Inquirer Paper Mill........................	William W. Harding........	1 " " 48 in.... 3 " " 17½ in....	3,836.00	22.25	120.90	5,395 12
5	Ripka Mills (Cotton).......................	R. Patterson & Co............	1 " " 20 in.... 3 " " 48 in....	7,810.56	22.00	243.40	9,846 62
6	Eagle Mill (Cotton and Woolen)........	James Smith & Co............	1 Overshot, 18 ft....	1,517.25	....	36.10	1,400 00
7	Arcola Mill (Cotton).......................	James B. Winpenny.........	2 " 18 ft....	2,328.70	....	55.42	3,300 00
8	Wabash Mill (Cotton and Woolen)....	James M. Preston............	1 " 18 ft ...	490 05	....	11.66	392 62
9	Brown Roofing Paper Mill...............	Joseph Stelwagon...........	1 " 17 ft....	708 75	....	15.93	1,050 00
10	Schofield Mills (Woolen)..................	Thomas Schofield............	2 " 17 ft....	972.00	....	21 84	1,282 50
11	Mount Vernon Flour Mill................	Charles Delany...............	1 " 17 ft....	951.75	....	21.30	915 00
12	Flat Rock Paper Mills......................	Martin Nixon..................	1 Leffel Turbine, 48 ft.... 1 " " 40 ft....	6,852.60	19.50	189.29	8,194 00
13	American Wood Pulp Works............	American Wood Paper Co.	1 " " 35 ft.... 1 " " 40 ft.... 1 " " 48 ft....	6,747.30	19.50	186.38	8,330 00
			Totals.........	35,450.86	....	998.27	$43,100 61

NOTES.—Coef: for Swain's Wheel, Mill No. 2, = 0.80.
" " Leffel Turbine Wheel, Mill, No. 3, = 0.70, wheel working with about ⅓ gate.
" " " " at all other mills, = 0.75,—40″ wheel measured with Dynamometer, Oct. 1874, at Mill No. 12, gave 0.755.
" " Overshot Wheels, = 0.70.

The area of the drainage of the Schuylkill River has been computed to be 1,800 square miles, and the average annual rain fall is set down at forty-two inches, equal to 175,633,920,000 cubic feet, and if it be correct to assume a utilization of eighteen inches, or nearly forty-three per cent., the quantity would be 75,271,680,000 cubic feet, or 563,032,166,000 gallons per year, passing the dam at Fairmount, to tide water.

From the above, it is manifest that the river would afford an abundant supply of water, if a system of reservoirs was established in the mountains and at favorable points throughout the area drained, by which storm water could be impounded.

In the report of the Special Committee of the Commissioners of Fairmount Park upon the preservation of the purity of the water supply, October 11th, 1867, it is mentioned that it is only necessary to equalize the summer and winter flow of the river, to insure a supply of water very much greater than the present demand.

As far as practicable, the measures to accomplish this, as pointed out by the Committee, are the establishment of "pools or lakes of storage at several points on the river or its principal tributaries," in which storm water or that resulting from melting snows, may be arrested and reserved for gradual use, to be discharged into the natural channel, by means of such arrangements at the out-lets of the lakes or pools, as would equalize the flow throughout the year, and act as a protection against damage by floods.

The availability of these plans depends upon the finding of the requisite sites for the artificial lakes where they may be made without flooding valuable agricultural districts, and the creation of a sufficient number of lakes, reservoirs, or pools, so that every considerable creek or brook, flowing into the main trunk, may be provided with adequate means of storage.

To supply the City of Philadelphia with 100,000,000 gallons of water, daily, throughout a summer drought, by pumping at Fairmount, would (at fifteen gallons to one pumped) require 1,500,000,000 gallons, or a quantity five times greater than I have assigned to the minimum flow. It is apparent, therefore, that some means must be devised to increase the supply, and to reduce, largely, the quantity required for power, or steam must be employed for pumping, to meet the emergency of a dry season of seventy days duration.

The plan which I shall now present, so far as it relates to dams in the river, was originally suggested by me in my annual report to F. Fraley, President Schuylkill Navigation Company, December 23, 1854, and it had then for its object, the increasing of the supply of water for the navigation, to meet the wants of a large trade, whenever the necessity should arise, the supply of the City, by these means, not being at that time anticipated.

This mode of increasing the supply, avoids any objection which may be urged against the plan of artificial lakes, or of a system having for its object the perfect control of floods, of the practicability of which grave doubts may justly be entertained.

This scheme includes not only the creation of low dams and pools in the river, at present unoccupied by the navigation works, below the Blue Mountains, but the use of the 8 dams, and water of the existing navigation above that point, as well as of the waters of the reservoirs at Tumbling Run and Silver Creek in Schuylkill County.

In summing up the supplies of water from these sources, I begin with

Reservoirs in Schuylkill County.

1. Existing reservoirs.

Silver Creek.

On Broad Mountain, 7 miles above Pt. Carbon, 1500 feet above tide, at Philadelphia.

Length of dam at top, 1157 feet.

Water raise at dam, or depth of water over pipes, 37 feet.

Maximum height of dam, 42 feet.

Ponds, 58 acres.

Content, 42,780,500 cubic feet.

Drains 35,558,700 square feet, or $1\frac{275}{1000}$ square miles.

Length of reservoir pond, 2,320 feet.

Two exit pipes of 12 inches diameter.

Tumbling Run Reservoir at Mt. Carbon.

First or lower dam.

Above tide, 647.54 feet.

Length of mound, 418 feet.

Depth of water over pipes, 41 feet 6 inches.

Maximum height of dam, 47 feet 6 inches.

Ponds, 25.57 acres.

Content, 25,546,512 cubic feet.

Length of reservoir pond, 3,000 feet.

3 exit pipes of 12 inches diameter.

Second or upper dam.

Above tide, 694.25 feet.

Length of mound, 540 feet.

Depth of water over pipes, 57 feet. *

Maximum height of dam, 63 feet.

Ponds, 31.45 acres.

Content, 39,856,612 cubic feet.

Length of reservoir pond 3,580 feet.

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* The exit pipes of the upper dam, are about 10 feet below the surface of the lower, the lower dam backing upon the other to that extent.

Proposed Reservoirs.

Tumbling Run Valley has three sites above the existing reservoirs, with the following characteristics, and I number them from the existing upper reservoir, calling the first

No. 3.

Above tide, - - - - -	739.60 feet.
Water raise at dam, - - - -	45.3 "
Length of mound dam, - -	522 "
Area of reservoir, - - - -	31.31 acres.
Content, - - - - -	26,166,000 cubic feet.

No. 4.

Above tide, - - - - -	799.60 feet.
Water raise at dam, - - - -	43.3 "
Length of mound dam, - -	560 "
Area of reservoir, - - - -	37.29 acres.
Content, - - - - -	29,153,000 cubic feet.

No. 5.

Above tide, - - - - -	984.60 feet.
Water raise at dam, - - - -	30 "
Length of mound dam, - -	785 "
Area of reservoir, - - - -	102 acres.
Content, - - - -	70,000,000 cubic feet.

The combined capacity of the existing and proposed reservoirs in Tumbling Run Valley is 190,722,124 cubic feet.

From actual survey, under my direction, the area of the valley was found to be 167,284,100 square feet, equal to six square miles, or 3,840 acres; it lies between the Sharp and Second Mountains, which rise from 200 to 500 feet above it, with steep sides, favorable for drainage.

The dams of the navigation above Blue Mountain:

Beginning at the first dam below the town of Schuylkill Haven, known as No. 8, we have Nos. 8, 10, 11, 12, 13, 14, 15, 16, which, if diverted from their present use as slack water navigation, and drawn off five feet each, except the last, No. 16, or the Blue Mountain Dam (situated in the gap of the Blue Mountain, one mile below the mouth of the Little Schuylkill), twenty-five feet high, and could be drawn fifteen feet. The result of one draught from these would give 62,570,000 cubic feet. (Table "A.")

Low dams in the unoccupied bed of the river below Reading:

Between Lewis' Dam, No. 24, and the Vincent Dam, No. 25, there are twenty miles of unoccupied river bed, which is held in reserve by the Philadelphia and Reading Railroad Company for future improvement as slack water navigation. In this distance ten dams of six feet height could be built, capable of being drawn down six feet. At the former height and draught, these ten dams would afford at one draught 168,960,000 cubic feet. (Table "B.")

There are also four other sites for dams, namely: Reading; Custer's Island, near Royer's Ford; Vincent out-let lock, a short distance above Black Rock Tunnel, and Umstead's Island, near Perkiomen Junction, which would give at one draught, 59,136,000 cu. ft. (Table "C.")

The total of these quantities is as follows, viz.: Total of the quantities in reservoirs and dams in cubic feet:

	Cubic feet.
Silver Creek Reservoir, - - -	42,780,500
Reservoirs existing in Tumbling Run Valley,	65,403,124
Reservoirs in Tumbling Run Valley which may be constructed, - - -	125,319,000
Carried forward, - -	233,502,624

Brought forward, - -	233,502,624
Dams on the navigation above the Blue Mountains (a), - - - - -	62,570,000
New dams in the unoccupied bed of the river, below Reading, - - - -	168,196,000
Four other dams below Reading, - -	59,136,000
Add for dams below Reading, if made 8 feet high and drawn down 6 feet (168,196,000 + 59,136,000) × $\frac{2}{5}$ = - - -	90,932,800
Total cubic feet, - - -	614,337,424
Or in gallons, - -	4,595,243,931
To this add the minimum flow of the river for 70 days, 245,000,000 gallons × 70 =	17,150,000,000
Total gallons, - -	21,745,243,931

This quantity is equal, in round numbers, to 310,000,000 gallons per day, for use during a drought of seventy days duration without rain, which may be regarded as an extreme case.

Without entering into details with regard to the mode of operating this system of reservoirs in the river, it is only necessary to say, that they should be supplied with the means of quickly drawing the water of any one of them, when required, and the whole should be operated in such a way as never to withhold the natural flow of the river at its minimum, and always so as to be in readiness to store up surplus water from rains; thus, in part, holding back storm water, restraining floods, and equalizing the flow.

On the supposition that the whole number of dams are full at the opening of the spring seasons, which, as a matter of fact, will always be the case, they may be used in the event of an early drought with the positive certainty of being replenished by rain in time for later summer droughts, the first usually of moderate and the last of longer duration, are not exceptional occurrences on the Schuylkill.

Means of Increasing the Power for Pumping Water.

The utilization of the power of the 310,000,000 gallons of water per twenty-four hours, seems to me to involve among other things, an abandonment of the use of water power by the mills at Manayunk.

The Fairmount dam might be raised four feet, which would make the head at the Fairmount Works from mid tide, fourteen and a half feet, in place of ten and a half, as at present.

The Flat Rock dam could also be raised two feet, which would, of course, affect the water powers at Conshohocken, consisting of three mills, working now under a head and fall of about eight feet.

The elevation of the Fairmount dam four feet, would flow the water back to Hipple's lane bridge, and not reach Flat Rock dam.

Were these plans realized, it would be practicable to set at rest at once, all questions about the impurity of the water of the Schuylkill River in Fairmount dam, occasioned by sewage coming into it at Manayunk, and other impurities below that point, by conveying the water of Flat Rock dam by a conduit to each of the pumping stations, Spring Garden and Fairmount Works.

To properly carry out this plan, it would be necessary to remove the site of the Flat Rock dam, to a point about six hundred feet lower down the river, nearly opposite the south portal of the Flat Rock tunnel. Three objects would be gained by this change.

First, The avoidance of the expense of a conduit line around the bold projecting hill, through which the railroad tunnel passes.

Second, Bringing the water of the dam on the western side, convenient to a point for the erection of pumping works, to utilize the surplus water of Flat Rock dam, and supply a storage reservoir on the hills, so elevated as to permit the water to be carried to Belmont, or any other reservoir on the west side of the river.

Third, From this new dam a conduit may be taken down on the eastern side, through the town of Manayunk, to that portion of the park grounds between the Ridge avenue and the river below the Wissahickon creek, where a large subsiding reservoir could be formed, reaching from the Wissahickon to a point near Falls Village, the river hill and the drive skirting it forming one side of the basin.

This point is four miles from Fairmount Works, and three miles from Flat Rock Dam; estimating the lake at one-third of a mile long, the surface would probably be maintained twenty feet at least above the new surface of Fairmount dam.

Flat Rock dam being 36.10 feet above mid tide, with two feet proposed raise, would stand 38.10 feet above tide, while Fairmount, now standing 10.50 feet above tide, with proposed addition of four feet, would have an elevation of 14.50 feet, showing a difference between the levels of the respective dams of 23.60 feet after their alteration.

This lake, beside shortening the conduit line, may be made to form a charming feature of the park. A steam pumping station also, could be erected, to pump from it for the future supply by steam power of a natural basin or reservoir between the Falls Village and Germantown, or of a basin at Cambria and Thirtieth street, or some other high point mentioned by the Chief Engineer of the Water Department, in his annual report to Councils April 8, 1875.

Leaving the lower end of the conduit at Wissahickon, the conduit would pass on the east side of the river to the Spring Garden Works, and thence to a basin on the ground between Lemon Hill and the forebay at Fairmount, the surface of which would probably be elevated sixteen feet or more, depending upon the size of the conduit, above the proposed raised surface of Fairmount dam.

No provision has been made for the supply of the Belmont Works with water from the conduit, because it would involve a submerged crossing of the river from it, below Peter's Island bridge.

If the Belmont reservoir be supplied from a new pumping station at Flat Rock, the machinery of the works might be transferred to some other point on the east side of the river, where it could be used to aid in the supply of the East Park reservoir with water from the conduit.

A favorable location for such a station may I believe be found opposite Peter's Island, a short distance above the Columbia bridge.

Among the advantages which these plans secure, may be mentioned,—1. An increased supply of water for power. 2. Increased power by using the water at Flat Rock Dam, under a head of twenty-one feet, or more, and at Fairmount, under a head of fourteen and a half feet from mid tide, in place of ten and a half feet, as at present. 3. A reduction in the height to which the water is now pumped at Spring Garden and Fairmount Works.

The value of these advantages, and the increase of the water-power thus provided, I leave with you, and I only remark, further, that in looking at the results of the calculations of the hydraulics of Fairmount Dam, as made by J. W. Nystrom, C. E., for James Haworth, I was struck with the large quantity of water stated to have run to waste over the dam, each year for several years past. I can only account for this statement, by supposing that the observations and measurements on which these calculations were based, were made, or taken from the gauge at the inner basin at Fairmount, which has its zero point nine inches below the present top of the Fairmount Dam, as rebuilt in 1872, and since then, a temporary timber of five inches high, has been fitted upon that top, making, in all, fourteen inches.

Now if we say there are *fourteen* inches of water upon the dam, as indicated by this gauge, it will not be correct.

There will, in fact, be five inches upon the dam, but no water flowing over it.

Yours, very respectfully,

(signed) JAMES F. SMITH.

Reading, Pa., July 28, 1875.

STATEMENT "A."

Number.	Name.	Length in feet.	Average width.	Available depth.	Quantity—cubic feet.
8	Bowens........	6,000	120	5	3,600,000
10	Landing, vc...	4,500	150	5	3,375,000
11	Landing, vc...	3,300	130	5	2,145,000
×	Tunnel Canal	4,000	250	5	5,000,000
12	Auburn........	6,600	150	5	4,950,000
13	Auburn........	3,600	150	5	2,700,000
14	Lords...........	12,000	200	6	14,400,000
15	Hummels......	4,000	200	6	4,800,000
{ 16	Blue Mt.......	4,000	300	15	18,000,000
	Blue Mt.......	4,800	150	5	3,600,000
					62,570,000

Equal to 468,023,600 gallons.

STATEMENT "B."

Dams in the unoccupied bed of the river between Lewis's Dam and the Vincent Dam, 20 miles, rise $54\frac{20}{100}$ feet, or to surface of Lewis's Dam $75\frac{70}{100}$ feet.

Number of dams, 10, each six feet high, to be drawn four feet, average width 400 feet, equal to 1,263,820,800 gallons or 168,960,000 cubic feet.

STATEMENT "C."

Dam at Reading on site of Old Union Dam 5 feet high, 5,280×400×4=	8,448,000	cubic feet.
Dam at Custer's Island, near Royer's Ford 5,280×500×4×2 miles=	16,896,000	"
Dam at Vincent Outlet near Black Rock Tunnel, 5,280 × 500 × 4 × 2 miles = - - - -	16,896,000	"
Dam at Umsted's Island, near Perkiomen Junction, 5,280×500×4×2 miles = - - - -	16,896,000	"
	59,136,000	"

Equal to 442,337,280 gallons.

Amount of water consumed at Fairmount Lock.

Area of Lock, 2,100 square feet by $10\frac{1}{10}$ feet lift at mid-tide=21,210 cubic feet.

Assuming that of 30 boats passing each way per day, 50 per cent. alternate in using the lock, the 30+15=45 lockages per day.

And 21,210×45=	954,450	cubic feet.
Deduct displacement of 30 boats passing down 180 tons+boat 60 tons×30= 7,200 tons, - - - -	258,048	" "
Carried forward,	696,402	" "

Brought forward,	696,402	cubic feet.	
Add displacement of 30 light boats passing up 2,156 cubic feet×30= -	64,680	"	"
	761,082	"	"
Add leakage of locks, 12 locks full per day (Messrs Fisk & Hughes report on Chesapeake and Ohio canal, March, 1837, and Col. J. J. Abert report, 1838.)= - - - -	254,520	"	"
	1,015,602	"	"
	7,617,015	Gallons.	

Fairmount Pool=5,280 feet ×6 miles ×650 feet=20,592,000 square feet. $\frac{1015602}{20592000}$=.049 feet depth over the whole surface of the pool.

APPENDIX E.

THE PERKIOMEN STORING RESERVOIR.

The following table has been prepared to exhibit the method of determining the capacity of the reservoir for storage.

An inspection of the tables of the rainfall at the City Hospital of Philadelphia since 1825, shows that the irregularity of the rain fall during the year which would have required the greatest storing capacity to bridge over the dry season, was in the year 1858, although the rainfall of such a year as 1856 would erroneously lead one with less careful study to suppose that it would require more storage.

I have made this table on the assumption that the rainfall on the water shed of the Perkiomen is one-fifth more than at Philadelphia, in consequence of its greater elevation and exposure to the water-charged winds from the seaward; that the proportion of the rain water which is collectable varies with each month in the year, and that the loss by evaporation from the surface of the water after it has been collected in the reservoir, also varies with each month as does also the consumption or demand for water.

The last column of the table called "deficiency" shows the required capacity for storage in the reservoir.

Storage Capacity required for the Perkiomen Reservoir.

MONTHS.	Philadelphia Rain-fall in 1858.	Estimated Rain-fall on the Perkiomen one-fifth greater.	Percentage of Rain-fall collectable in each month.	Inches of Rain-fall collectable.	Millions of gallons collectable into the reservoir from 220 square miles.	Inches of evaporation from the surface of the lake for each month.	Evaporation in million gallons.	Waste and loss from all causes.	Percentage of consumption per month.	Consumption at an average of 150 million gallons per day.—Million gallons.	Total demand from reservoir. — Million gallons.	Surplus. — Million gallons.	Deficiency.-Million gallons.
January	2.60	3.12	90	2.81	11,240	1.15	63	30	82	3,690	3,783	7,457	
February	2.29	2.75	80	2.20	8,800	1.65	90	30	83	3,735	3,855	4,945	
March	1.09	1.31	70	0.92	3,680	0.82	45	30	85	3,825	3,900	....	220
April	4.64	5.57	60	3.34	13,360	2.07	112	30	94	4,230	4,372	8,987	
May	5.01	6.01	50	3.00	12,000	1.62	88	30	105	4,725	4,843	7,157	
June	4.50	5.40	40	2.16	8,640	7.10	386	30	115	5,175	5,591	3,049	
July	1.35	1.62	30	0.49	1,960	6.75	368	30	120	5,400	5,798	....	3,838
August	4.94	5.93	20	1.19	4,760	7.79	424	30	115	5,175	5,629	....	869
September	1.49	1.79	40	0.72	2,880	5.41	295	30	109	4,905	5,230	....	2,350
October	1.83	2.21	60	1.33	5,320	7.40	403	30	104	4,680	5,113	207	
November	5.62	6.74	80	5.39	21,560	3.95	215	30	100	4,500	4,745	16,815	
December	4.50	5.40	90	4.86	19,440	3.66	199	30	88	3,960	4,189	15,251	
Aggregates and averages	....	47.85	59⅙	28.41	113,640	49.37	2,688	360	100	54,000	57,048	63,868	7,057

ESTIMATES FOR A GRAVITY SUPPLY FROM THE PERKIOMEN.

The Dam.

220,000 cubic yards of embankment at 40 cts., -		$88,000
21,000 cubic yards of puddling at 40 cts., -		8,400
7,000 cubic yards of slope wall, &c., at $2.00,		14,000
4,000 cubic yards of excavation for puddle (part rock) at $2.00, - -		8,000
2,000 acres, partly cleared and some grubbing,		50,000
Waste weir, - - - -		40,000
Temporary wooden trunk and moving the same, - - - -		10,000
Piping, etc., - - - -		20,000
2,000 acres of land at $100, -	$200,000	300,000
Houses, barns, water power, &c., - -	100,000	
Moving railroad, say eight, miles, -		240,000
Add, - - - - -		1,600
		$780,000

Of the conduit, masonry alone, *per lineal foot.*

On solid earth or rock—

Brick masonry, 1.56 cubic yards $12, - - - -	$18.72	
Rubble masonry, 1.51 cubic yards at $7, - - - -	10.57	
		$29.29
Generally the cost will not exceed, -		$29.00

In rock excavation—

Brick masonry, 33.22 cubic feet= 1.23 cubic yards at $12, -	$14.76	
Rubble masonry, cubic feet =0.61 cubic yards at $7, -	4.27	
		$19.03

When the rock excavation is light the cost will be only, - - - - $16.27

Plan No. 11 A., per sketch, centre cutting 11′ above grade, side hill 2 to 1—

Rock excavation, 168.5 cubic feet =6.24 cubic yards at $1, -	$6.24
Rip rap, 1.17 cubic yards at $2, -	2.34
Back filling, 6.11 cubic yards at $40,	2.44
	$11.02

Paving and ditches for upland water, 130 at 40, -	$52.00
Paving 2,000 feet at $2,	40.00

Per 100 feet, - $92.00=per 1 ft. .92 $11.94

Note.—It appears that the difference between 7′ and 11′ cutting does not much influence the cost of grading for the conduit.

Plan 12 A.—On level ground at grade, embankment 18 feet high, slopes $1\frac{1}{2}$ to 1.

Area, - -		630. sq. ft.
Deduct area of conduit masonry,	82.96	
Area of space of conduit,	128.75	211.71
		418.29 sq. ft. 15.5 c. yds. at .40, $6.20

Plan B.—

With 5 feet cut in earth excavation=4.26 cubic yards at .40, - - -	$1.70	
Back filling=9.66 cubic yards at .40, -	3.86	
		$5.56

Plan C.—

With 8 feet cut in earth excavation=7.7 cubic yards at .40 - - -	$3.08	
Back filling=8.33 cubic yards at .40, -	3.33	
		$6.41

Plan D.—

Ground 3 to 1, centre cut 8 feet excavation, 9.18 cubic yards at .40, -	$3.67	
Back filling=12.07 cubic yards at .40, -	4.83	
	$8.50	
Deduct excavation put in embankment 4.13 cubic yards at .40, - -	1.65	
		$6.85

NOTE.—By excavation for conduit, cut ½ to 1 it reduces cost to, - -	$4.72

Plan E.—5 feet cut in rock.

Excavation of 2.78 cubic yards at $1.00, - - -	$2.78
Embankment = 9.4 cubic yards at 40 cents, - - -	3.76
	$6.54

NOTE.—The masonry saved in conduit = $8.00 per foot.

Plan F.—8 feet cut in rock costs $7.00 and saves $10.00 in masonry.

Plan 13 A.—Conduit supported on solid wall 400 feet long, average 18 feet below grade.

400 × 18 × 21 = 5,600 cubic yards, at $5.00, - -	$28,000
Embankment from grade up 400 feet $6.50 (plan A), -	2,600
Carried forward,	$30,600

Brought forward,	30,600	
Culvert 8 feet semi-circle, 150 feet at $12.00, -	1,800	
Embankment below grade. 20,000 cubic yards, 40 cents,	8,000	
	$40,400	
Say per foot, - - - -		$100
Plan 13 B.—Embankment average 15′ high, -		85
Plan 13 C.—Embankment average 5′ high, -		31
Plan 13 D.—Embankment average 10′ high, -		60
Plan 14 A.—Pipes 700′ east branch of Perkiomen, 30′ average depth, 3 pipes of 4′ diameter - $54 =	$37,800	
2 pipe chambers, -	12,000	
	$79,800	
Per foot, - - -		$71
Plan 14 B.—Pipes 1,200′ 8 Skippack, -	$64.800	
2 pipe chambers, - -	12,000	
	$76,800	
Per foot, - - -		$64

Plan 15 A.—

Tunnel—16′ × 7′ = 112 sq. ft.

Segment, 16′ diam. = 100

212 = 8 c. y. at $6 = $48

Lining 43′ × 8″ = E. = 1 c. y. at $12 = 12

$60

Less cost of conduit, - - - - 29 = $31

ESTIMATE OF THE COST OF THE GRAVITY PLAN FROM THE PERKIOMEN

Arranged to deliver two hundred millions of gallons per day into the East Park Reservoir.

		Price per foot.	
49,000	lineal feet of rock-work plan, -	$15,	$735,000
1,100	lineal feet of rock-work plan, -	17,	18,700
21,000	lineal feet of rock-work plan, -	11,	231,000
29,260	lineal feet of earth, - -	8,	234,080
38,070	lineal feet of earth, - -	7,	266,490
1,600	lineal feet, supported on low walls of masonry, - -	30,	48,000
5,700	lineal feet, supported on low walls of masonry, - -	31,	176,700
6,750	lineal feet, supported on high walls of masonry, - -	50,	337,500
14,100	lineal feet (pipes) - - -	66,	930,600
600	lineal feet, supported on high masonry, - - - -	70,	42,000
2,650	lineal feet, supported on high masonry, - - - -	80,	212,000
1,100	lineal feet, supported on high masonry, - - - -	100,	110,000
2,800	lineal feet tunnel, - - -	40,	112,000
173,730			$3,454,070
8,000	lineal feet of pipes, - - -	54,	432,000
156,740	lineal feet of conduit, - -	29,	4,545,460
18	ventilators, - - - -	1,000,	18,000
Three more pipes, when needed, 22,800 feet, - - - - - -		54,	1,231,200
Land drains, conduits, road and farm crossings, fencing, etc., - -			400,000
The cost of the Dam, etc., - - - - -			780,000
Total cost, including large contingencies,			$10,860,730

The above estimate can be reduced as follows: to deliver *seventy-five millions of gallons per day*, and the arrangement will not waste any of this expenditure when enlarged for a supply of *two hundred millions.*

Deduct 4 pipes of 22,800 feet length at $72 per foot, - - - - -			$1,641,600
The cost of 9,750 feet of solid masonry foundations across deep valleys, is - - -		$901,850	
Substituting two pipes therefore, at $36 =	$351,000		
16 chambers at $8,000 each, - -	128 000	479,000	
Saving, - - - - - -			422,850
Saved by omitting the brick lining in tunnels, 9,200 feet at $19 - - - - -			174,800
Saved on 13,800 cubic yards of tunnel excavation at $6, - - - - - -			82,800
Saved by omitting the brick lining in 89,000 feet of rock excavation, making an average of $8.50 per foot, - - - - -			756,500
Total saving, - - - -			$3,078,550

There are some other changes which could be made in the plans of constructing these works, which without impairing their efficiency, would still farther reduce the first cost, and yet furnish an ample supply of water for the next five or six years from the Perkiomen, for less than eight millions of dollars.

Whenever this plan of supply is carried into effect the entire expense of pumping into the lower reservoirs will cease, and the expense of pumping into the upper ones (Belmont, Roxborough, etc.), will be greatly reduced.

This saving in pumping, if capitalized, as shown by the following table, would be equal to $3,000,000, with the present supply of 50 millions of gallons per day; $5,500,000, when the consumption reaches 75 millions of gallons per day; $8,000,000, when the consumption reaches 100 millions of gallons per day; and $13,000,000 when the consumption reaches 150 millions of gallons per day.

WM. J. McALPINE.

Table showing the expense of pumping SAVED *by the Perkiomen plan, when the consumption of water is 50, 75, 100, and 150 millions of gallons per day, considering the cost of pumping by water power at $3 per million gallons one hundred feet high, and that by steam power at $15.*

PREPARED BY W. J. McALPINE.

Ratio of consumption.	No. feet high pumped.	Saving per day on 50 millions of gallons.	Saving per day on 75 millions of gallons.	Saving per day on 100 millions of gallons.	Saving per day on 150 millions of gallons.	
70	100'	25 M. at $3 = $75 00	25 M. at $3 = $75 00	25 M. at $3 = $75 00	25 M. at $3 = $75 00	All water delivered to the first system.
		10 at $15 = 150 00	27½ at 15 = 412 50	45 M. at 15 = 675 00	80 M. at 15 = 1200 00	
		35 M. $225 00	52½ M. $487 50	70 M. $750 00	105 M. $1,275 00	
20	135	10 M. at $20.25 = $202 50	15 M. at $20.25 = 303 75	20 M. at $20.25 = 405 00	30 M. at $20.25 = 607 50	Water pumped from Fairmount pool to 135 feet.
10	105	5 M. at $15.75 = $78 75	7½ M. at $15.75 = 118 12	10 M. at $15.75 = 157 50	15 M. at $15.75 = 236 25	Water pumped from Flat Rock pool to 135 feet.
100		$506 25	$909 37	$1,312 50	$2,118 75	
		$506.25 x 365 = $184,781.25	$909.37 x 365 = $331,923 70	$1,312.50 x 365 = $479,062 50	$2,118.75 x 365 = $773,343 75	Cost of pumpage per year, being the interest at 6 per cent. on following:
		$3,079,687 50	$5,532,061 66	$7,984,375 00	$12,889,062 50	Capital.

Description of the Plans of the Perkiomen Dam and Conduit.

(C) Showing the section of valley at the site of the embankment:

(C 1) The cross section of the dam, with the method of constructing it; also, the various elevations of the water level in the conduit, of the water surfaces in the reservoir, and of the extra storage surface, together with the mode of connecting it with the rock foundations and slopes, so as to render it secure.

(D) A section of the conduit, lined with brick, having 128.75 feet sectional area, capable of delivering 200 millions of gallons of water per day.

(F) Sections of the conduit showing the method of construction, both in rock, on steep side-hill, and in earth on level ground, with overdrains.

(G, H) Cross-section and elevation of the solid foundations in masonry for carrying the conduit across the smaller valleys.

(I, K, L) Plan, section and elevation of pipe chambers, where it is proposed to conduct the water by pipes over the valleys.

Plans of the Delaware.

(M) A cross section of the proposed open canal for bringing the water from New Hope or Scudder's Falls.

(N) Plan of a conduit and covering designed for the feeder along the Delaware River where its flooring is below low water.

APPENDIX F.

NOTE ON THE SOURCES OF WATER SUPPLY.

It was agreed by the Commission, that any of its members might express their views, as individuals, in the appendix.

We wish to say that we believe that the vital statistics of Philadelphia, and the results of careful chemical analysis, show that the water now pumped from the Fairmount Forebay, is as good as that supplied to most large cities. We think that it is not as good as it once was, and that prompt measures should be taken not only to prevent it from becoming worse, but, also, to restore the river as nearly as possible to its former purity. We think that a sewer from Manayunk to tide water, is required, not only for this purpose, but also for sanitary reasons, apart from the question of water supply, and that it ought to be promptly constructed.

We believe that the water of the Delaware, to be pumped at Lardner's Point, will be much better than that now obtained at the Kensington Water Works; and we believe that there is a very large body of wholesome water in the Delaware, between Lardner's Point and Trenton. The condition of the tidal tributaries, and the distance above the City to which the effect of sewage and refuse from manufactories may hereafter extend, should, we think, at some future time be carefully investigated.

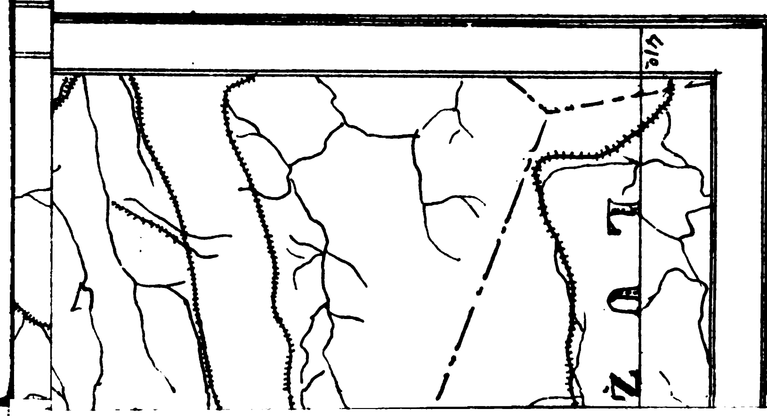
The proposed site in the Valley of the Perkiomen, about thirty-four miles from Philadelphia, is the nearest and best place that we know of, where an impounding reservoir could be constructed, large enough to store the storm waters, for the supply of the city, by a gravity conduit. The construction of such a work would require several years; an immense outlay of money; and a great increase of the city debt. We do not think that it should be undertaken, until other measures have been tried, and more complete surveys and careful estimates made.

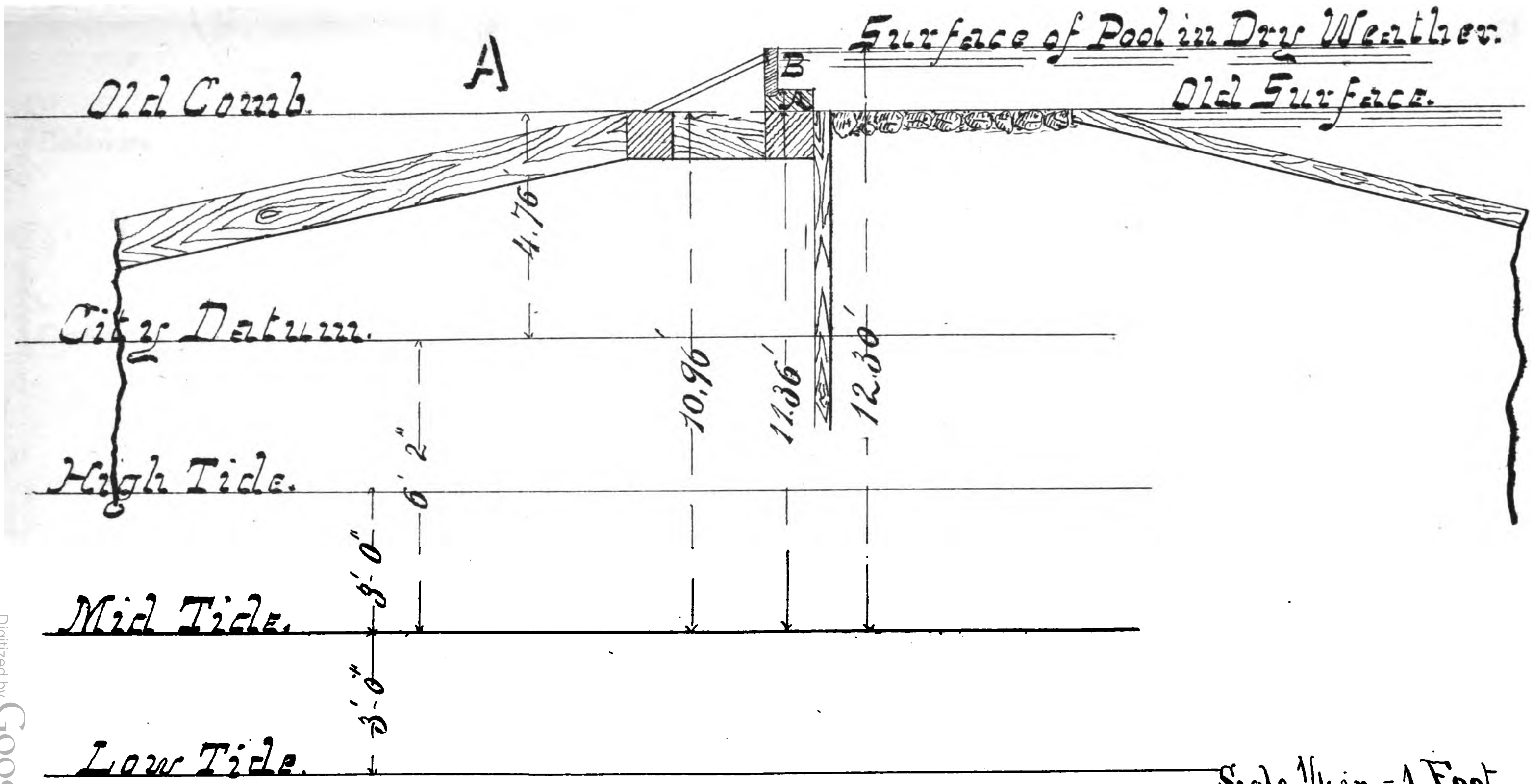
SOLOMON W. ROBERTS,
W. MILNOR ROBERTS,
WM. E. MORRIS.

Table of Rain Fall in Philadelphia from 1810 *to* 1874.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1810													32.66
1811													34.97
1812													39.30
1813													35.63
1814													43.14
1815													34.67
1816													27.95
1817													36.01
1818													30.18
1819													23.35
1820													39.61
1821													32.18
1822													29.86
1823													41.85
1824													38.74
1825	0.84	3.26	4.63	.83	1.72	3.59	2.06	3.70	2.61	1.25	1.36	3.72	29.57
1826	1.11	2.13	5.80	3.87	.19	4.655	3.68	2.75	2.00	5.83	1.85	1.28	36.145
1827	2.86	3.55	1.23	2.83	2.50	2.09	2.97	5.75	.79	5.91	4.76	3.26	38.50
1828	2.05	2.75	3.35	3.82	3.49	2.69	5.33	1.51	4.62	1.39	6.71	.26	37.97
1829	5.37	3.75	2.87	4.99	2.68	3.44	4.35	4.61	2.01	2.30	3.97	1.51	41.85
1830	1.63	2.06	4.115	1.815	3.75	5.99	4.07	3.87	2.93	4.31	5.35	5.18	45.07
1831	6.22	2.44	3.97	5.20	1.07	3.56	4.17	5.39	5.33	4.51	1.88	1.20	44.94
1832	4.58	2.66	1.90	2.98	5.40	1.55	2.62	5.69	1.40	3.41	2.59	5.09	39.87
1833	3.97	1.24	2.22	.70	5.88	5.28	4.15	3.39	3.82	10.05	2.18	5.67	48.55
1834	2.49	2.22	2.02	2.83	3.52	3.99	4.35	.62	3.57	3.29	3.01	2.33	34.24
1835	2.75	1.81	3.83	4.33	1.99	6.27	6.55	2.05	2.63	1.22	3.19	2.68	39.30
1836	7.62	2.99	1.75	3.47	2.28	7.31	2.91	1.97	1.82	3.59	3.34	3.61	42.66
1837	2.50	3.58	3.76	2.83	4.86	2.83	5.89	4.06	2.28	.66	3.23	2.56	39.04
1838	2.20	2.19	3.171	3.586	3.577	6.600	2.376	2.780	9.519	4.896	3.350	1.044	45.238
1839	5.037	3.424	1.504	1.507	6.073	3.922	2.516	4.644	2.919	2.831	3.100	6.262	43.739
1840	1.841	3.009	2.626	6.827	2.688	5.948	4.538	5.554	2.502	5.734	2.486	3.647	47.400
1841	7.837	1.387	5.821	6.456	3.269	3.114	3.280	9.102	1.895	3.198	4.224	5.917	55.500
1842	1.358	4.265	2.835	5.307	5.865	3.192	11.805	3.786	1.269	1.712	3.487	3.657	48.538
1843	1.440	2.540	4.415	4.723	2.045	1.686	4.543	9.255	4.856	3.220	4.148	4.041	46.912
1844	4.052	1.449	4.430	1.354	3.091	3.351	5.284	2.399	4.034	5.025	2.951	2.753	40.173
1845	3.760	4.738	2.415	2.580	1.599	3.725	2.763	7.298	2.155	2.529	2.500	3.959	40.021
1846	4.630	3.330	4.598	2.112	3.444	3.300	4.604	4.272	.249	2.444	7.970	3.437	44.39
1847	4.730	4.569	4.700	.585	1.567	3.305	2.765	3.182	8.070	3.000	2.836	5.785	45.094
1848	2.030	1.443	2.756	1.541	4.902	4.433	3.281	1.714	1.805	3.747	2.343	5.007	35.002
1849	.730	2.610	5.470	1.752	3.995	2.195	2.933	6.975	1.404	5.595	2.600	5.836	42.095
1850	4.770	2.870	4.750	2.665	6.500	2.030	5.970	8.329	7.732	1.092	3.320	4.515	54.548
1851	1.230	3.110	3.475	4.565	4.817	3.438	2.524	2.555	1.180	3.025	3.356	2.275	35.500
1852	2.011	2.710	4.270	6.445	3.034	4.030	4.060	4.400	1.293	2.267	6.055	5.174	45.749
1853	1.845	4.440	2.462	3.835	5.173	1.100	6.296	3.088	4.463	3.470	2.320	2.165	40.657
1854	2.331	4.203	1.615	7.750	6.935	2.390	3.024	.842	3.798	1.545	2.834	2.910	40.180
1855	2.337	2.352	1.684	2.050	2.965	7.949	6.400	2.786	4.000	4.111	2.037	5.425	44.096
1856	4.537	1.237	2.232	3.515	2.595	1.986	1.508	6.000	4.014	1.296	2.070	2.937	33.927
1857	3.532	.790	1.831	6.786	5.547	7.500	3.915	7.590	1.105	2.690	1.450	5.550	48.286
1858	2.595	2.285	1.087	4.640	5.015	4.495	1.345	4.941	1.492	1.842	5.615	4.500	39.852
1859	6.675	3.660	6.985	5.610	2.250	6.013	4.071	4.736	7.681	3.132	3.820	3.490	58.123
1860	3.225	2.755	1.415	3.800	3.817	2.885	.985	8.401	2.850	4.520	6.130	3.310	44.093
1861	5.245	2.065	3.925	3.705	6.640	3.880	2.560	3.137	4.402	3.797	4.875	2.092	46.44
1862	4.795	4.640	3.553	4.160	2.308	6.975	2.465	.925	3.980	4.770	4.790	1.650	45.011
1863	4.720	4.680	5.885	7.015	4.510	4.250	6.009	1.447	.875	2.465	2.700	4.633	49.189
1864	1.705	.551	5.170	3.795	8.685	2.345	3.770	1.920	7.165	1.820	3.930	5.145	46.001
1865	3.610	5.825	4.710	2.830	7.210	4.750	2.970	3.770	7.960	3.050	3.960	5.610	56.255
1866	3.145	6.615	2.150	2.930	4.680	2.960	2.520	2.181	8.705	4.145	1.760	3.465	45.256
1867	1.762	3.892	5.465	1.810	7.320	11.025	2.887	15.816	1.720	4.320	2.940	2.730	61.187
1868	3.620	2.520	3.360	5.440	7.005	4.370	3.514	2.056	8.908	1.737	5.280	3.595	51.405
1869	4.280	4.760	5.305	2.120	4.235	5.585	2.885	1.280	3.250	6.320	3.725	5.115	48.860
1870	4.075	2.532	4.060	5.605	6.280	2.895	3.947	5.115	1.710	3.895	2.102	1.889	44.105
1871	3.466	3.086	5.814	1.829	3.383	3.773	6.811	5.971	1.772	4.863	4.293	2.259	47.320
1872	1.267	1.185	3.377	2.497	2.808	4.223	11.215	8.319	3.820	5.363	3.381	3.662	51.117
1873	6.048	5.607	2.242	4.191	4.783	.887	5.553	12.289	4.045	5.889	4.995	1.757	58.286
1874	4.218	2.823	1.595	7.509	2.697	2.664	2.759	6.531	3.987	1.650	2.229	2.249	40.911

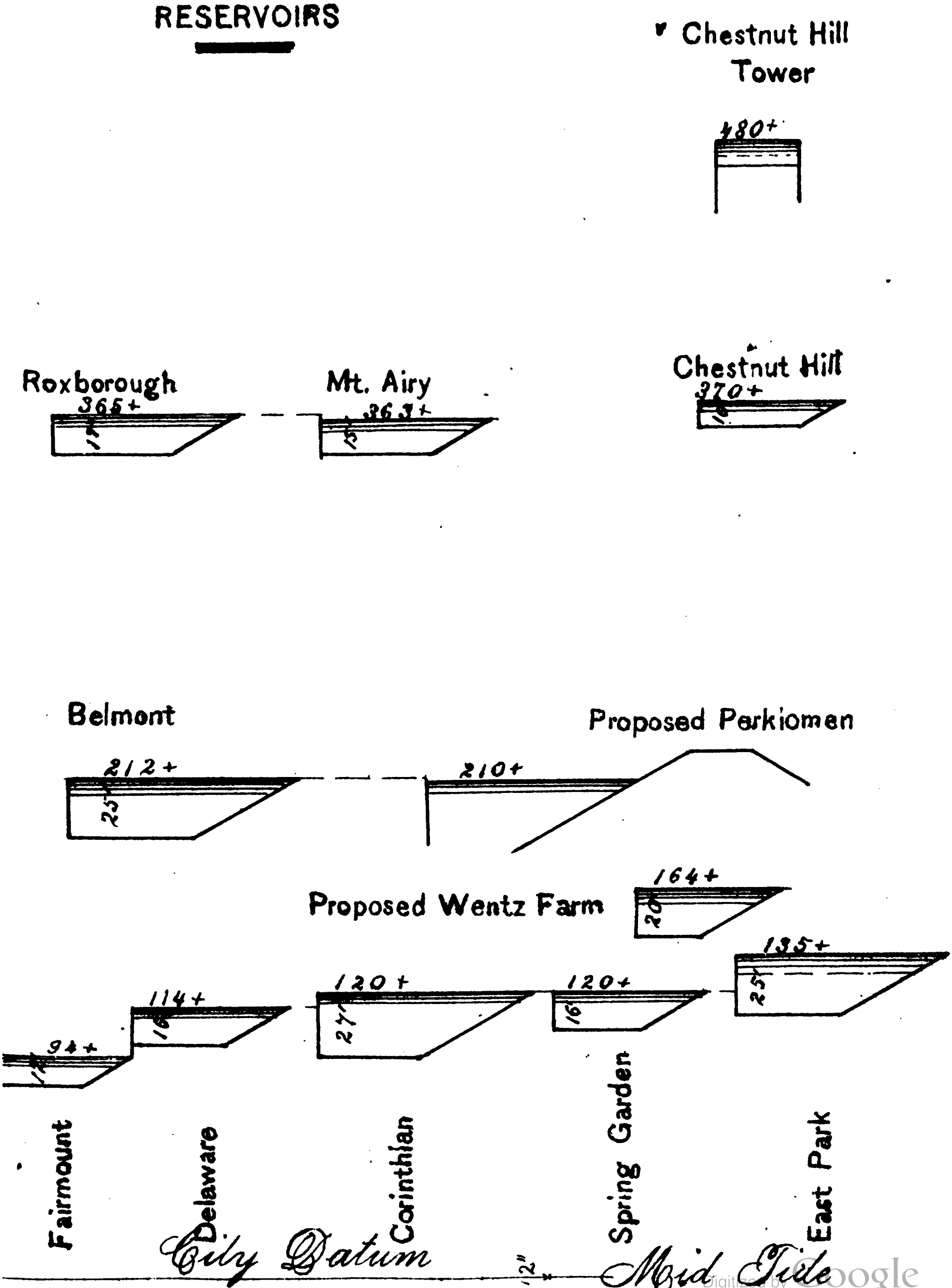
Height of gauge at Hospital, 50 feet above the level of the sea.
The observations from 1810 to 1824, inclusive, were taken at Spring Mills, Pennsylvania.

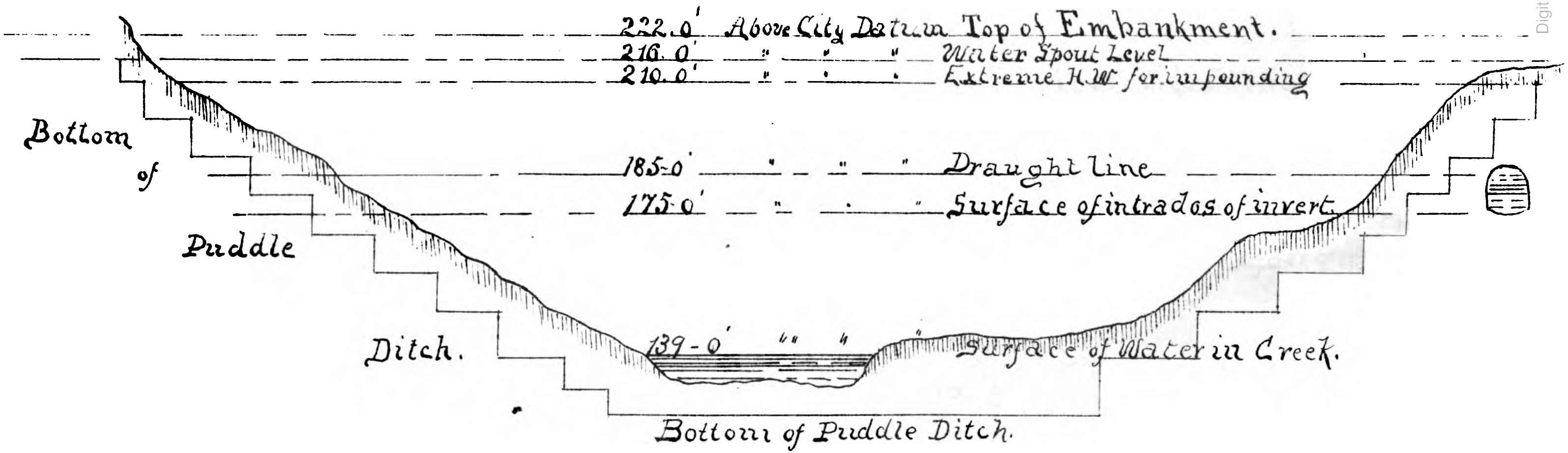




Fairmount Dam
Showing the additional height
in use in low Water.

Diagram
SHOWING
ELEVATION & DEPTH
OF
RESERVOIRS

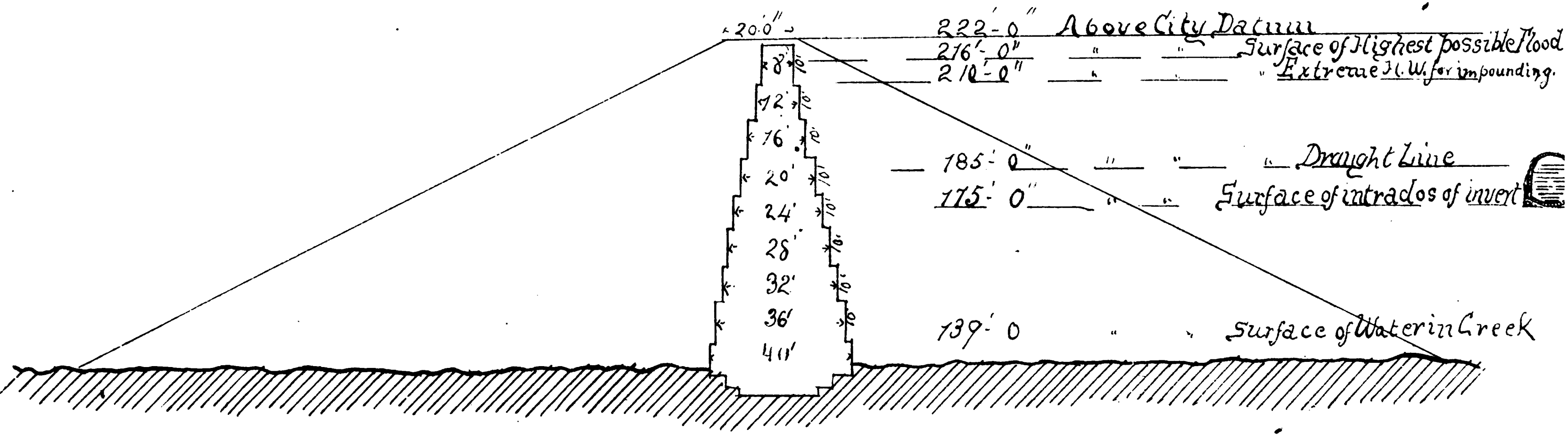




Scale
Horizontal 100 ft. per. inch.
Vertical 50 " " "

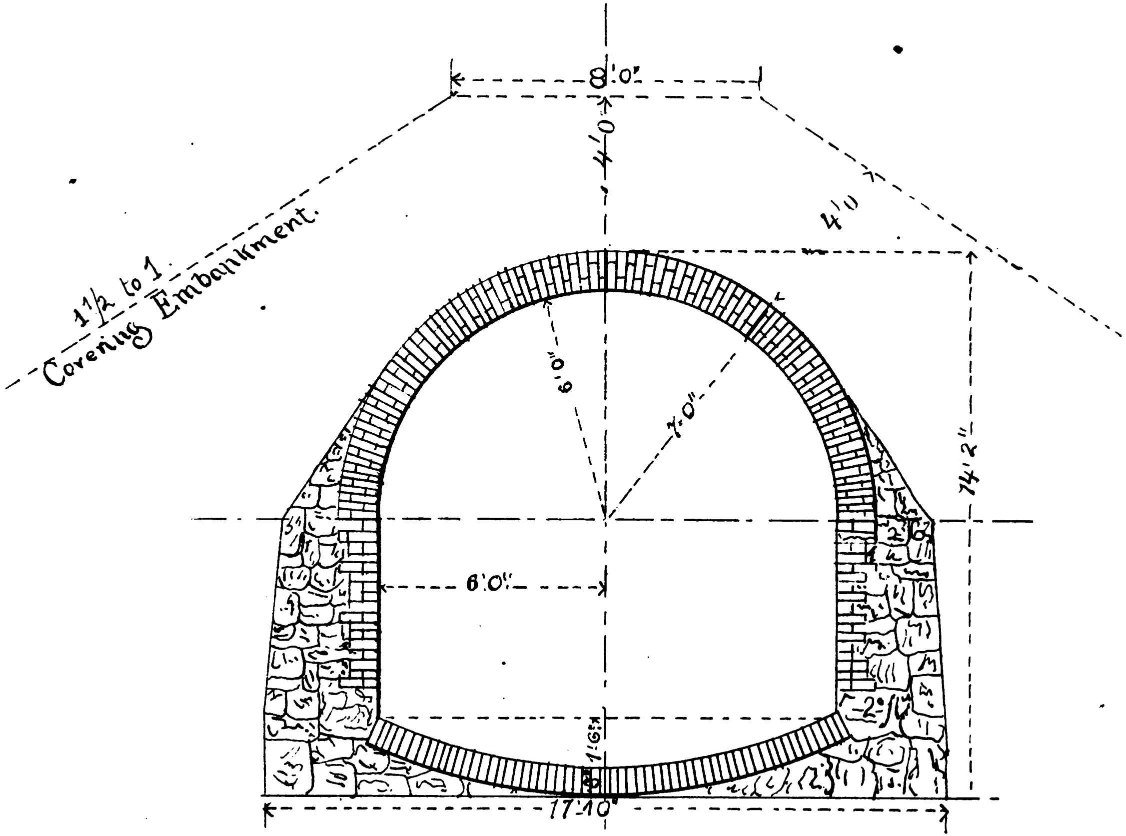
Section of Perkiomen Valley &c Site of Dam.

C. 1



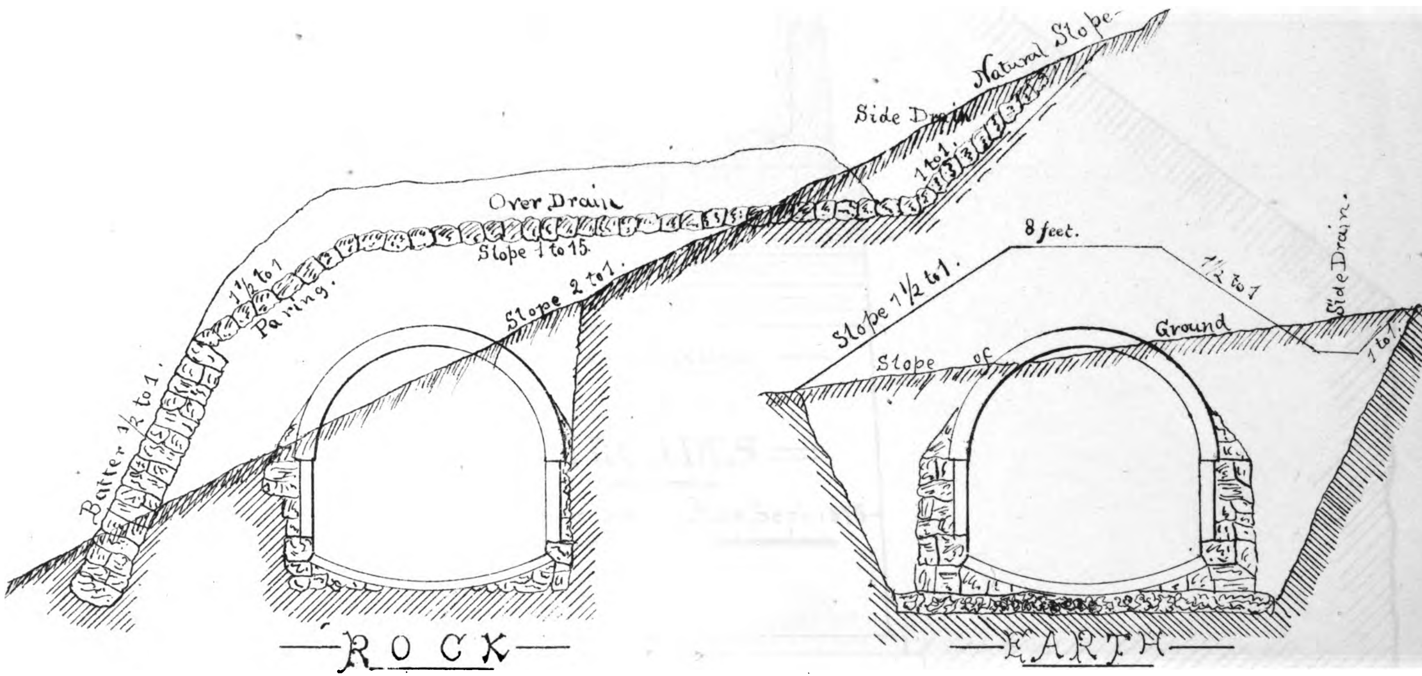
Scale 50 ft. per inch.

Cross Section
of the
Perkiomen Dam
at the
Centre of Creek

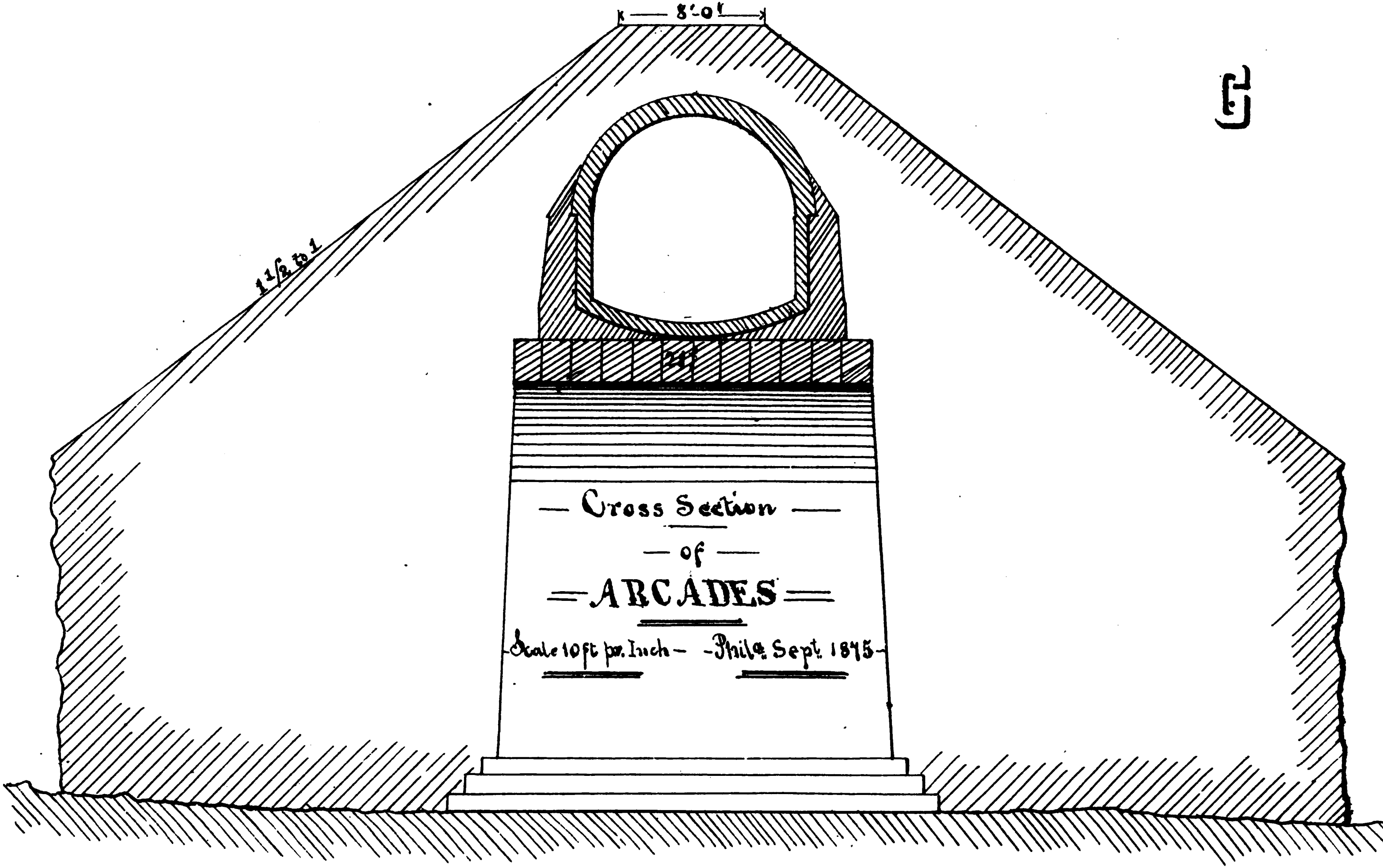


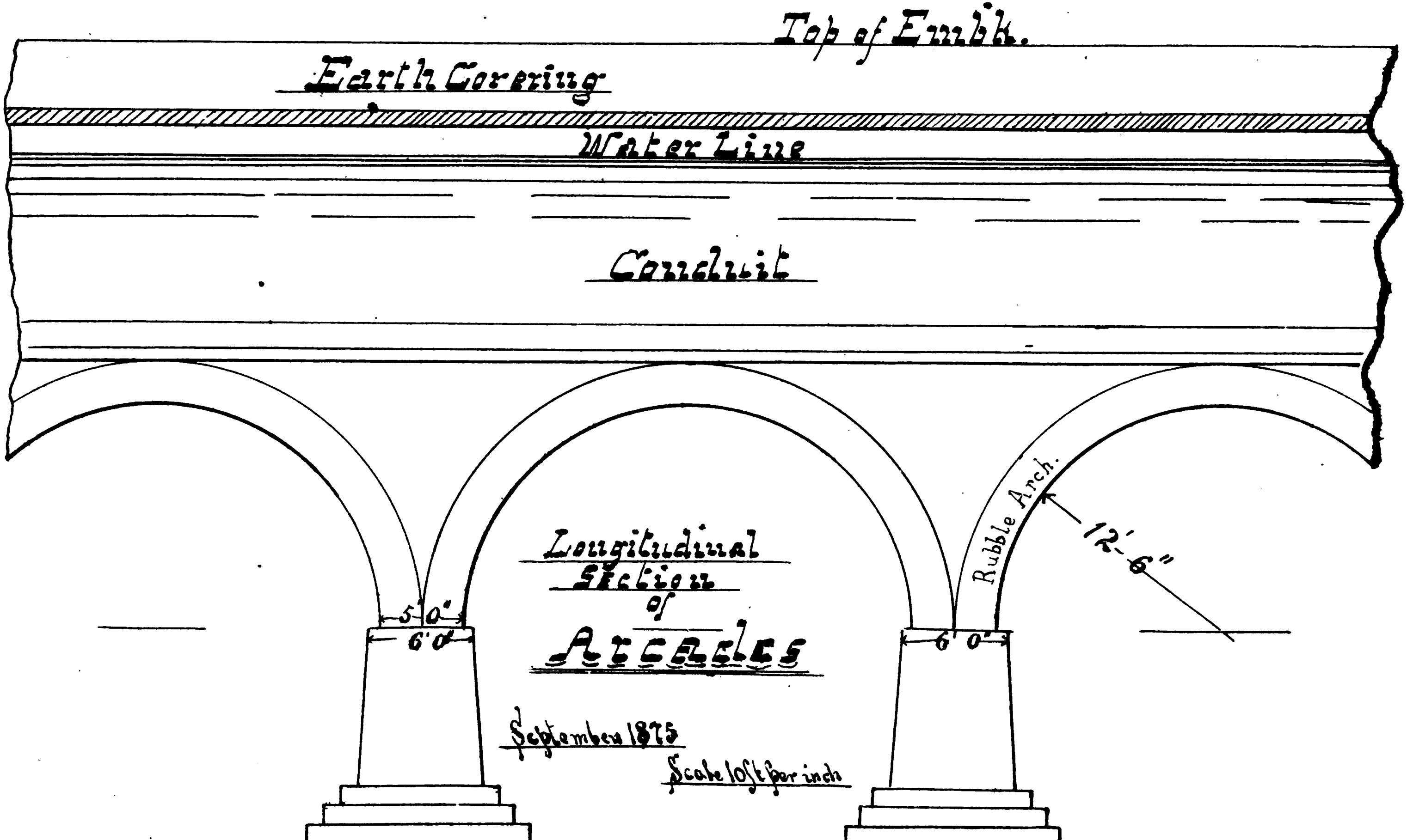
— Scale 1 in = 5 Feet —

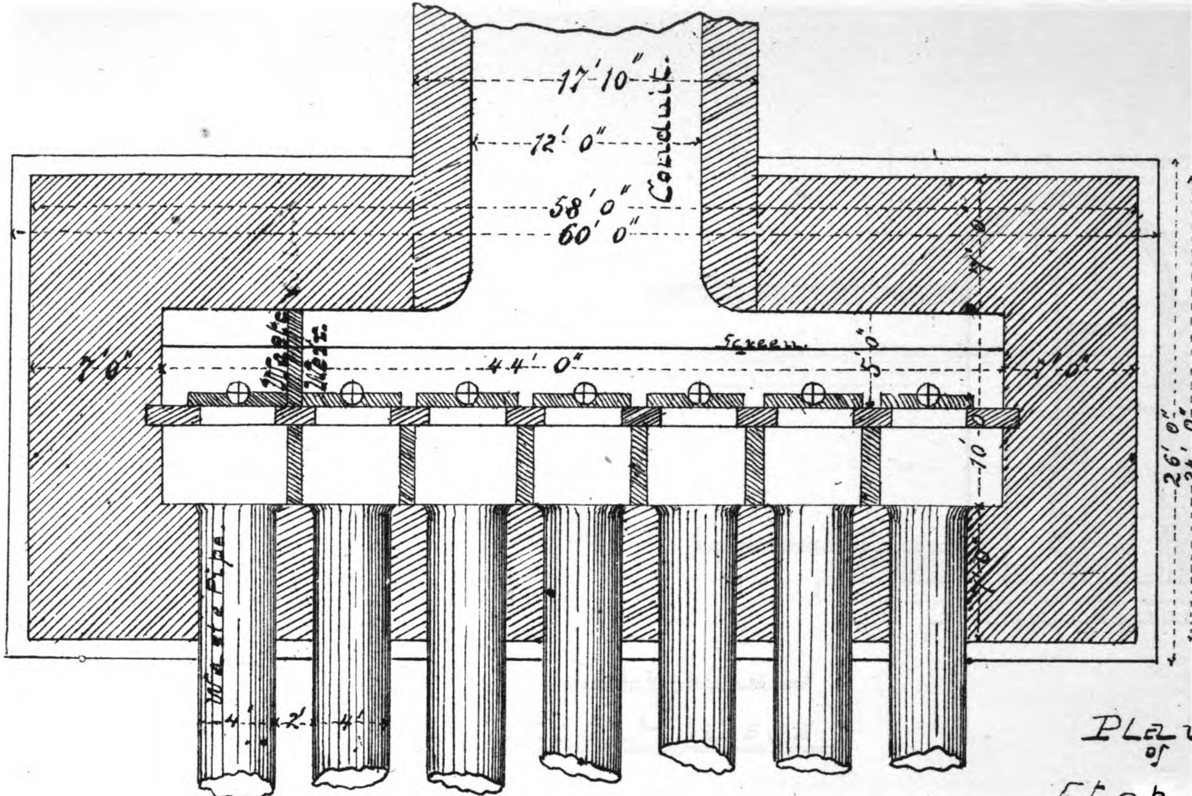
E



Scale 10 feet per. Inch.


8'0"
1 1/2 to 1
Cross Section
of
ARCADES
Scale 10 ft pr. Inch - Phila. Sept. 1875


Top of Embk.
Earth Covering
Water Line
Conduit
Longitudinal Section of Arcades
Rubble Arch.
12'-6"
5'0"
6'0"
6'0"
September 1875
Scale 10 ft per inch

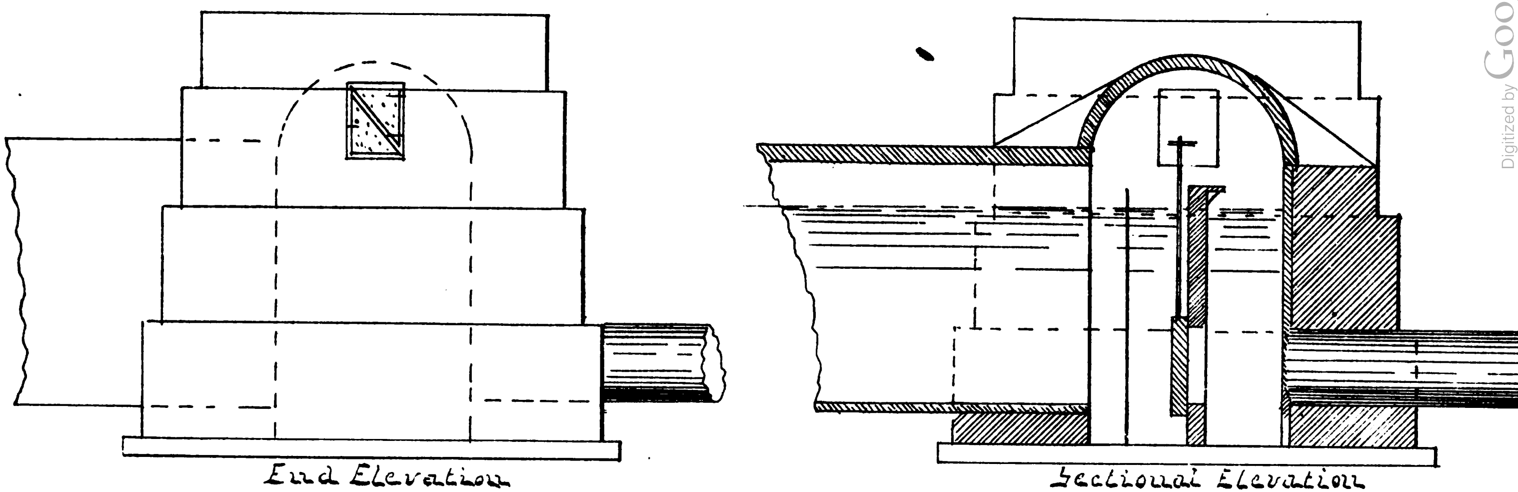


Plan of Stop House

Scale 10ft. per inch

September 1875.

K

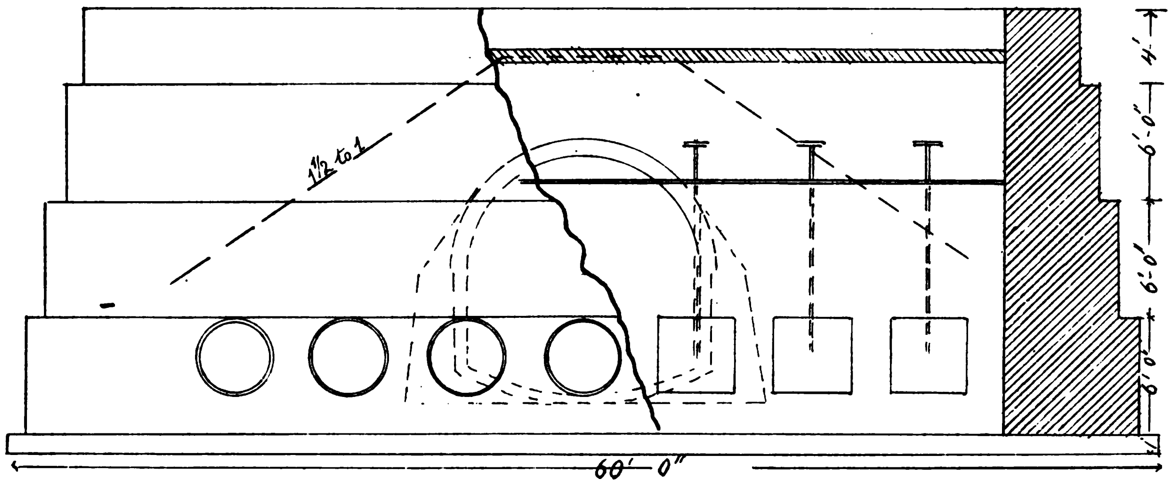


Elevations of Stop Houses

Scale 1in: 10 Feet

September 1875.

L

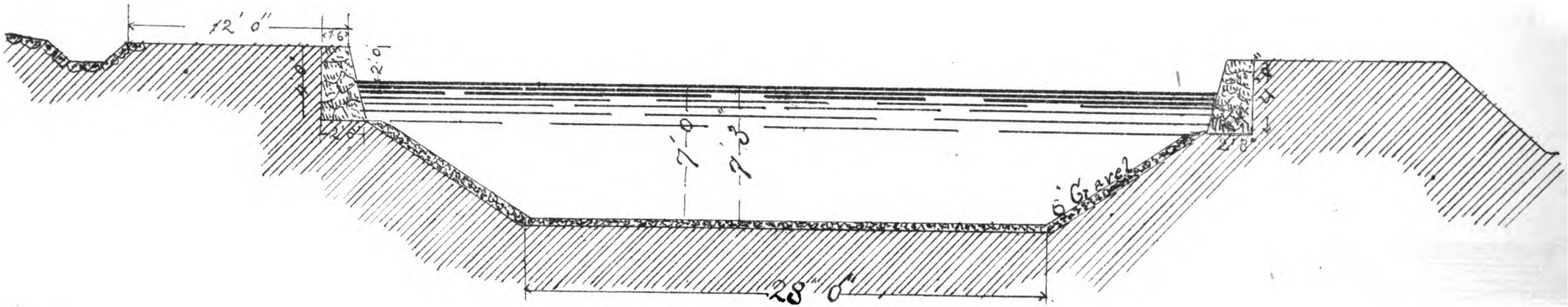


Elevation
of
Stop House

Scale 10 feet per inch

September 187

M



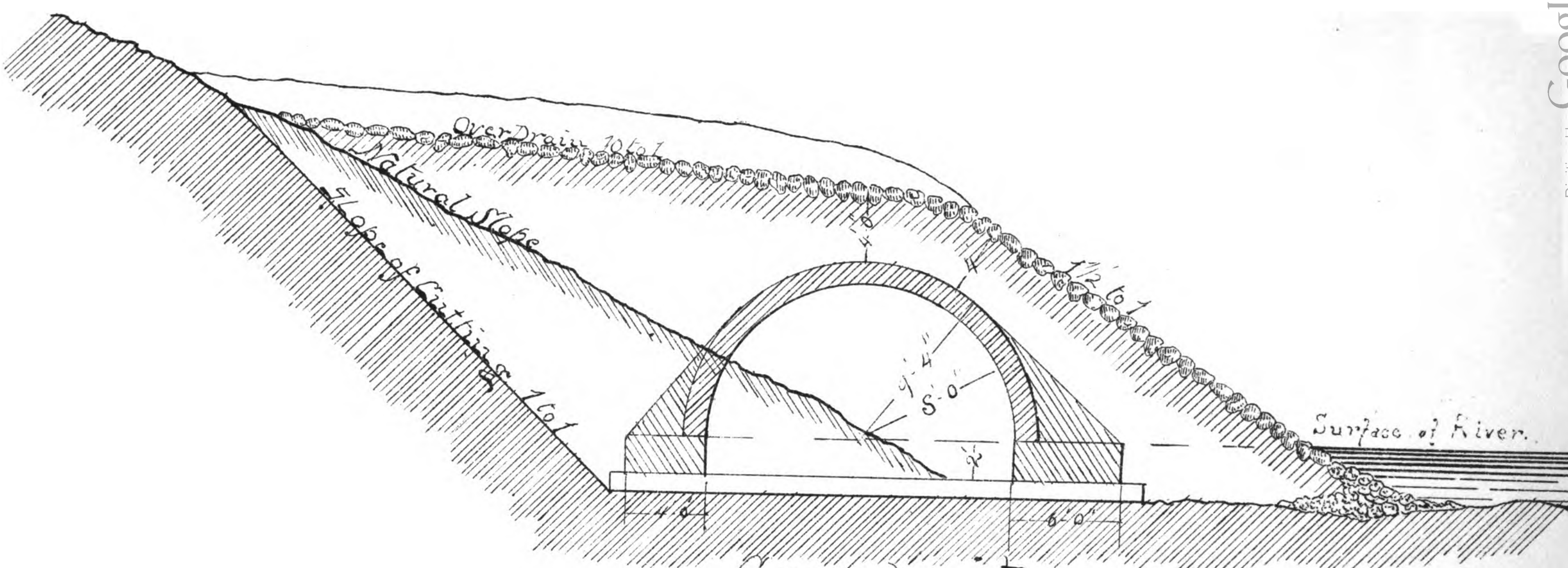
Plan for Open Canal

Fall per mile 3 inches.

Scale 10 ft per inch

September 1875.

N



Conduit
along
Delaware River
Where the Wooden Flooring is submerged
at
Low Water.

Scale 10 ft per inch.

September 1875.