Department of Public Works

BUREAU OF WATER

City of Philadelphia

1909

Description

OF THE

Filtration Works & Pumping Stations

ALSO

Brief History of the Water Supply

CITY OF PHILADELPHIA

JOHN E. REYBURN, MAYOR

DEPARTMENT OF PUBLIC WORKS

GEORGE R. STEARNS, DIRECTOR

BUREAU OF WATER

FRED C. DUNLAP, CHIEF

1909

DESCRIPTION OF THE FILTRATION WORKS

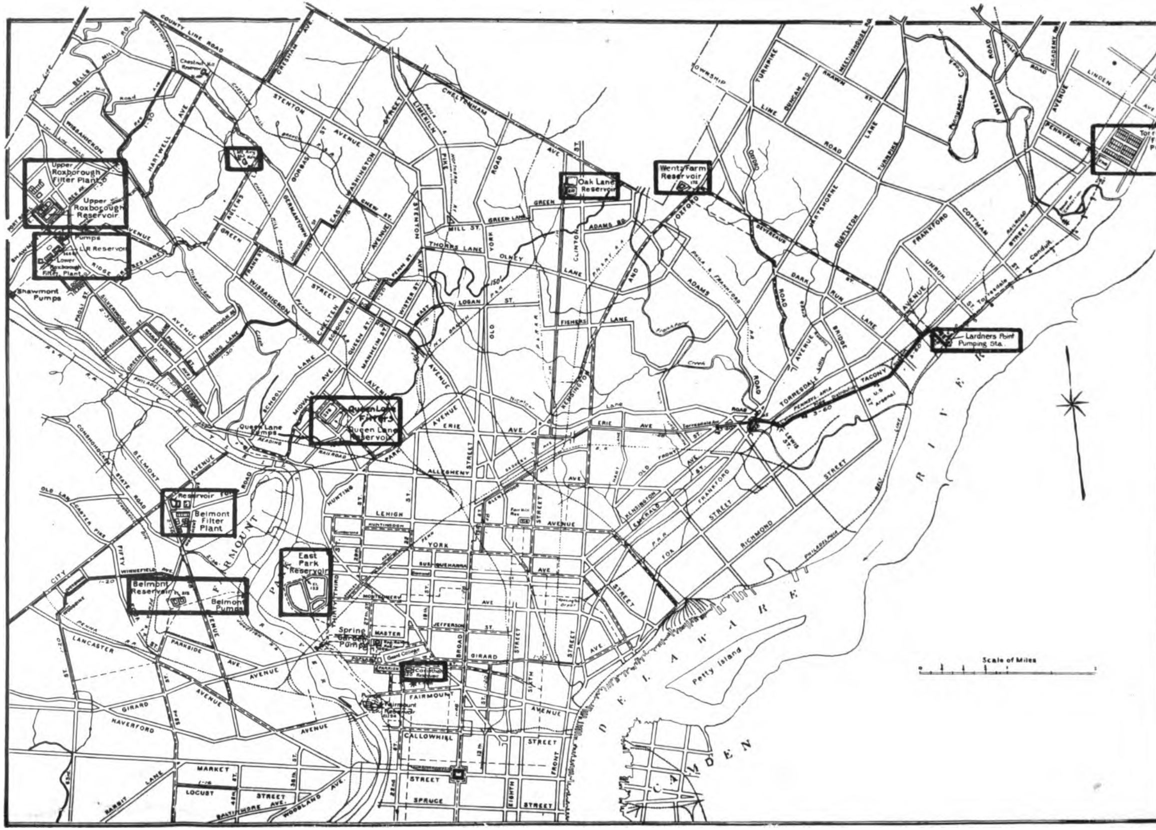
AND

PUMPING STATIONS

ALSO

BRIEF HISTORICAL REVIEW OF THE WATER SUPPLY

1789—1900



Location of Filter and Pumping Stations and Reservoirs.

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General Description of the Filtration Works and Pumping Stations

The water supply for the City of Philadelphia is taken from the Delaware and Schuylkill rivers within its geographical limits. Before the filtration works were constructed, about 95 per cent. came from the Schuylkill river and the remaining 5 per cent. from the Delaware river. As a result of one of the recommendations of the Commission of 1899, which formulated the general plan adopted for the betterment of the water supply, viz., to limit the quantity taken from the Schuylkill and make the larger extensions on the Delaware, this condition has been practically reversed. At the present time, approximately 70 per cent. comes from the Delaware, but upon completion of the Queen Lane filters and with all the stations operating to their full capacity, 65 per cent. of the total supply will be taken from the Delaware river.

In locating the various filter stations due consideration was given to the utilization as far as possible of the existing pumping stations, reservoirs, etc., nevertheless this change caused the abandonment of the Fairmount and Spring Garden pumping stations, two of the oldest, and the latter the largest on the Schuylkill river.

Prior to the completion of the improvements made since 1901, all of the water was pumped normally to artificial reservoirs constructed on elevated sites from which it was distributed through pipes by gravity except in some of the higher districts where it was re-pumped as is the case under the present system.

This same condition prevails at all the stations on the Schuylkill river with the exception that the water is filtered after leaving the reservoirs and thence distributed by gravity. The water taken from the Delaware, however, is first filtered and then pumped under pressure direct into the distribution system.

The filtration system is comprised of five separate filter stations—Lower Roxborough, Upper Roxborough, Belmont, Torresdale and Queen Lane, and with the exception of the Queen Lane, were designed and almost completed under the direction of Mr. John W. Hill. Four of the stations are located on high plateaus along the Schuylkill valley, as the relatively steep and rocky banks of the river did not afford suitable sites for filter beds. Where possible, use was made of the existing reservoirs for sedimentation basins. The Torresdale station is located on the right bank of the Delaware river above Pennypack Creek, and is the largest station in the world.

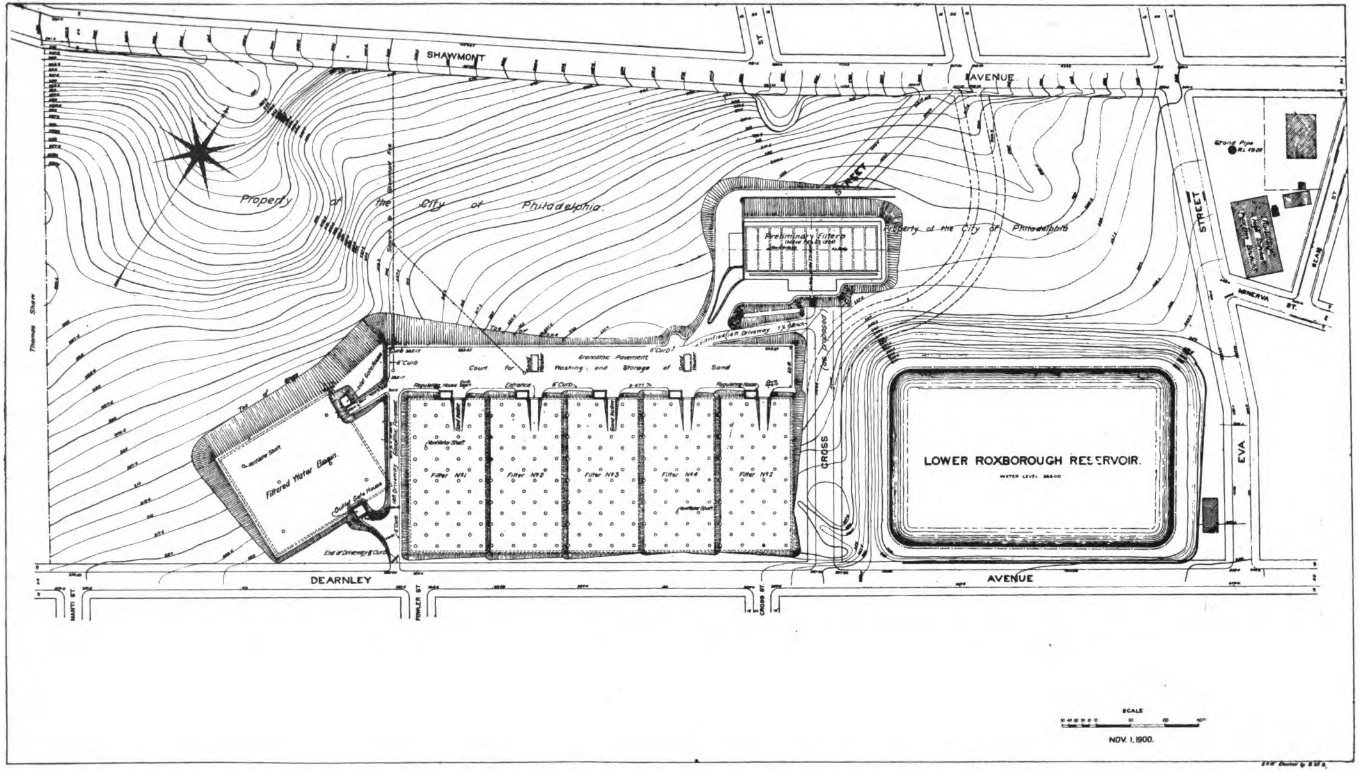
The nominal daily capacity of each station is as follows:

Schuylkill River:		
Lower Roxborough	12,000,000	gallons
Upper Roxborough	20,000,000	"
Belmont	40,000,000	"
Queen Lane (under construction)	70,000,000	"
Delaware River:		
Torresdale	240,000,000	"
Total	382,000,000	gallons

LOWER ROXBOROUGH FILTERS

This station, the first to be constructed, is located near Ridge and Shawmont avenues, adjacent to the Lower Roxborough reservoir in the 21st ward. It is supplied from the Roxborough pumping station located at Shawmont on the Schuylkill river near the City boundary on the northwest, and consists of a sedimentation basin, eleven preliminary filters and five final or slow sand filters. The Lower Roxborough reservoir, formerly used as a storage basin, after some slight changes was converted into a subsiding basin having a capacity of about thirteen million gallons or one day's supply for the filters.

The water is pumped into the reservoir at the bottom at the east end, and is drawn off near the surface through a screen chamber



Lower Roxborough Filter Station

at the west end. The basin operates upon the continuous subsidence system, and will give a subsidence of the Schuylkill river water for twenty-four hours before it is passed to the preliminary filters. From the preliminary filters the water is passed to the plain sand filters, and thence to the clear water basin. There is no supplementary pumpage with the exception of that necessary for the purpose of cleaning the sand.

The preliminary filters at this station consist of eleven concrete tanks, 16 feet wide, 64 feet long, 5 feet 6 inches deep, inside measurements, in which is placed at the bottom 5 inches of coarse gravel, ranging in size from 2½ to 1½ inches diameter; above this a layer of crushed furnace slag, 10 inches thick, ranging in dimensions from 1½ to ¾ inch; above this a layer of crushed furnace slag 24 inches thick, ranging in dimensions from ¾ to ¼ inch, and above this a layer of compressed sponge, 9 inches thick, weighing about five pounds per square foot of surface. The sponge is compressed on the layer of slag by a set of narrow planks spaced ½ inch apart which are pressed down on the sponge layer by timber beams running lengthwise of the filter tank and screw jacks, reacting upwards against I beams. These beams are spaced on 8 feet centers, and span the filter tanks transversely.

The water is introduced into the bottom of the tanks through 5-inch diameter perforated tile pipes, percolates upwards through the gravel, crushed slag and sponge, and is drawn off at the top of the filters over brass wire plates having rectangular notches 22½ inches long and 9 inches deep.

The water enters the filters at the rear end and is drawn off at the front end into galvanized iron boxes, from which it flows into the collecting pipe and is thence conducted to the plain sand filters.

The preliminary filters each have a filtering area of 1,024 square feet, and when all are in service, delivering 12,000,000 gallons per day, each will deliver 1,090,909 gallons, or at the rate of 46.4 million gallons per acre per day.

The filters are cleaned on an average of once a month by reversing the current at a rapid rate and wasting the water into sewers through a 20-inch pipe drain at the bottom. When the sponges become heavily clogged, which occurs approximately twice annually, they are removed from the tank by mechanical appliances and washed in laundry washers driven by electric motors.

The final filters, of which there are five in number, are of the same general type as those in use in a number of cities in Continental Europe, in Albany, N. Y.; Washington, D. C., and Pittsburg, Pa. Owing to the topography of the site, it was found necessary to locate the filters in a series of steps, the difference in level between the two adjacent filters being 2 feet 9 inches. The filtered water basin is located at a still lower level. Each filter measures 109 feet by 219 feet 10 inches on the inside and has a net filtering area at the nominal sand line of about 0.537 acre.

The floors of the filters are built of concrete in the form of inverted groined arches, 6 inches thick at the center and 14 inches thick under the piers, and on a puddle lining. The puddle lining consists of a mixture of clay and broken stone, and is carried up around the outside walls to a point one foot above the water line of the filters.

The vaulting is built of concrete in the form of semi-elliptical groined arches, 14 feet span, 3 feet rise, 6 inches thick at the crown, and 21 inches thick over the piers, which are 22 inches square at the sand line and battered to 34 inches square at the base. Ventilator shafts are provided for the admission of light and air during scraping. On top of the vaulting is placed a layer of broken stone 4 inches thick for the purpose of conveying rain water to the drains leading down through the piers and dividing walls to a point just above the sand level.

The 24 inch main collectors, extending the entire length of each filter, are built entirely of concrete, and are covered with movable concrete slabs. Six inch lateral collectors enter this drain at the top through special terra-cotta fittings.

The lateral collectors are placed in each bay and consist of a line of six inch diameter vitrified pipe perforated all around from end to end and plugged at the end remote from the main collector. Around the collectors and for a height of six inches from the floor is placed gravel ranging from 3 inches to 1¾ inch in diameter. Above this is placed a four inch layer of gravel ranging in size from 1¾ to ⅝ inch diameter. On top of this a three-inch layer of gravel ranging in size from ⅝ to ¼ inch diameter is placed. On top of this is placed a two-inch layer of gravel ranging in size from ¼ inch diameter to material which would be retained on a sieve having fourteen meshes to the linear inch, and above this a final layer of one inch thick coarse sand which would pass a No. 14 sieve and be retained on a No. 20, the whole depth of the underdrain gravel being 16 inches. Above the gravel underdrains to a depth averaging approximately 36 inches is placed the filter sand having an effective size of from .28 to .36 m.m. with a uniformity co-efficient of about 2.5. Some of the sand was dredged from the Delaware river and some was taken from sand banks in the southern part of New Jersey.

Each filter is provided with a regulating house in which all valves pertaining to the operation of the filters are located, also automatic effluent regulators which maintain a uniform rate of filtration regardless of the loss of head or friction through the sand which is constantly changing. Each filter is also provided with a large entrance at the court level to afford facilities for caring for the filters. The piping is of cast iron and is located in the courts or filter streets in front of the filters. The piping system consists of supply, effluent, raw water drain, refill, valve chamber drain, overflow, and pressure lines for the sand washers.

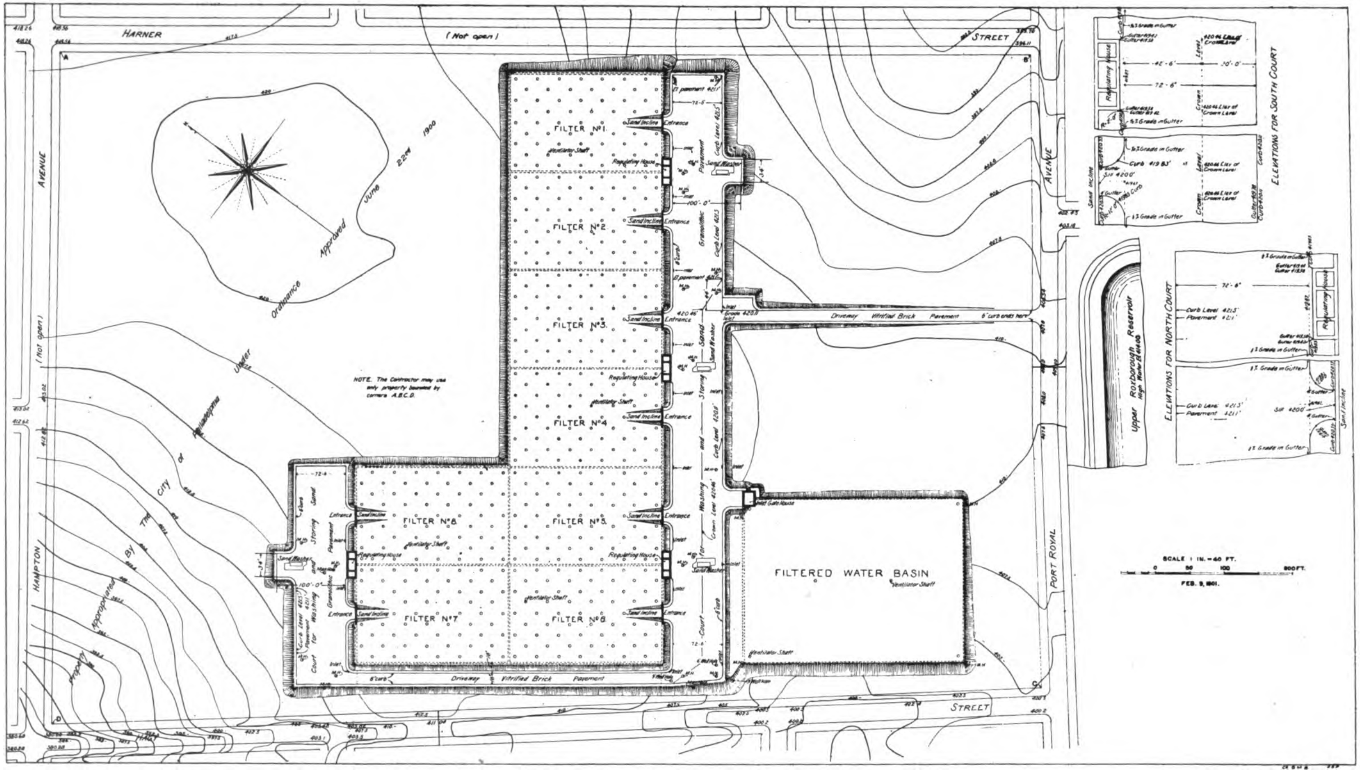
The sand washers, two in number, are located in the court outside the filters and are of the ejector type. The washer consists of a series of hoppers 36 inches in diameter into which is discharged dirty sand from the filters. The sand finds its way to the bottom of the hopper and is ejected to the next hopper. The dirty water overflows from the hoppers and passes to the sewer.

The filtered water basin is similar in construction to the filters, except that it is deeper, and the piers are 22 inches square for their entire height. The capacity of the basin at the nominal water line is 3,000,000 gallons. On top of the vaulting is placed a layer of puddle, filling up the depressions over the piers, with its top surface graded from a high point at the center of the basin to the four sides. On this puddle is placed a layer of broken stone, and in this 4 inch drains with open joints are laid to collect the rain water and lead it to the 8 inch pipe around the basin and connecting with the overflow.

This station supplies Manayunk and the lower elevations of Germantown.

UPPER ROXBOROUGH FILTERS

This station, the second to be constructed, is located north of



Upper Roxborough Filter Station.

the intersection of Port Royal and Hagy avenues in the 21st Ward, adjacent to the Upper Roxborough reservoir, which is used as a sedimentation basin, and is supplied from the Roxborough pumping station. The reservoir not having sufficient elevation to supply the filters by gravity, the water after it is passed through both basins of the reservoir is pumped to the filters by centrifugal pumps located in the extension of the Roxborough Auxiliary pumping station. This station is some distance from the filters but the pumps were placed there as boiler equipment and part of the pipe system were already in place and could be utilized in connection with the operation of the Upper Roxborough filters. The station consists of eight covered sand filters, a filtered water basin and an administration building.

Preliminary filters were not made a part of this station owing to the long period of sedimentation obtained in the Upper Roxborough basins, which have a capacity of 147,000,000 gallons, or about nine days' supply for the filters as operated at the present time.

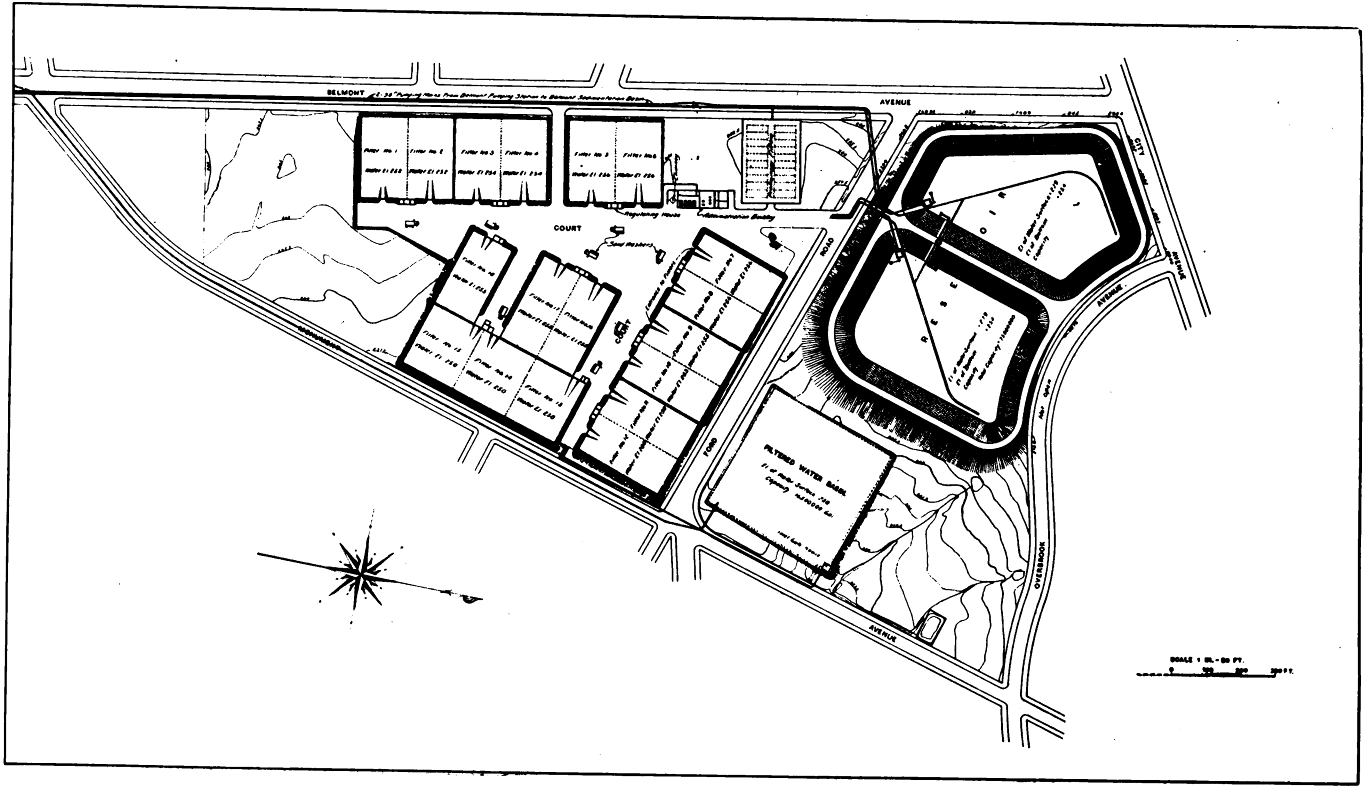
The topography of the site is such that the filters are all constructed on one level, with the filtered water basin situated lower.

Each filter measures 140 feet 8 inches by 219 feet 10 inches, and has a net filtering area of 0.698 acre. The filters and filtered water basin are the same type of construction as at Lower Roxborough. The regulating houses are located at the front of the filters and each house controls two beds. The filtered water basin measures 237 feet 8 inches by 318 feet 10 inches. It is 15 feet deep and has a capacity of eight million gallons. This station supplies the high areas in the northern part of the city, such as Chestnut Hill, Mt. Airy, upper Germantown and upper Roxborough.

In the administration building are installed two duplex pumps driven by gasoline engines to supply water to the sand ejectors and washers at a high pressure. Each pump has a capacity of 1,200,000 gallons daily against a head of 200 feet.

BELMONT FILTERS

The Belmont filter station, the third to be constructed, is located in West Philadelphia at Ford Road and Belmont avenue, and filters the water for the entire section of the City west of the Schuylkill river. This station receives its supply from the Belmont pump-



Belmont Filter Station.

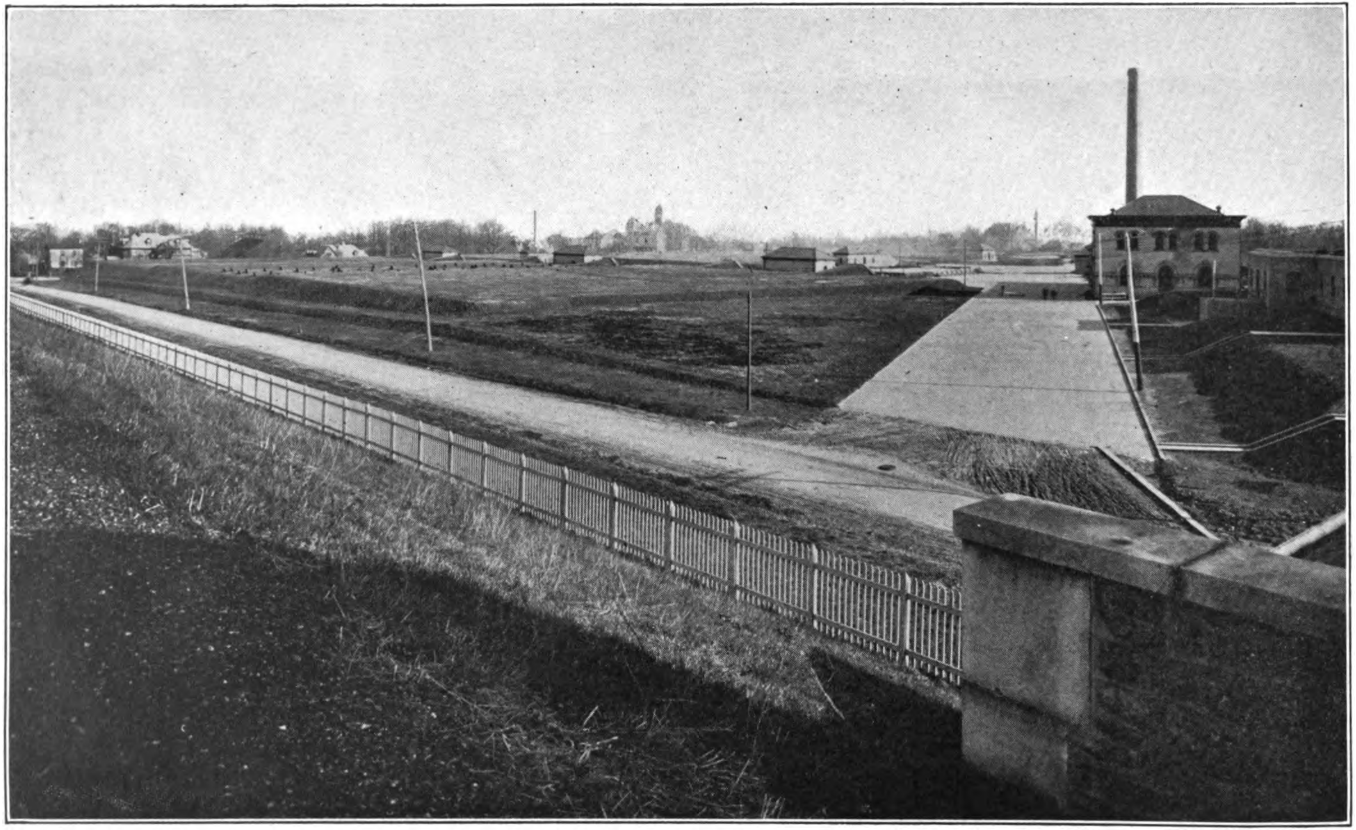
ing station, located in West Fairmount Park on the Schuylkill river, near Columbia bridge.

The Belmont station consists of two subsiding basins having a capacity of 36,000,000 gallons each, or representing approximately about one day's sedimentation of the water; nine preliminary tanks and eighteen plain sand filters; a clear water basin; eight hopper sand washers, electric lighting equipment, laboratories, etc.

The sedimentation reservoir consists of two divisions or basins each 25 feet deep, measured at the flow line, elevation 279 C.D. The reservor is constructed on the hillside, and is partly in excavation and partly in fill. The embankments are 18 feet wide at the top with a two to one slope on both sides. The lining consists of a layer of clay puddle 18 inches in thickness consisting of a prepared clay and gravel. On top of the puddle on the floor a five-inch layer of concrete was placed, and on the slopes the concrete has an average thickness of seven inches. Over the concrete floor and extending halfway up the slopes was placed an asphalt lining ¾-inch thick, which was placed in two layers, each uniformly ⅜-inch thick, consisting of a mixture of asphalt, asphaltic mastic and grit.

The valves for controlling the admission and discharge of the water are located in the Gate Chamber, constructed at the end of the division embankment on the outer side. These valves are arranged that either basin can be used independent of the other or both may be by-passed. In order to obtain a high degree of sedimentation for this reservoir, the piping is so arranged that the water is forced through a main laid on the floor in each basin with outlets near their extreme ends. The water then passes diagonally across one of the basins to a floating discharge pipe near the end of the division embankment, and is likewise delivered at the extreme end of the opposite basin, and before the water is delivered to the filters it must pass the entire length of this basin, where it is drawn from the top through another floating pipe connected to the screen chamber, thus completing the full transit to both compartments of the reservoir.

As at Lower Roxborough, the water, after leaving the sedimentation basin, is passed through preliminary filters which were constructed under a guarantee contract with Mr. P. A. Maignen after his own plans. There are nine separate filter tanks divided into



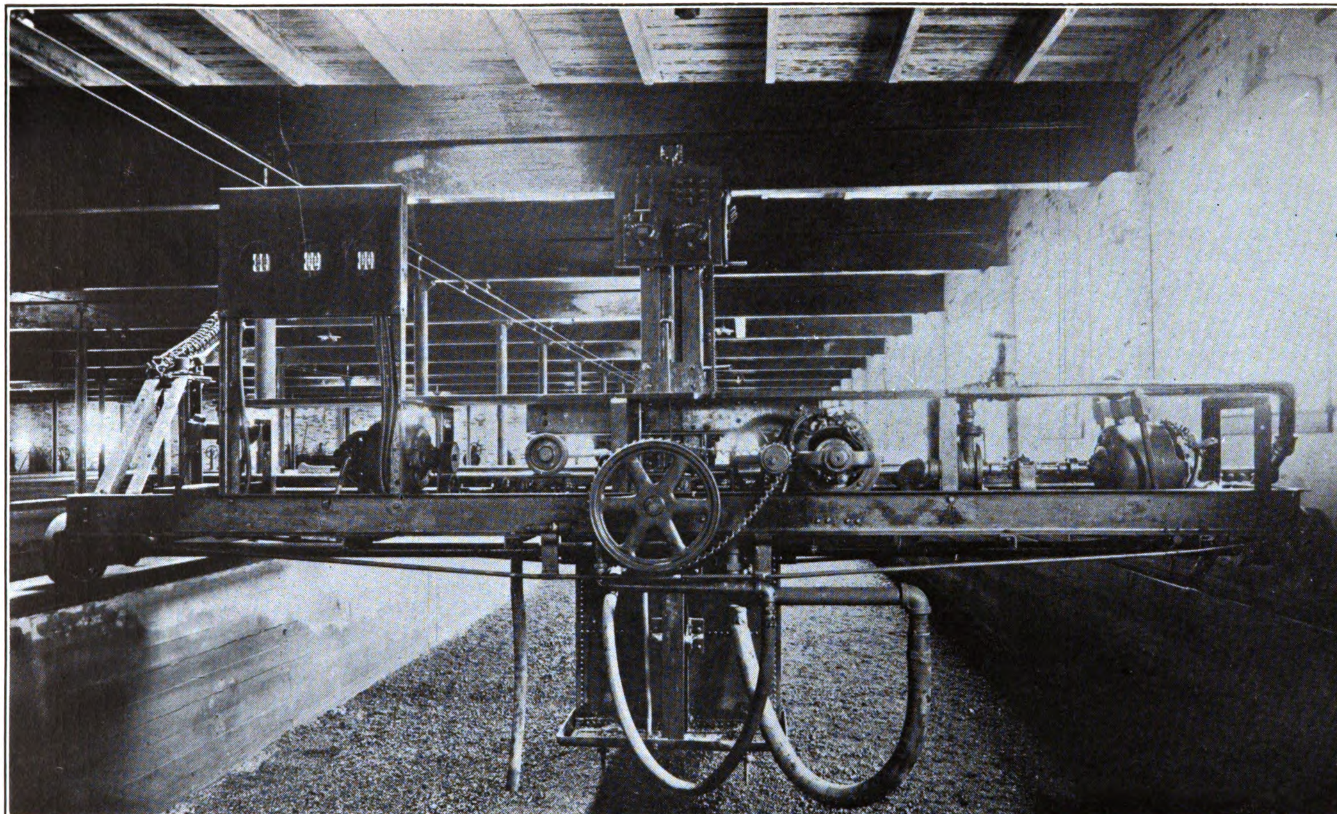
Belmont Filters

three compartments each. The first compartment, which is uncovered, contains ordinary coke, and the water is admitted at the bottom at the end of the tank and passes horizontally to the next compartment, which is filled with a sponge layer about six feet deep. The water is introduced at the bottom of this compartment and passes upward through the sponge and flows on to the third compartment, which contains a layer of coke breeze ranging from 1/8 to 1/4-inch in diameter. The water is filtered downward through the coke breeze at the rate of forty million gallons per acre per day.

Experience with this system showed that the first and second compartments are not economical in operation for reducing turbidity and the coke breeze is now depended upon to do the work. The original arrangement to clean the coke breeze was cumbersome and several different methods were tried, but as none gave satisfaction, the City finally installed a Blaisdell washing machine. This machine consists of an inverted box about four feet square and two feet deep, which is sunk under the water in the filter to the filtering surface and is held in position and operated from a movable platform supported on the filter walls. The box contans a revolving hollow axle and head from which perforated teeth project into the filter any desired distance. The box can be raised or lowered and the platform moved longitudinally or laterally, all electrically operated by one man. The box is moved over the surface of the filter while at the same time the teeth are made to revolve slowly. Water under a pressure of twenty pounds per square inch is introduced through the axle, head and teeth, passing in fine streams into the coke through the holes in the teeth.

A centrifugal pump connected with the top of the box draws away a little more water than is supplied through the teeth and discharges it to the sewer. The machine is constructed so that it can be transferred easily from one filter tank to another.

The general arrangement of the final filters is irregular owing to the shape of the property on which they are located and are grouped in three batteries of six each. The topography of the site was such that the filters were constructed in a series of steps conforming as closely as possible to the original surface, the greatest vertical distance between any two filters being three feet. The filters are rectangular in shape, eight measuring 120 feet 2 inches by 272 feet 8 inches on the neat lines, seven measuring 135 feet



Belmont Preliminary Filters. Blaisdell Sand Washing Machine.

5 inches by 242 feet 2 inches, and the other three 165 feet 11 inches by 196 feet 5 inches.

Each filter is approximately .735 acre in filtering area and with pre-filtered water is capable of being operated at a maximum rate of six million gallons per acre daily, giving a capacity of 67,000,000 gallons daily for the final filters. A year's trial on two of the filters has amply demonstrated the practicability of the six million rate at this station. However, the capacity of the preliminary filters is but 40,000,000 gallons daily, and is the limiting feature of this station's output. By remodeling the coarse coke and sponge compartments, it will be possible to bring the capacity of the pre-filters up to that of the final filters with comparatively small cost.

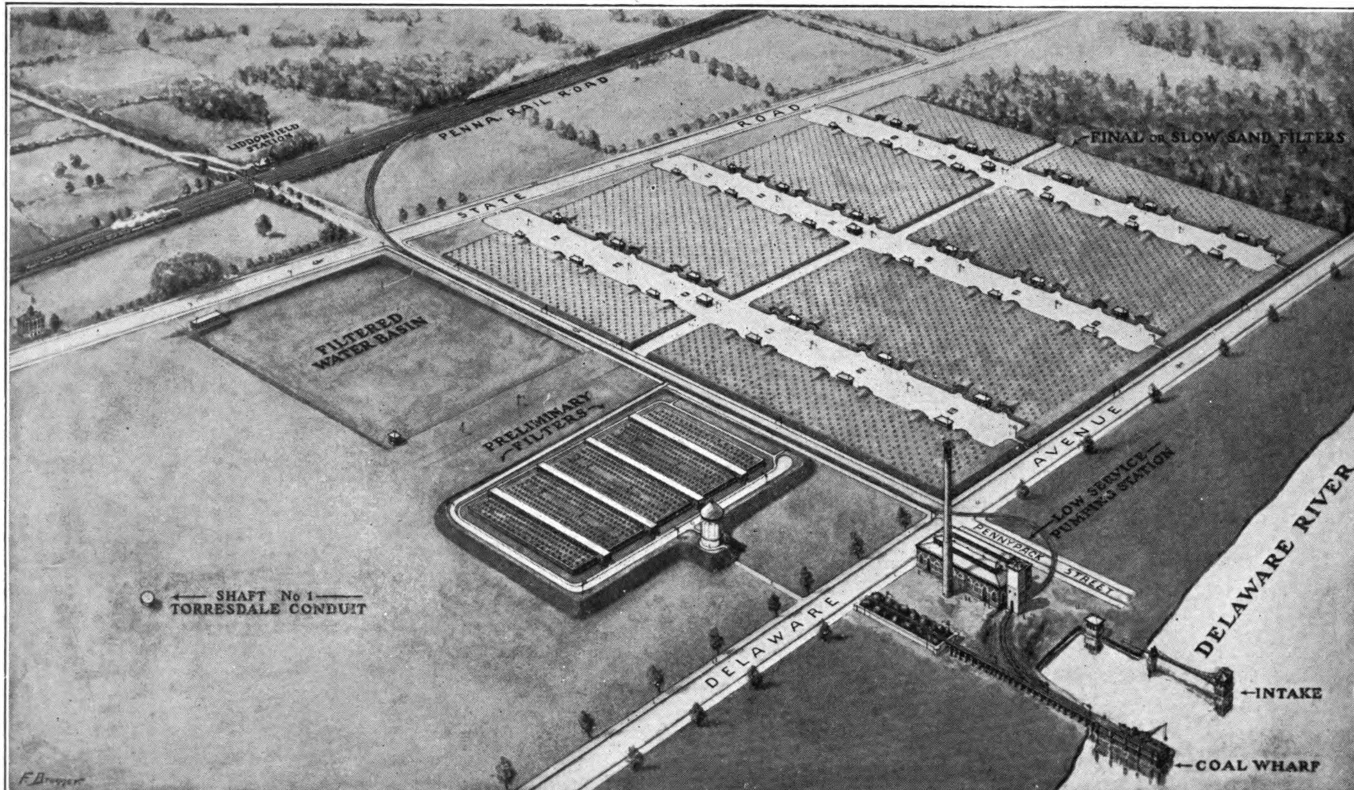
The general construction of the filters is similar to those of Lower and Upper Roxborough, the floor, piers, walls, vaulting and puddle lining being essentially the same.

In such portions of the floors as were built on fill, expanded metal was embedded in the concrete. As far as possible the regulating chambers of two adjacent filters were constructed in one house at the end of the dividing walls between the filters, but where the location and elevation were such that this could not be accomplished, single chambers were provided. Each filter has its own valve chamber in which is located the floating weir for controlling the rate of filtration.

The filtered water basin is rectangular in plan, measuring 382 feet 2 inches by 396 feet on the neat lines and has an available depth of 15 feet for storing water, with a capacity of 16,500,000 gallons. In general construction it is similar to the filters and to those constructed at Roxborough. The filtered water is admitted through an inlet chamber at one corner, and is drawn off in another from the bottom direct into the distribution mains.

TORRESDALE FILTERS

The Torresdale filters, the fourth station constructed, is located on the Delaware river approximately eleven miles up stream from the centre of the city, at Delaware avenue and Pennypack street, in the 41st Ward, near the northeastern city boundary. Its daily capacity is 240,000,000 gallons, the largest works of this kind in the world. It occupies an area of over 200 acres and sufficient ground has been acquired to provide for future extensions.



Torresdale Filter Station.

The station consists of an intake, a low lift pumping station, preliminary filters, sixty-five slow sand filters and a filtered water basin, and furnishes water to that portion of the city between the Delaware and Schuylkill rivers lying below contour 75.

Intake

The intake extends into the Delaware river seventy feet beyond the Port Warden's line. It is approximately 700 feet in length and is constructed of reinforced concrete, horseshoe-shaped in section, 14 feet wide by 10 feet 6 inches, inside dimensions. It is provided with two gate houses, one at the outer end and one midway.

The second house was originally intended for an inlet from a sedimentation basin, to be constructed in the river. It was utilized before the completion of the outer portion of the intake to take water from the river at this house, by means of a channel dredged to the river, thus permitting the operation of the filters at an earlier date than would have been practicable had it not been provided.

The intake chambers are built of concrete, provided with shut-off gates and removable screens, the former being operated by electric power. The chambers are covered by granite and brick houses, which conform to the general architecture of the other buldings at this station. The inland end connects with the pump well in the engine room of the low service pumping station.

Pumping Station

The Torresdale pumping station pumps water from the Delaware river on to the preliminary filters which are 37.5 feet above mean high tide, and also provides water under pressure for cleaning the preliminary and final filters.

It contains six forty million gallon R. D. Wood & Company centrifugal pumps driven by Reeves cross compound engines, and one of the same capacity made by the Allis-Chalmers Company, driven by a Bates cross compound engine; nine 300 H. P. Heine boilers equipped with Murphy stokers and Sturtevant economizers; three 75 K. W. generators driven by De Laval turbines, direct connected; two De Laval turbines driving centrifugal pumps of one and two-and-one-half million gallons daily capacity respectively for washing sand in the final filters; two De Laval turbines driving centrifugal pumps of five million gallons daily capacity each for washing preliminary filters; one Deane motor driven triplex pump and accessories, also coal and ash handling machinery. One forty million gallon capacity centrifugal pump, driven by a De Laval steam turbine, is under contract.

The large centrifugal pumps are placed immediately over the pump well and are of the double suction type. They discharge through a 36-inch diameter pipe into a header 11 feet in diameter, located on the north side of the engine room, which is so connected with a second header that the water can be delivered to the preliminary filters, or these filters may be by-passed and the slow sand filters supplied direct from the river.

An open coal pocket is located south of the boiler house and has a capacity of 3,000 tons storage. The coal is loaded from the the wharf by a steam crane with clam-shell bucket on to a car by which it is transported to the storage pocket or to a coal tower; if to the latter, it is elevated to bunkers in the boiler house. Ashes are delivered to the same tower through an underground passage, where arrangements are made for loading on to cars, and they may then be disposed of either by rail or boat.

The stack is of reinforced concrete, nine feet internal diameter and 250 feet high. The building measures 179 feet by 108 feet, and is constructed of mottled brick with terra cotta trimmings and asbestos slate roof.

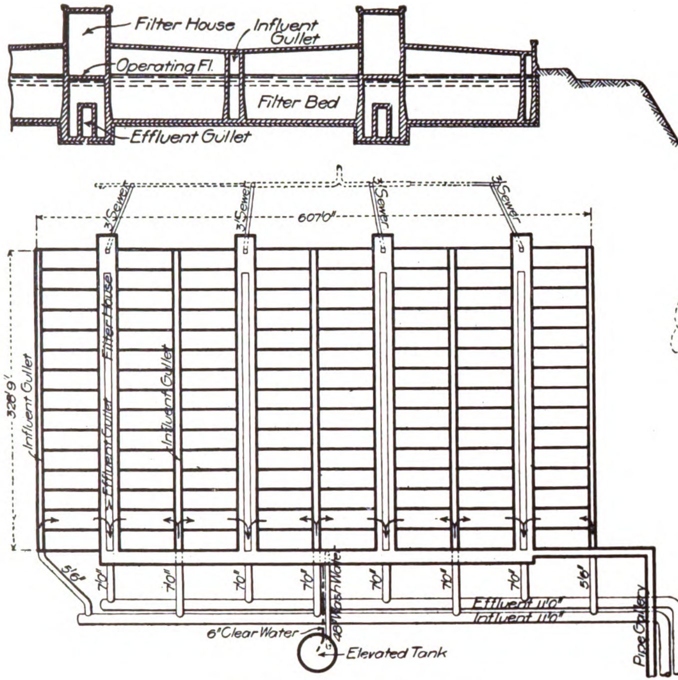
Data Relating to Forty Million Gallon Centrifugal Pumps and Boilers, Torresdale Pumping Station

Pumps.

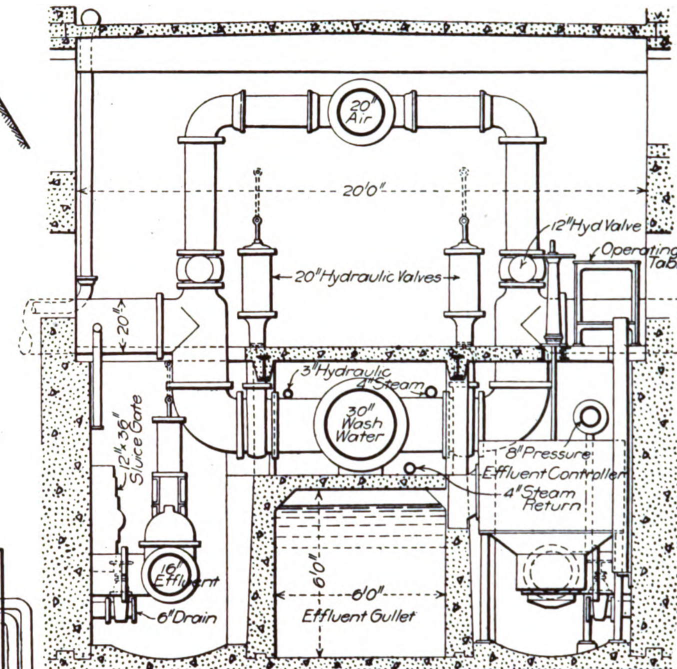
	R. D. Wood & Co.		Allis-Chalmers Co.	
Type of engines	Gross compound vertical			
	High.	Low.	High.	Low.
Cylinder diameter	16″	32″	16″	32″
Stroke, feet	1.67		1.67	
Revolution per minute	170		162	
Diameter suction pipes, two (2)	30″		24″	
Diameter discharge pipe	36″		36″	

Boilers.

Type	Water Tube, Murphy Stokers.
Number of boilers	9
Number of tubes	189
Length of tubes	18 feet
Diameter of tube	3½ inches
Steam drums, one (1)	48 inches diameter
Length of steam drums	23 feet
Length of grate	7½ feet
Area of grate	66 square feet



Part Sectional Plan of Plant.



Cross Section through Filter House.

Torresdale Preliminary Filters.

Preliminary Filters

The unfiltered Delaware river water is pumped through an 11-foot riveted steel conduit covered with concrete of a minimum thickness of six inches onto a system of preliminary filters. These filters in general are of the mechanical type, using both water and air in washing but omitting the coagulant. They are located directly south of the slow sand beds at an elevation high enough to cause the water to pass through both the preliminary and final filters by gravity. They are arranged in rows or batteries of fifteen each with two batteries facing each filter house, or thirty being controlled at each house or gallery of which there are four, making a total of 120 beds. Each bed measures 20 feet 3 inches by 60 feet in the clear, and is controlled by an individual operating table. The influent is admitted through a gullet at the rear of the beds and is controlled by a 16-inch hydraulic valve operated from the table located in the filter gallery.

The floors, walls and roofs are in general constructed of concrete. The walls of the filter houses are brick faced both inside and outside and are trimmed with granite. The roof over the filter beds is a six-inch reinforced concrete slab carried by 18-inch 60-pound I beams, 7 foot centres, completely encased, spanning the width of the bed. Manholes 3 feet in diameter are placed in the roof over each bed and are arranged in two rows of three each and one directly over the valve admitting raw water from the influent gullet. The concrete roof slab has a covering 16 inches deep, composed of 2 inches of broken stone or clean gravel, 10 inches of sandy material and 4 inches of top soil. Roof drains of 4-inch terra cotta pipe are placed at convenient intervals and are covered with a nine-inch mound of broken stone. The manholes rise six inches above the top covering from the filters and are equipped with screens so that the filters may be ventilated. Electric lights are placed in all the beds and the galleries are heated in winter by steam from the pumping station.

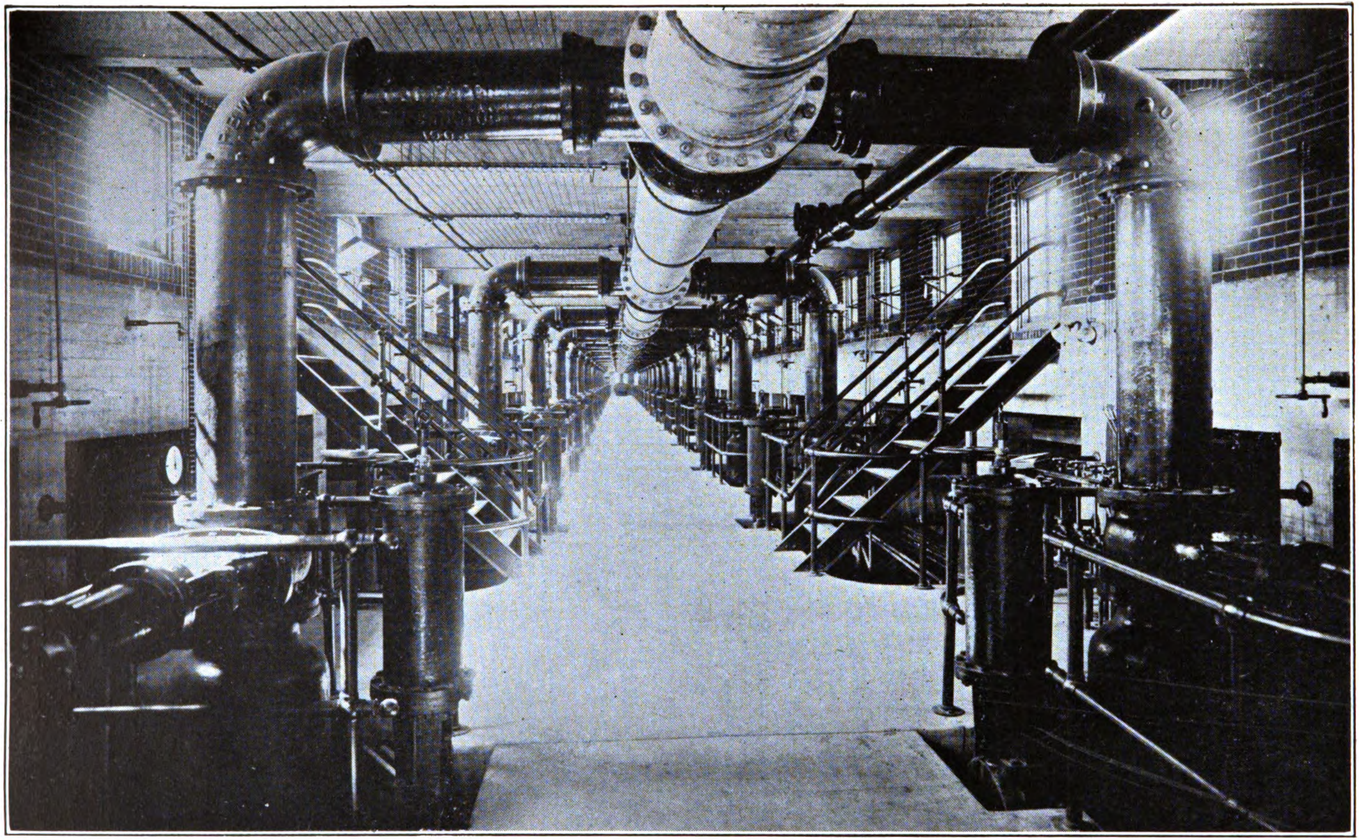
The 11-foot riveted steel conduit has outlets 7 feet in diameter for each double row of filters, of which there are three, and 5 feet 6 inches in diameter for each single row, of which there are two.

The influent gullets run the full length of the plant, and, as noted, serve one or two batteries of beds. They are formed by longitudinal walls at the backs of the beds of adjacent batteries and are roofed with six-inch reinforced concrete slabs carried by concrete brackets extending out eight inches from the vertical walls of the gullet. The wash water gullet is constructed of reinforced concrete 12 inches wide and 4 feet 3 inches deep. Extending out latterly on each side of this gullet and terminating at the side walls of a filter are sheet steel wash water troughs 18 inches wide, increasing in depth from six inches at the wall line to nine inches at the gullet.

The filtering materials consist of 15 inches of gravel varying in size from 2 to 3 inches, four inches of gravel varying from 5/8 to 1½ inch, three inches of gravel varying from ¼ to ½ inch, eight inches of gravel varying from 1/8 to ¼ inch, and twelve inches of sand varying from 0.8 to 1 m.m. The depth of water carried over the filtering materials is four feet. Two collectors extend the full length of each bed and on each side of the wash water gullet; they are built of reinforced concrete rectangular in shape, 30 inches wide and 8 inches deep, inside measurements.

After passing through a hydraulically operated valve and an effluent controller, the water passes to the effluent gullet, which is of reinforced concrete rectangular in shape and is located under the operating gallery of each house. These gullets are connected on the same side of the plant on which the raw water is admitted to a second eleven foot riveted steel conduit which carries the prefiltered water to the slow sand filters. Thirty-inch wash water mains are laid on top of the effluent gullets, and from these the wash water piping is led into each filter through 20-inch spiral riveted galvanized pipe suspended from the roof and connected at the centre of the bed and directly above the wash water gullet with four 12-inch pipes diverging toward the corners of the bed. These diverging pipes in turn each connect with two eight-inch pipes directly above the filtered water collectors and from these eight-inch pipes vertical downtakes of the same diameter connect with a manifold. There are eight manifolds in each filter which have 1½-inch galvanized laterals with 3/16-inch holes in the bottom extending on 5¾ inch centers. The holes are likewise placed on 5¾ inch centres.

The wash water is drained from the wash water gullet through a 12 x 36 inch hydraulically operated sluice gate discharging into the wash water drain, which simply consists of an open space be-



Torresdale Preliminary Filters. Operating Floor.

tween the wall of the filter bed and the side of the effluent gullet. Final discharge of the wash water is through a 3-foot circular brick sewer at the end of the filter house opposite from the general piping system.

The main air supply consists of a 20-inch pipe running the full length of each filter house and is suspended from the roof. A blower for supplying the compressed air, operated by electric motor, is located in each house and the systems in the four houses are connected by pipes laid in the gallery at the eastern side of the plant. The air system is connected to the wash water piping and air is introduced through the manifold in the bottom of each filter.

The operating floor is constructed of reinforced concrete with a minimum clear width of six feet between openings which are left at intervals around the piping, etc. On this floor are placed the operating table, loss of head gauges and gauges for showing the rate of operation for each bed. A wash water tank constructed of reinforced concrete is located outside to supply the wash water under pressure and to give storage for intervals when washings are quite frequent. This tank contains two separate compartments, one for wash water and one for filtered water used for drinking and sanitary purposes. The tanks occupy the upper part of the tower, the floors being at an elevation of 27 feet above the surrounding filters.

All power required for the preliminary plant is generated at the pumping station, to which underground connection is had by means of a gallery in which all pipes, cables, etc., are easily accessible.

The entire preliminary plant is constructed on filled ground, which was carefully rolled in thin layers, and as in all the other filter plants, clay puddle was used in order to insure water tightness.

Final Filters

The final filters, sixty-five in number, are located to the northward of the preliminary filters and are arranged in four groups or batteries so that each filter faces a court, of which there are three. The filters are all rectangular in shape, forty-three measuring 140 feet 8 inches by 235 feet 8 inches, twenty-two measuring 132 feet 2 inches by 253 feet 2 inches and have an area of approximately

¾ acre each, and are all constructed on one level. They are built of concrete, covered by groined arches and have puddle under the floor and surrounding the side walls, and in all essentials details are similar to the other plants. As at Upper Roxborough and Belmont stations double regulating houses are used where possible. The effluent is discharged into pipes laid under the courts, which connect with a reinforced concrete conduit, horseshoe-shaped section equivalent to 10 feet in diameter, leading to the filtered water basin.

The wash water is carried off by sewers, and is at present discharged into the Pennypack Creek through an outlet sewer 8 feet 6 inches in diameter. It is proposed in the near future to construct a sewerage purification plant adjacent to the filter site which will treat the sewerage from the filters as well as other sewerage emptying into the Pennypack Creek. While the creek flows into the Delaware river near the intake, no bad effect has been experienced on this account up to the present time. In the courts of the filters are constructed shelter houses for the convenience of the employes. The laboratory is located on State Road south of the filters opposite the filtered water basin.

Filtered Water Basin

The filtered water basin lies south of the filters near the preliminary filters. It is constructed on lower ground and its elevation is such that the water is delivered to it from the final filters by gravity. It is rectangular in shape measuring 601 feet 10 inches by 762 feet 2 inches with an available depth of 15 feet and has a capacity of fifty million gallons at the normal water line. In general construction the basin is similar to the filters and the other filtered water basins. The filtered water passes into the basin at one of its corners through an inlet gate house which is provided with eight sluice gates and is arranged so that the filtered water basin can be shut off and the water passed around it through a reinforced concrete conduit 8 feet in diameter. A 72-inch valve is placed on the by-pass and is constructed so that it can be operated electrically from the interior of the inlet gate house.

In the opposite corner an outlet chamber is constructed where provision is made for placing wood stop planks which may be used to prevent water entering from the by-pass in the event of emptying the filtered water basin. An overflow chamber is constructed in the conduit leading to the entrance shaft of the Torresdale Conduit so that when the water level reaches an elevation of 7.25 C.D. it will overflow into the sewer already described. The top of the filtered water basin, as at the other stations, is made water tight and the surface water is drained to the sewer.

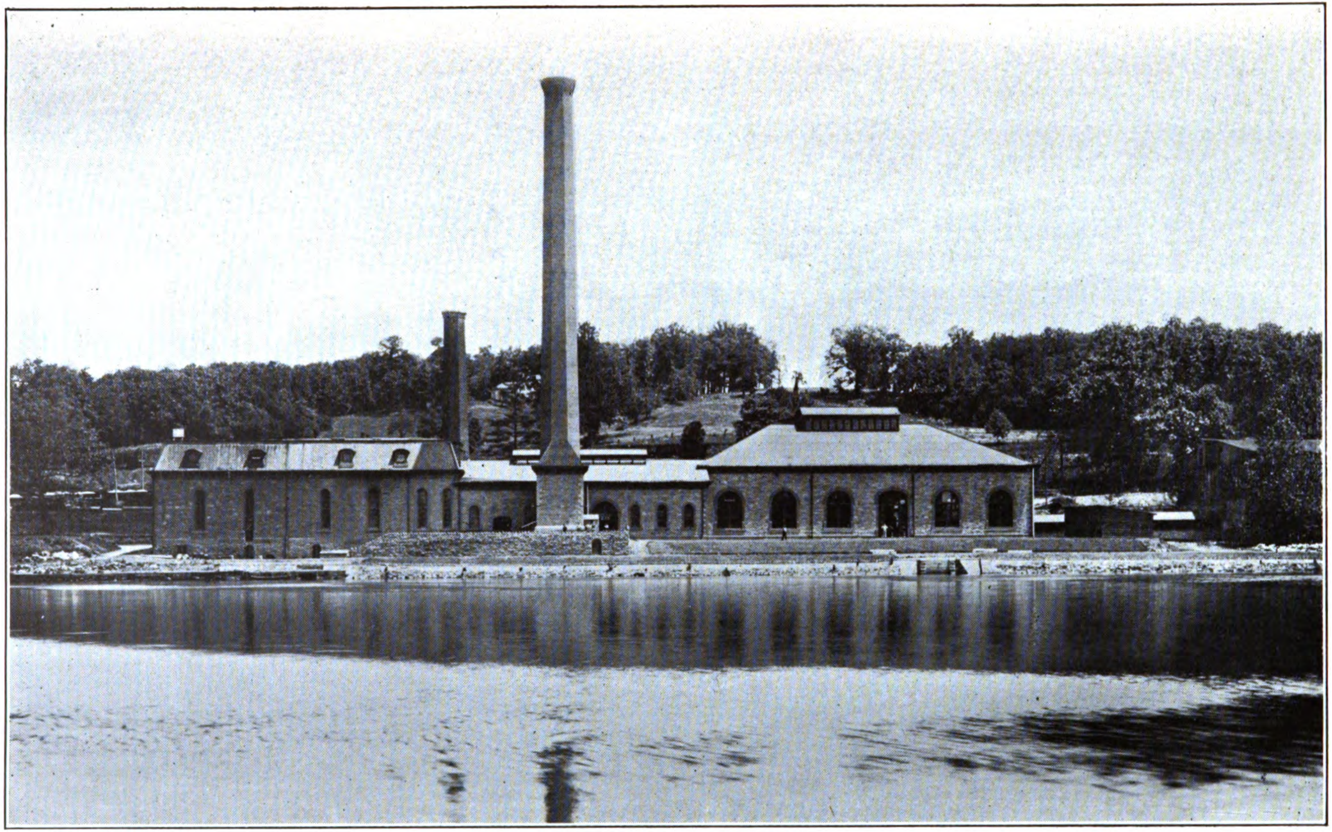
TORRESDALE CONDUIT

The Torresdale Conduit carries the filtered water from the Torresdale station to the Lardner's Point pumping station three miles below on the Delaware river, where it is pumped into the distribution system. The Conduit is 13,809 feet in length between end shafts, and is constructed entirely in tunnel 10 feet 7 inches internal diameter. The elevation at the entrance shaft is 127 feet below the ground surface and the lower end is 10 feet higher. The purpose in constructing it on a rising grade to the lower end was to prevent air locks. The shaft at the upper end is connected with the conduit leading from the filtered water basin of the Torresdale filters, and is of the same diameter as the Conduit. Provisions have been made in the construction of this shaft for a future connection to the Torresdale filters, in case of their extension.

The upper portion of the shafts are constructed of steel shells which extend through the soil down to and partly into the rock and are lined with brick. The elbows at the bottom of the shafts are built of concrete on 15 feet 9 inches radii. The tunnel is lined with hard-burned brick backed with concrete. The lining in the invert is everywhere of two courses of brick laid on a cradle of concrete. The arch ring varies from three to five courses of brick depending upon the nature of the material in the roof of the tunnel. The shaft at the Lardner's Point end has a diameter of 21 feet for the upper 40 feet and decreases funnel shape into the lower portion of the shaft, which is 10 feet 7 inches in diameter. Two connections are made with this shaft and are respectively 14 feet and 7 feet in diameter. These connections are made of riveted steel bolted on two cast iron nozzles which are in turn bolted to the steel shell of the shaft and lead to the pump well in the Lardner's Point pumping station.

DISTRIBUTION FROM LARDNER'S POINT

The entire Torresdale (old East Park) distribution system which was originally adopted to convey the major portion of the water



Roxborough Pumping Station.

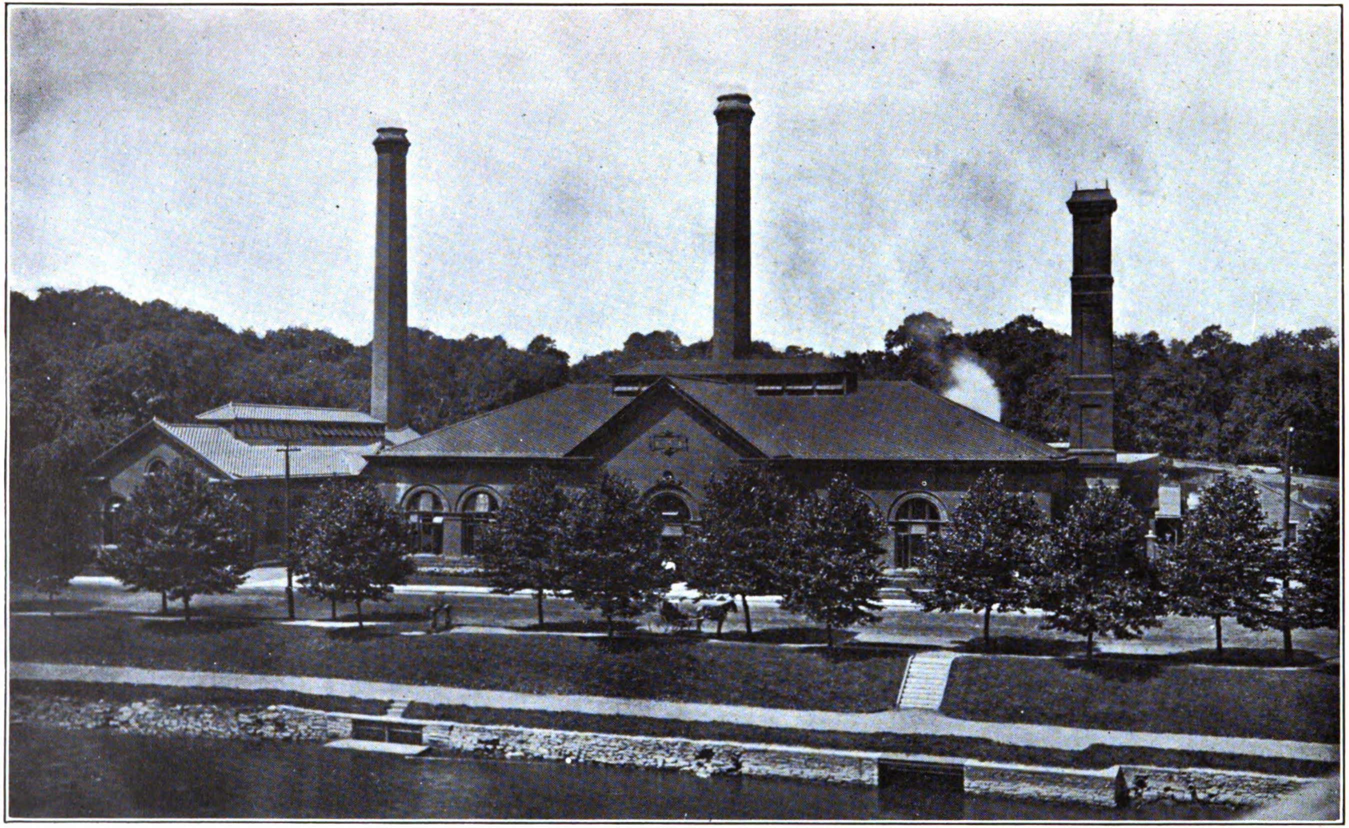
supply from the pumping stations on the Schuylkill river required radical changes in order to accommodate the conditions incident to the introduction of the filtered water system whereby, as heretofore indicated, the major portion is brought from the Delaware river. In order to reach the centre of the distribution of the former system, it was necessary to construct three lines of 60-inch cast iron pipe, each three miles in length, and some 22 miles of 48-inch pipe. On the lines of 60-inch pipe about 4,000 feet apart are located ten valve chambers containing a system of 48-inch valves connected and so arranged that either line entering the chamber may be taken out of service without interfering with other lines, thus making it feasible to examine and repair a part of the distribution system and secure the largest possible benefit from the remaining lines. These chambers are constructed of concrete and contain from 8 to 17 48-inch geared valves.

OAK LANE RESERVOIR

This reservoir was constructed, as a part of the new system, to compensate for the variation in consumption in the Torresdale distribution district. It is located at Fifth street and Chelton avenue in the 42d ward, and is constructed in two compartments, each having a capacity of 35 million gallons with a normal water depth of 20 feet 6 inches and a flow line 210 feet above city datum. Connections are made by two 48-inch lines through gate chambers, one to each basin. The basins are connected by two 36-inch equalizing pipes through the division embankment, on which are placed valves so that either basin may be used independent of the other. The reservoir is constructed partly in fill and partly in embankment, lined with clay puddle, concrete and asphalt, and in all respects is constructed similar to the Belmont sedimentation basin excepting that the floor is formed of inverted groined arches for the purpose of distributing pier loads in the event of it being found necessary to cover this basin.

PUMPINGS STATIONS

There are four high duty stations, three of which are located on the Schuylkill river, and one, Lardner's Point, connecting with the Torresdale Conduit which pumps Delaware river water after it passes through the filters at Torresdale. The three on the Schuyl-



Belmont Pumping Station.

kill river are the Roxborough, Belmont, and Queen Lane which supply raw water to filter stations of the same name.

Roxborough Pumping Station

The Roxborough pumping station is located on the Schuylkill river near the northwestern City boundary approximately ten miles from the centre of the city. This station consists of six Worthington pumps, five with a capacity of five million gallons daily and one with a capacity of six million, five hundred thousand gallons daily; one Holly pump of ten million gallons capacity, and two Snow pumps of five million gallons daily capacity each, all horizontal compound pumps. The boiler equipment consists of eight internally fired tubular boilers of 100 H.P. capacity, and four water tube boilers of 500 H.P. capacity each.

Belmont Pumping Station

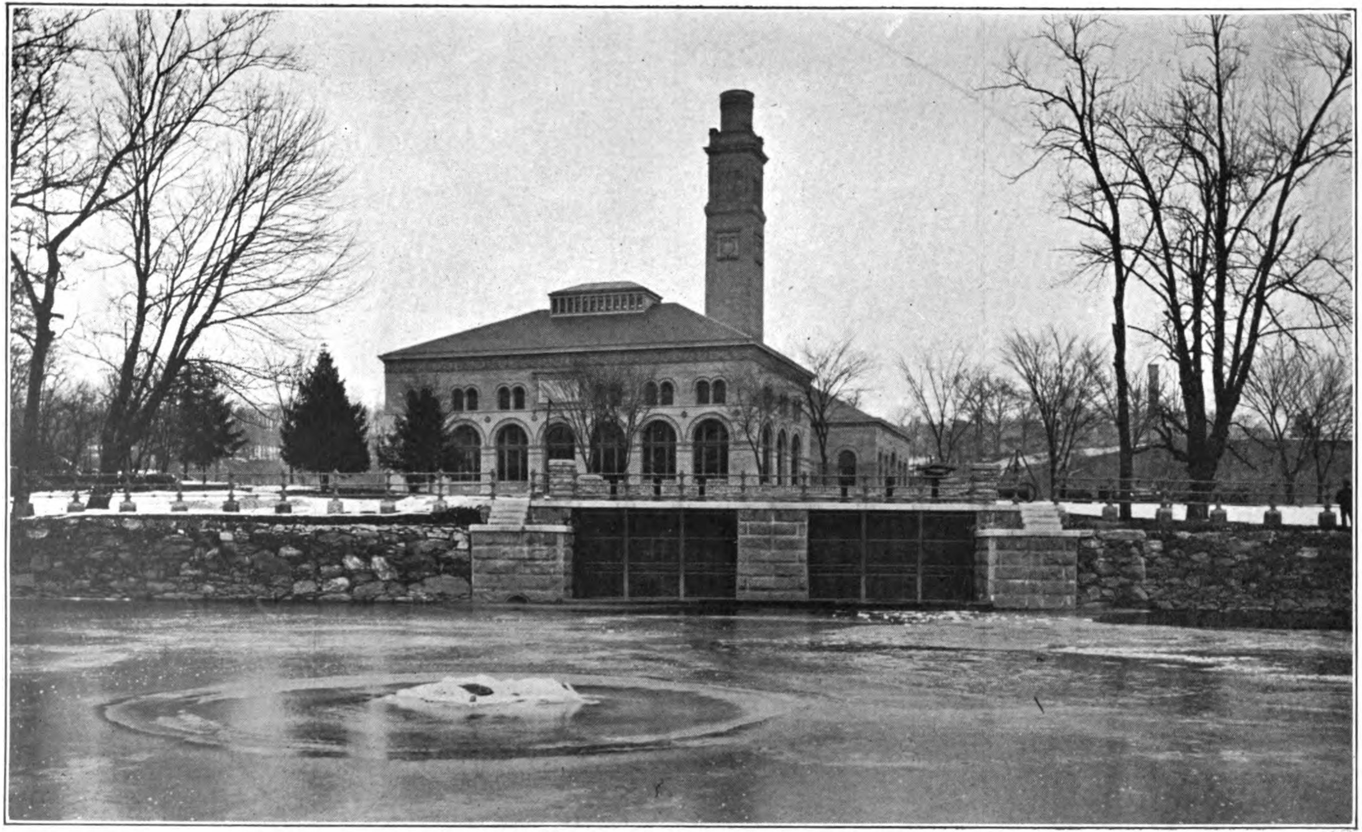
This station is located on the Schuylkill river in West Fairmount Park near the Columbia railroad bridge, and is about five miles below the Roxborough pumping station. It consists of two Bethlehem Steel Company's horizontal compound pumps of ten million gallons daily capacity, one Worthington compound pump of seventeen millin gallons daily capacity, and three Holly compound pumps of ten million gallons daily capacity.

The boiler equipment consists of twenty-six 125 H.P. internally fired tubular boilers.

Queen Lane Pumping Station

This pumping station is located on the Schuylkill river in East Fairmount Park approximately 600 feet below the mouth of the Wissahickon Creek. It consists of four Southwark vertical triple expansion pumps of twenty million gallons daily capacity each, 24 internally fired tubular boilers of 200 H.P. each.

The pumps are connected with the river intake by two masonry conduits leading into either end of the engine room each supplying two pumps. Gates and screens are provided at the intake which is constructed in two sections of rubble masonry. As at Lardner's Point, the pump ends of each pumping engine are located in the basement with the floor intervening at an elevation so that the engines and crank shafts are above the floor level. The smoke



Queen Lane Pumping Station

flues in the boiler house are connected to a stack 200 feet high, 12 feet internal diameter.

A modern coal handling plant is about to be installed to take the coal from the Reading Railroad, nearby, and transport it to the boiler room by tunneling under Ridge avenue and Park property.

Water is delivered from this station to the Queen Lane reservoir through two lines of 48-inch cast iron pipe.

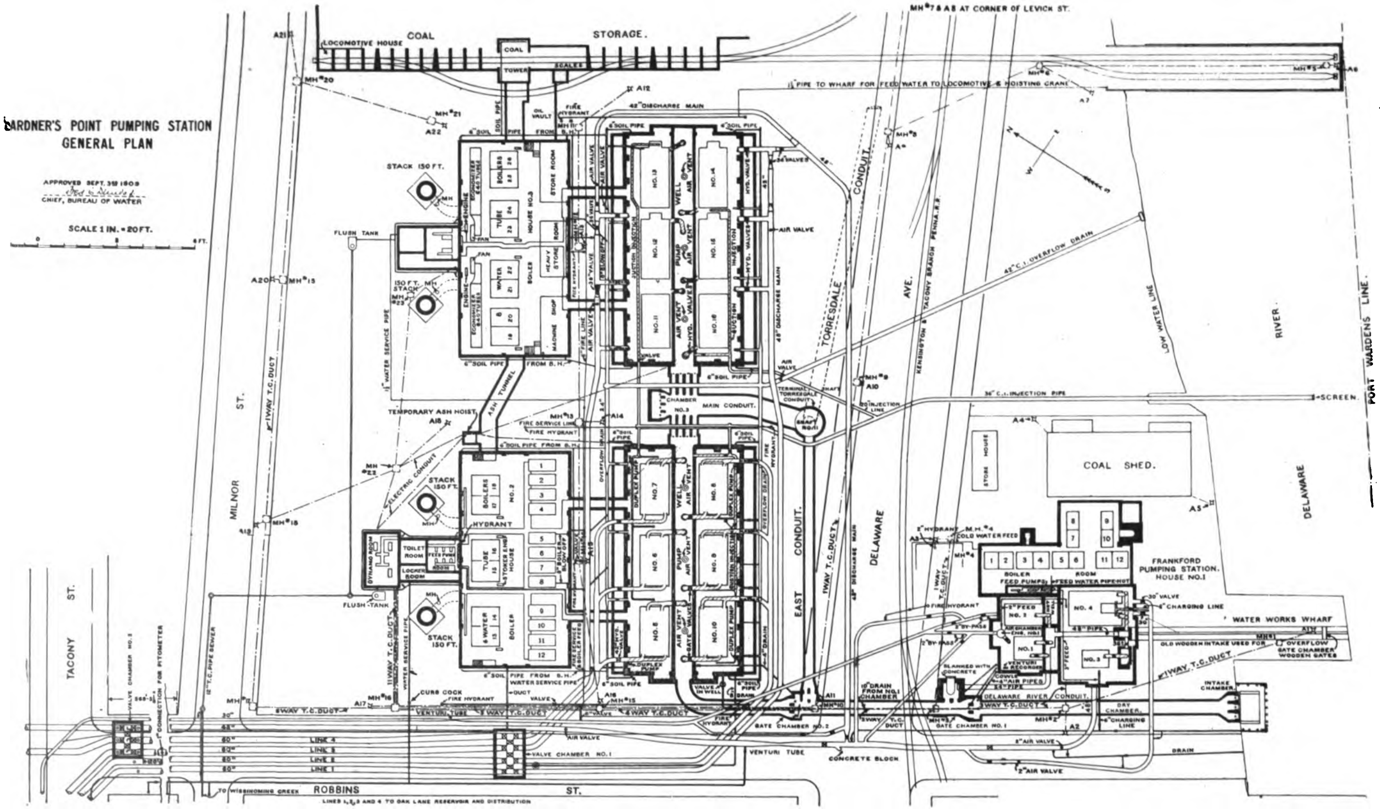
Lardner's Point Pumping Station

The pumping plant at Lardner's Point consists of three separate pumping stations. The first is an old station formerly termed the "Frankford pumping station" and was used in the old system to pump water from the Delaware river to the Frankford Distribution System. It is now termed No. 1 House, and the connection with the river has been closed and a new connection made to the filtered water conduit leading from the outlet shaft of the Torresdale Conduit.

No. 1 pumping station or the old "Frankford" consists of one compound vertical Cramp pump of ten million gallons capacity, one Wetherill horizontal ten million gallons capacity, one Southwark vertical twenty million gallons capacity and one Southwark vertical-horizontal fifteen million gallons capacity. For this station there are twelve Marine type boilers of 200 H.P. capacity each.

Two entirely new stations were constructed and contain twelve (12) vertical triple expansion Holly pumping engines of twenty million gallons daily capacity each. The engine rooms are built separate from the boiler houses and are 171 feet long by 87 feet wide, constructed of gray standard size brick trimmed with granite and terra cotta. All the roof coverings are of red tile. The water ends of the pumps are set in the basement under the floor of the engine room, and the entire steam ends are all above the floor level. The pump well is located under the basement floor in the centre of the engine houses, extending their full length. It is constructed of reinforced concrete horseshoe-shaped in section, 14 feet in width and height.

Between Engine Houses Nos. 2 and 3 a gate chamber is located which controls the discharge from the larger connection to the outlet shaft of the Torresdale Conduit. It is connected to the pump



Lardner's Point Pumping Station. General Plan.

well of both houses, and gates have been installed for connecting the pump well of a future house to be located west of the present plant.

The boiler houses of the new stations are of the same general architecture and contain the following:

House No. 2: 6—Edge Moor Water Tube Boilers, 500 H.P. capacity each, equipped with Wetzel stokers.
12—internal fired tubular boilers, 200 H.P. capacity each.

House No. 3: 8—Edge Moor Boilers, 500 H.P. capacity each, equipped with Wetzel stokers and two Green economizers.

In the annex of boiler house No. 2 are three 50 K.W. generators each, furnishing light for the entire station and current for the coal handling machinery electric crane, etc.

The smoke flues of the boiler houses are connected to four brick chimneys 150 feet high and 7 feet internal diameter—two for No. 2 and No. 3 Houses of the Custodis and Heinicke type respectively.

The coal is delivered to overhead pockets of 3,000 tons capacity in the hoiler houses of Nos. 2 and 3 stations by means of a tower and belt conveyor with capacity for handling 50 tons per hour. Coal may be received either by rail or by boat, and the general design of this equipment is similar to the one at Torresdale.

Data Relating to Engines and Boilers in Nos. 2 and 3 Houses, Lardner's Point Pumping Station.

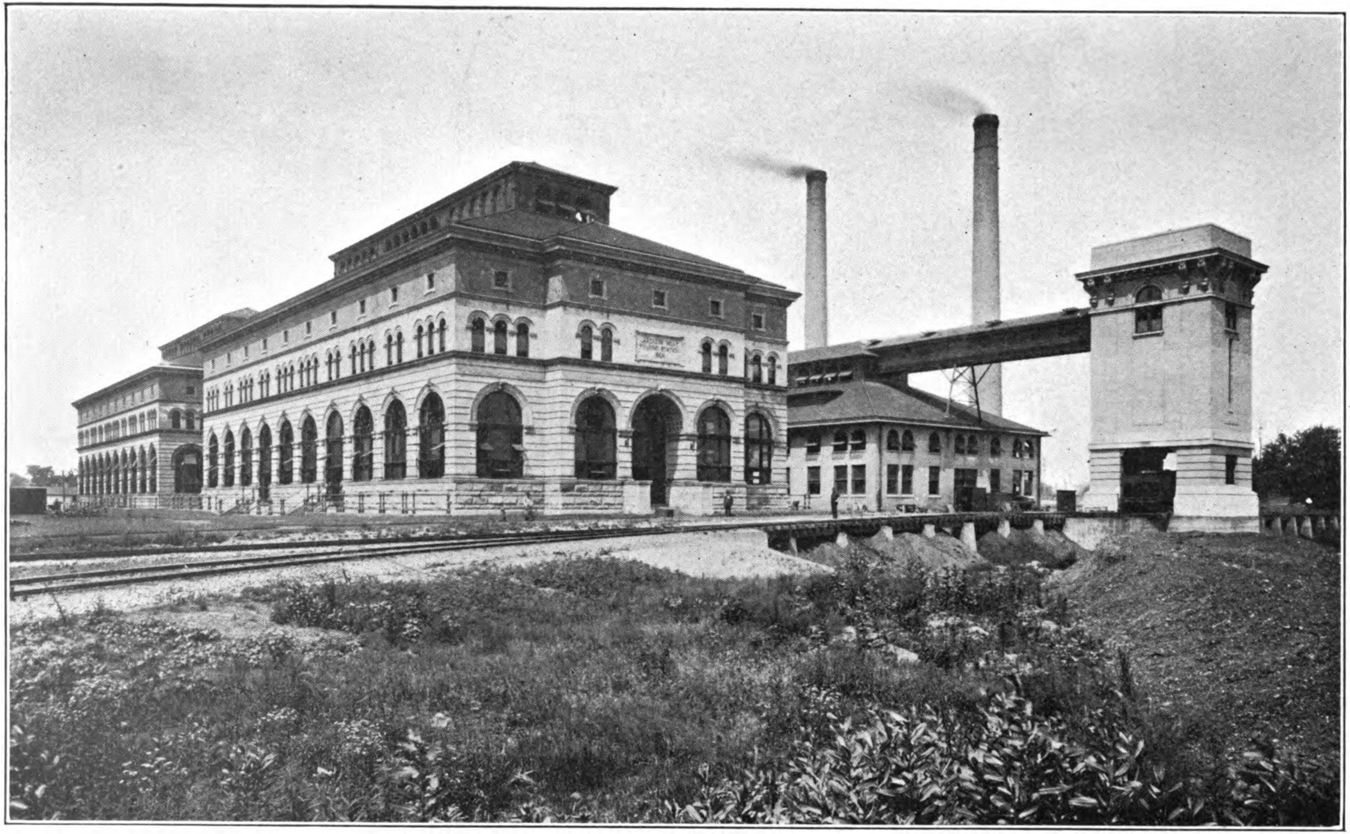
ENGINES.

Nominal capacity of each engine	20,000,000 gallons daily
Number of revolutions per minute	20
Stroke	5½ feet
Piston speed, feet per minute	220

	High.	Intermediate.	Low.
Cylinder diameter	32″	60″	90″
Diameter piston rod	7½″	7½″	7½″

	First.	Second.
Receiver volume	205 cu. ft.	304 cu. ft.
Receiver heating surface	166 sq. ft.	304 sq. ft.

	Diameter.	Length.
Crosshead pins	12″	11″
Crank pins	12″	11″
Shaft bearings	17½″	32″
Shaft at centre	20¾″	



Lardner's Point Pumping Station.

Distance rods—Four (4) each 5 inches diameter.
Air pump—One (1) 28 inches diameter, 66 inches stroke.
Feed pump—One (1) 3¼ inches diameter, 66 inches stroke.
Feed water heater—One (1) in exhaust, 308 square feet.
Fly wheels—Two (2) 20 feet diameter and weighing 32 tons each (approximate).
Throttle valve—8 inches diameter.
Exhaust pipe—24⅜ inches diameter.
Suction pipe—Main 42 inches diameter, branch 30 inches diameter.
Discharge pipe—Main 42 inches diameter, branch 30 inches diameter.
Suction injection—8 inches and 10 inches diameter.
Force injection—3 inches and 3½ inches diameter.
Overflow—18 inches diameter.
Diameter of plungers—33 inches.

	No. 2 House.	No. 3 House.
Number of pump valves	960	864

BOILERS.

Furnace Flue Tubular

Number of boilers	12
Diameter of shell	108 inches
Length of shell	20 feet
Thickness of shell	15/16 inch
Number of fire boxes	2
Diameter in inches	41
Length of fire boxes	8 feet
Number of tubes	195
Length of tubes	9 feet 3 inches
Diameter of tubes	3½ inches
Length of grate	5¾ feet
Area of grates	40¼ square feet.

Water Tube Boilers.

Number of boilers	14
Stoker	Wetzel
Number of tubes	252
Length of tubes	18 feet
Diameter of tubes	4 inches
Steam drums (two)	36 inches diameter
Length of steam drum	21 feet
Length of grate	8½ feet
Area of grate	102 square feet

In addition to the stations described, there are five high service stations which pump filtered water into stand pipes to supply the higher districts. Three of these stations are located in the Roxborough district and supply Upper Roxborough, Chestnut Hill and Mt. Airy. One is located in West Fairmount Park, connected with the Belmont filters and supplies Overbrook and adjacent areas.

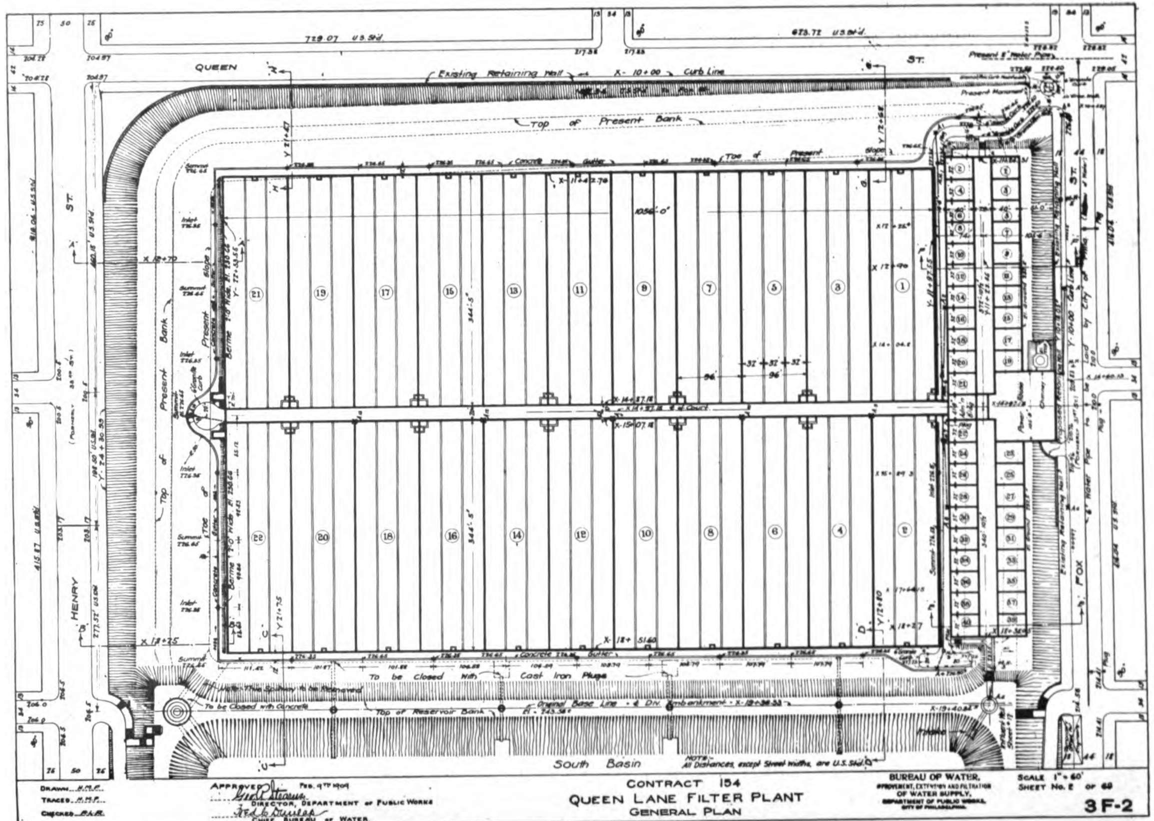
Frankford High Service station is in the Torresdale district and supplies Fox Chase, etc. The total capacity of all the high service stations is about twenty-seven million gallons daily.

The old Fairmount works where the pumps were operated by water power with a nominal capacity of 33,290,000 gallons daily, and the Spring Garden station, which is a steam power station with a nominal capacity of 170,000,000 gallons daily, being no longer a part of the present system, were both put out of service about March 1st, 1909.

* * * * * * *

QUEEN LANE FILTERS

As originally designed, the general plan for the filtration of the water supply embraced only the four filter stations already described, namely, Upper and Lower Roxborough, Belmont and Torresdale, but the rapid growth of the city attended by a corresponding increase in consumption made it necessary to augment the present capacity of these stations by adding to them or building a separate station. The Queen Lane pumping station and reservoir, together with the connecting pipe lines, being comparatively new, having been placed in service during 1895, on account of their location and the little expense necessary for their utilization as a part of the present system, offered a feasible and economical plan for the location of a filter plant in the north basin of the Queen Lane reservoir. Aside from the advantages gained by having the stations more or less divided so that in case of accident to the large mains, it need not necessarily deprive a very large portion of the city of water, as would be the case if practically all the water supply depended upon one large station, another condition favorable to the placing of filters in the Queen Lane reservoir is that the original pipe distribution system may be utilized to deliver water to a portion of the city without any addition or alterations, as would be necessary in case this same district were supplied from Torresdale. A contract, therefore, was entered into and the work is now under construction for placing a filter station at Queen Lane reservoir.



Queen Lane Filter Station. General Plan.

Sedimentation Basin

This station as planned and under construction contemplates using the south basin of the Queen Lane reservoir as a sedimentation basin which has a capacity of 177,000,000 gallons or about two and one-half days' sedimentation with the filters working at their nominal rate of 70,000,000 gallons per day. It is 30 feet deep with an elevation of 238 C.D. at its flow line. Water will be introduced at one corner and drawn off at the other end through a gate chamber to be constructed as a part of the filter plant.

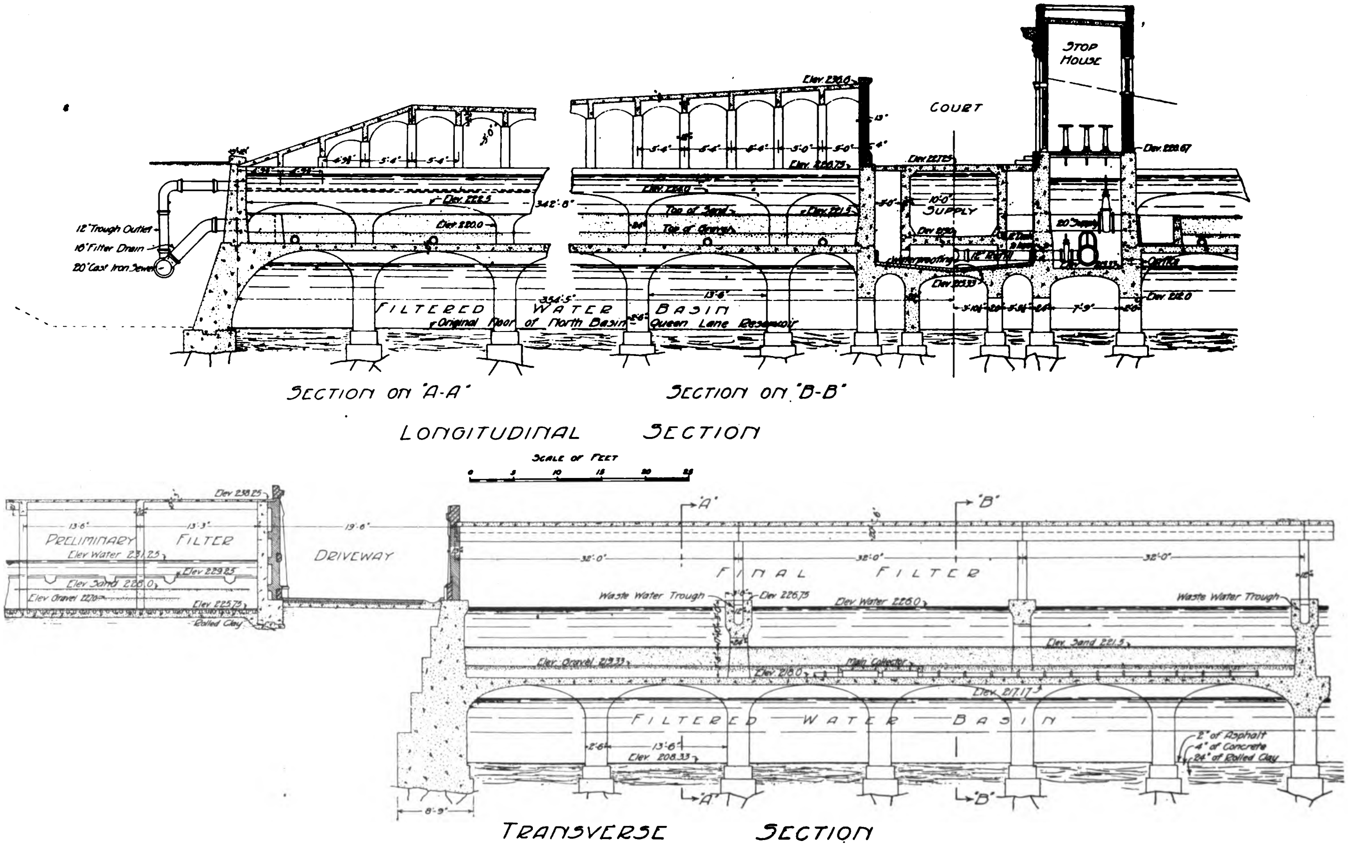
The water after passing from the sedimentation basin is delivered to preliminary filters through a 7-feet steel conduit surrounded by concrete, and is controlled in a circular gate chamber located at the eastern end of the embankment next to the filters by three, 3 feet by 4 feet hydraulically operated sluice gates.

Preliminary Filters

The preliminary filters, forty in number, measuring 32 by 40 feet each, are located partly on the original reservoir embankment and partly on fill, in two rows, separated by a power house and administration building at the centre, making two separate preliminary filter operating galleries. In all their essential details these filters are, with the exception of their interior dimensions, identical with those constructed and in operation at Torresdale, excepting that the water is introduced at front instead of at the rear, and is drawn off through an effluent discharge located immediately under the raw water supply, both of which are located under the floor of the operating gallery. The effluent is discharged at an elevation of 245 C.D. from both batteries in the centre line of the plant, where it is carried through a main supply in the centre of the final or sand filters. These filters are all covered by a reinforced concrete roof. The elevation of the water surface is fixed at 231.25 C.D. or 6.75 feet below the flow line of the sedimentation basin.

Final or Slow Sand Filters

The filters will be located immediately west of the preliminary filters inside of the north basin of the reservoir. The method of filtration is the same as employed at the other stations, but the filters are constructed on different lines, inasmuch as they will be built immediately over the filtered water basin and supported on



Queen Lane Filters. Sections.

piers and groined arches. There are 22 separate beds each having dimensions of 344 feet 5 inches by 96 feet. They are arranged in two groups or batteries separated by a court 20 feet wide under which are placed the raw water conduit and the necessary piping and drains. The supply will be received from the preliminary filters through a rectangular, reinforced steel conduit 10 feet wide by 7 feet 4 inches high, which is connected to each filter by a 20-inch pipe leading through the chamber of the regulating house in which is placed a valve to regulate the rate of flow into the filter.

The filtered water is passed from each filter direct through a rectangular orifice placed in the wall of the chamber of the regulating house to the filtered water basin. The only piping required to be extended the full length of the plant is the refill pipe, which is 12 inches in diameter and two lines of pressure pipe for washing sand, which are 12 inches in diameter.

The filters are supported on rectangular piers constructed on 16-feet centres, 2 feet 6 inches square, extending through the floor of the reservoir, the foundations for which are carried to rock. The floor of the filters forms the roof of the filtered water basin and is constructed of groined arches ten inches thick at the crown with a rise of 3 feet 9 inches. The side walls have a minimum thickness of 2 feet and are of reinforced concrete. The main collector is built of reinforced concrete in two sections, each having an area of 9 inches by 4 feet, covered by a reinforced concrete slab 6 inches thick. The lateral collectors are of 6-inch terra cotta pipe extending either side from the main collector spaced at 16 feet intervals.

The filter roof is carried on square concrete piers spaced on 5-feet centres and average about 6 feet in height, allowing head room between the water surface in the filters, and the underside of the roof beams of a minimum of 5 feet. The roof is of reinforced concrete supported on reinforced beams 19 inches deep and 6 inches wide and 32 feet span. The roof proper is 6 inches thick.

The filtering material will consist of a layer of gravel 16 inches in depth, varying in size from 3 inches in diameter to about 1/16 inch in diameter. Over the gravel is placed a layer of sand 20 inches in depth. Requirements as to size, etc., are the same as at the other stations.

The regulating houses all face the centre court or aisle and each accommodates two filters. The filters will be drained at the rear through a 20-inch pipe, which connects with a drainage system leading to the sewers.

The power station and administration building are located at the eastern end over the discharge pipes in the centre of the plant. In the power house will be placed boilers and pumps for pumping water for cleaning the filters and the electric lighting equipment, etc. A steel tank 35 feet in diameter and 30 feet high is supported above the roof and will be used to store wash water for the preliminary filters. It is enclosed by brick walls architecturally treated to conform to the other buildings.

The administration building adjoins the power house and will be arranged with lockers and quarters for the men, as well as offices for the Superintendent, etc.

Filtered Water Basin

As already indicated, the plant is a two-story structure, the filtered water basin occupying the entire space under all the final filters, a space 1056 feet by 709 feet, and when filled to its nominal depth, 9 feet, it will have a capacity of 50,000,000 gallons, or approximately two-thirds of a day's supply for the district.

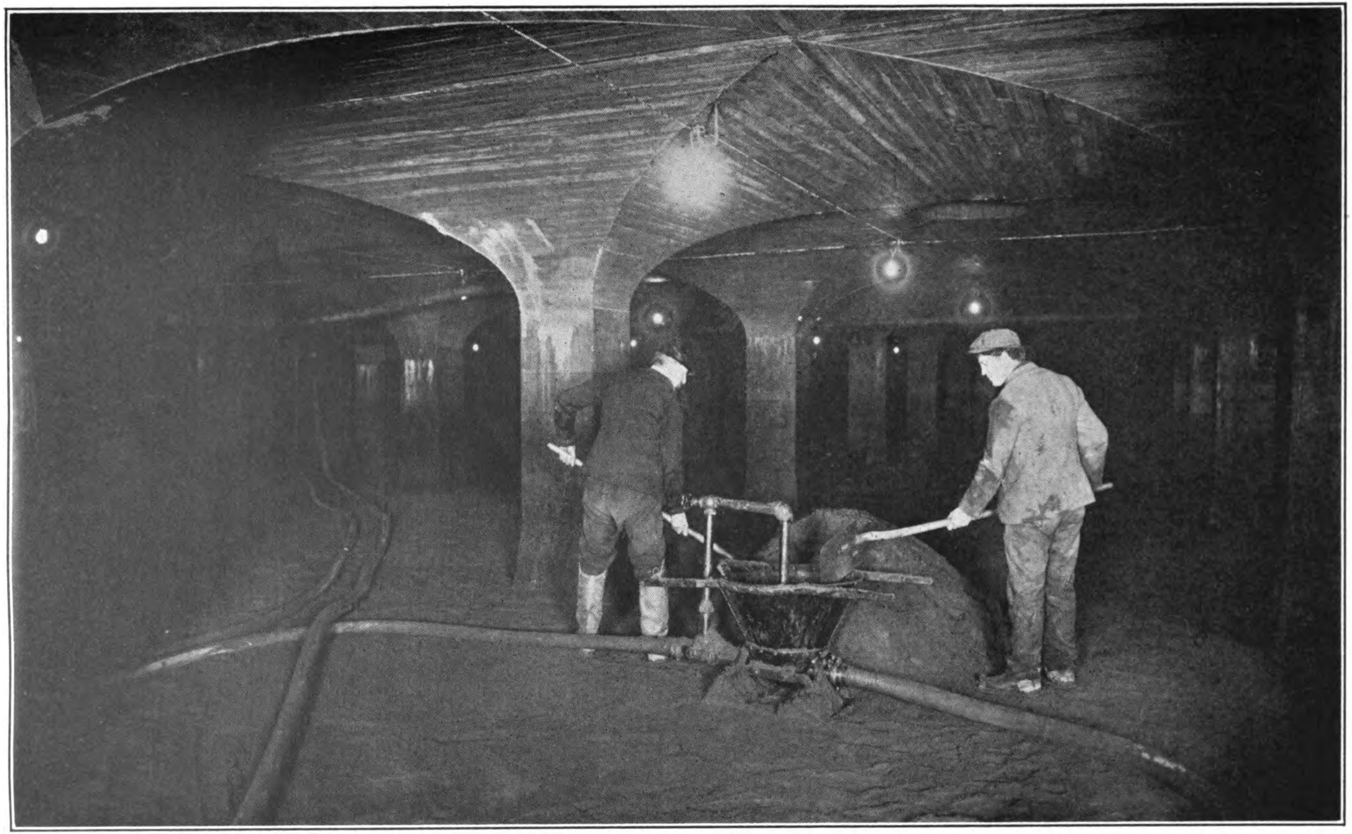
Excepting on the east, the side walls are of plain concrete 4 feet 6 inches thick and support the side walls of the final filters. The east wall is formed by the retaining wall supporting the embankment under the preliminary filters. The floor of the original reservoir forms the floor of the filtered water basin, and is lined with four inches of concrete covered with two inches of asphalt concrete.

Two riveted steel outlets covered with 6 inches of concrete, five feet in diameter connect with the original gate chamber of the reservoir, a part of which is left intact under the power house. By this arrangement the old gates and outlet pipes are made use of.

* * * * * * *

METHODS OF CLEANING FINAL FILTERS

At the time the filters were first put in operation, the method followed in cleaning the filters was practically the same as that employed in Continental European cities and London, and for slow sand filters in this country. It consisted in taking the filter out of service and allowing the water above the sand level to slowly



Sand Ejector in Service.

filter through until the level had subsided to a depth of about one foot below the surface of the sand bed. Laborers then entered the filter and scraped off the upper dirty layer of sand containing mud and other suspended matter. The depth of this scraping was regulated by the depth of the layer of discolored sand and varied from one-half to one inch, although at times a much greater depth has been removed. The dirt thus scraped from the sand layer was placed in piles at convenient distances apart and was then shoveled into a portable ejector.

The sand ejector consists of the well-known "Korting" ejector with nozzle and throat extensions connected by two lines of fire hose one of which supplies water under pressure to operate the ejector, and the other to conduct the mixed sand and water from the ejector to the washer located in the court outside the filter. The ejector not only transports the sand from the filter but it was found that it did about one-half of the work of cleaning. The sand was then delivered into the first hopper of the sand washer, which is of the same general type as the ejector, and then passed again to a second hopper from which it was discharged into piles on the court in front of the filters. The only manual work connected with the transportation and washing of the sand was represented by the scraping and the shoveling of the sand into the ejector and once a year placing the same back into the filters.

The quantity of sand handled to each ejector averaged approximately ten cubic yards per hour, requiring about 2,800 gallons of water per cubic yard.

In point of efficiency the method was satisfactory, but it was thought that more economical methods could be obtained, and it has the objection of keeping a considerable portion of the plant out of service during periods of re-sanding which, as stated, occur annually.

Methods whereby the sand could be cleaned in the filters without removing to the courts were investigated and resulted in trying what is known as the "Brooklyn" method. The first trial of this method was made at Torresdale, where it was imperative to operate the plant before the sand washing pumps could be installed, and as this kind of machinery is not required in the Brooklyn process, recourse was had to this method. It originated in the Department of Water Supply, Gas and Electricity in New York, and was suc-

Cleaning Filters. "Brooklyn" Method.

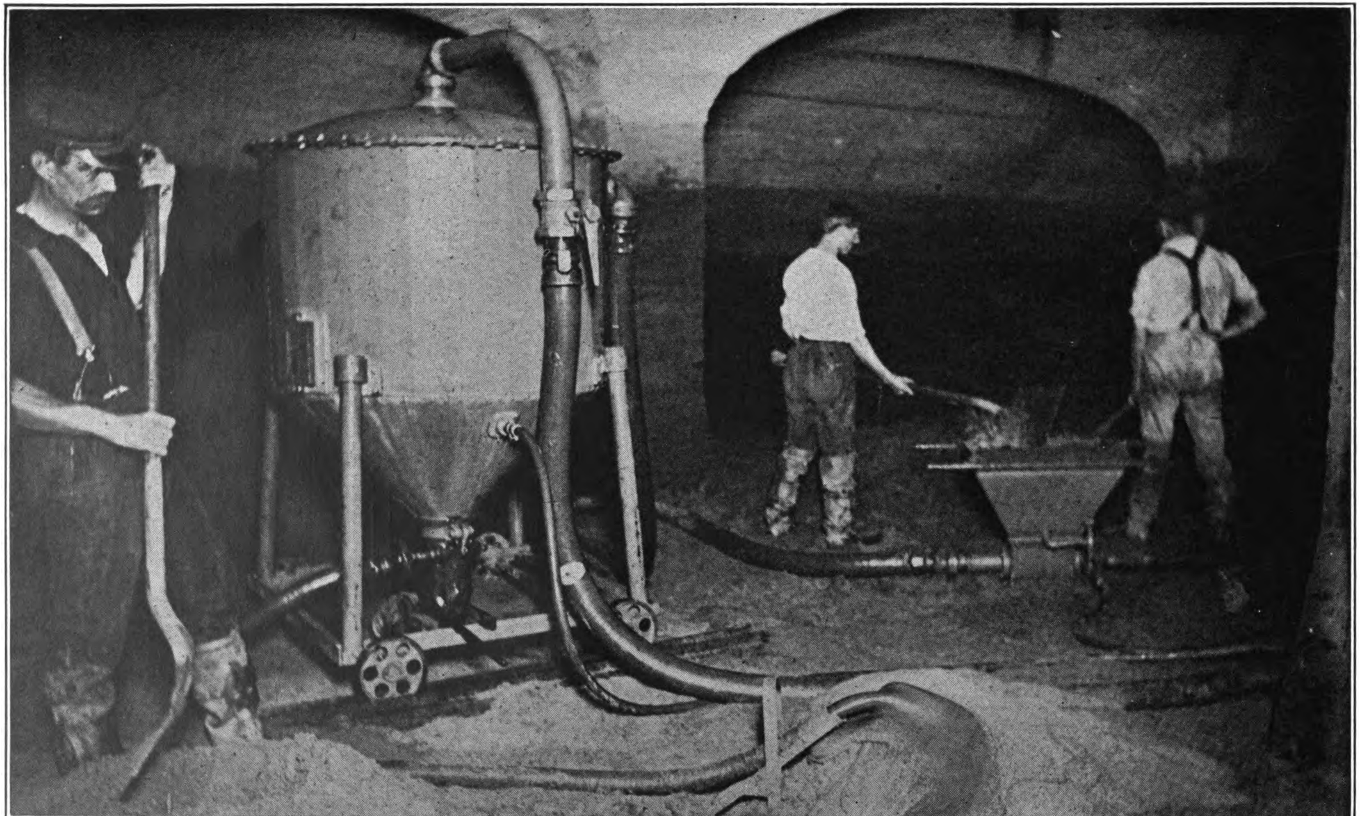
cessfully employed at the filter beds in Hempstead and Forest Stream, Borough of Brooklyn, also at the Jerome Park experiment station, Borough of the Bronx. This method obviates the necessity of removing the dirty sand scraped from the surface of the filters and storing it in the courts, as the entire work is accomplished without removing the sand from the beds. The water is drained to a depth of a few inches above the sand surface and outlets which permit the water remaining above the surface of the sand to flow off are then opened. The wash water is applied at one end of the bed and is allowed to flow over the surface of the sand at the rate of about one-half foot per second velocity. The direction of the flow is guided by boards set on edge, thus forming channels of the width of a bay or approximately 15 feet. As the water flows over the sand the layer is raked by men standing on the surface of the bed, which is continued until the water flowing from the surface is practically clear. Water is then applied through the usual inlets and filtration resumed.

This method was first tried at Torresdale, as already stated, in order to place the filters in operation at the earliest possible moment, and later tried at Belmont, where the water is pre-filtered, and since has been used at the Roxborough plants. At these stations its operation is quite successful.

When the "Brooklyn" method was first tried at Torresdale, which was prior to the operation of the preliminary filters, the results obtained were not entirely satisfactory and another method was tried.

This method involves the separating of the sand from the dirty wash water in the filter and immediately restoring it in place without removal to the courts. It is known as the "Nichols" method (after the name of the inventor of the separator) and consists of ejecting dirty sand and water by an ordinary sand ejector into a separator which is moved into the filter during the process of cleaning. The separator consists of a closed steel cylinder 42 inches in diameter, three feet high, having a cone shape bottom in which is placed a valve and hose conections, through which the sand is forced from the separator.

The interior of the separator is arranged with a system of baffles and a disc, so that there is a down-flowing stream of sand and an up-flowing stream of wash water, and they are so proportioned that



''Nichols'' Sand Separator in Operation

practically no sand is carried away in the wash water, which passes out at the top of the separator and is carried out of the filters to the sewers. The clean sand is discharged from the separator through a two-inch hose and distributed in the filters in small piles on the surface of the sand bed and then spread and leveled by hand.

The apparatus weighs about 700 pounds and is mounted on wheels so that it can be readily moved. It has a capacity for handling about ten cubic yards of sand per hour, using about 1,200 gallons of wash water per cubic yard of sand, and works under a pressure of 65 pounds.

In point of efficiency, there is little that can be urged in favor of any one of the methods over the others, that is, where pre-filtered water is used or where the applied water has received a long period of sedimentation, as at Upper Roxborough. In point of economy, however, the "Nichols" method has the advantage over washing in the courts inasmuch as it saves the cost of restoring the sand, otherwise, the cost is about the same.

The "Brooklyn" method is found to be much cheaper, but how much cannot at this time be stated, as it is believed it will be necessary to remove at least five or six inches of the sand bed and put it through an ejector and separator and replace the same about on an average, every eighteen months. This method has not been in operation for a sufficient length of time to ascertain how much should be added to the present cost for this item. While it uses more water than the other methods, it requires no re-pumpage, as the water is not required to be under pressure, as is the case with the other methods, and has a lower cost in this respect.

COST OF IMPROVEMENT, EXTENSION AND FILTRATION OF THE WATER SUPPLY

The first contract in connection with the Improvement Extension and Filtration of the water supply was made in 1900 for an experimental filter plant, but work did not begin on any of the permanent structures until 1901. Since the starting of the work about 170 contracts have been executed, covering about every class of work and material entering into water works and water purification construction. They embrace almost every type of pumping engines from a single centrifugal low service pump to a triple expansion high duty engine of the most modern design, as well as steam turbines driving single and double stage centrifugal pumps and electric generators; compound high speed engines, traveling cranes, locomotives, coal handling machinery, structural steel, buildings, tunnels, conduits, and concrete work in almost all its forms.

Below will be found in round numbers the cost of the filtration work and its adjuncts, additions to the distribution system, also repairs made to machinery in the old pumping stations. These figures do not include land damages, expense incurred at the experimental station and administrative expenses, but do include the cost of engineering, inspection and such incidental expenses:

Lower Roxborough Filters	$ 480,000
Lower Roxborough Preliminary Filters	100,000
Upper Roxborough Filters	1,080,000
Belmont Filters	2,480,000
Belmont Preliminary Filters	212,000
Belmont Sedimentation Basin	600,000
Torresdale Filters	7,100,000
Torresdale Preliminary Filters	1,160,000
Torresdale Intake	225,000
Torresdale Pumping Station, including buildings and pumps	723,000
Torresdale Conduit	1,635,000
Lardner's Point Pumping Station, buildings and pumps	2,800,000
Oak Lane Reservoir	665,000
Distribution System	5,250,000
Repairs to Pumps and Stations	1,500,000
Queen Lane Filters and Equipment	1,900,000
	$27,910,000
*Additional Distribution System	250,000
	$28,160,000

COST AND EFFICIENCY OF FILTRATION

These are subjects involving considerable detail and are only mentioned here in a general way in order that some idea may be obtained as to what has been accomplished with reference to these very important features relating to municipal water supply.

There is a very material difference in the cost of filtration at the different stations due to their wide variance in capacity and to the fact that none of the plants have identical conditions. For these reasons a comparison of cost of operating the different plants is difficult, if not misleading.

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*Estimated.

The following table shows the average cost of filtration per million gallons at the various stations for the period March 1st to August 1st, 1909, exclusive of interest and depreciation, distributed to various items entering into the total cost. This period is selected as it begins with the first operation of the preliminary filters at Torresdale:

Preliminary Filters.	Lower Roxboro.	Upper Roxboro.	Belmont.	Torresdale.
*1—Attendants	$0.40		$0.18	$0.16
2—Labor	.09			.03
3—Maintenance & repairs.	.91		.26	.08
4—Total	1.41		.44	.27
Final Filters.				
5—Office	.43	$0.36	.18	.07
6—Attendants	.37	.61	.23	.15
7—Cleaning Filters	.35	1.07	.98	.35
8—Labor, etc. (see note)..	.75	.92	.84	.28
9—Laboratory	.52	.46	.32	.13
10—Total	2.42	3.42	2.55	.98
11—Total both filters......	3.83		2.99	1.25
12—Low lift pumpage......				1.87
13—Grand total	3.83	3.42	2.99	3.12
Average quantity filtered Mill. gallans daily....	11.3	13.8	37.5	216.0

*1—Keeps log and washes filters.
2—Cleaning up and keeping grounds in order.
3—Repacking valves, replacing fuses, repainting, etc.
5—Superintendent and clerical work.
6—Keeps bi-hourly record of gauges, operates valves for cleaning filters, etc.
7—Labor of scraping and washing sand.
8—Cutting grass, painting, janitors, watchmen, repairs to pipes, etc., and cost of lighting.
9—Collecting and making bacteriological analysis of samples of water from rivers and each filter daily and chemical analysis weekly. Semi-weekly analysis are made of samples collected from numerous taps throughout the city.

Filter Attendants ....$800 per year
Laborers ....$2.00 per day of 8 hours

The distinctive feature of the Philadelphia filtration system is the double process—that is the use of preliminary and final filters. The objects of double filtration are:

(1) To increase the total capacity of the plant.
(2) To reduce the unit cost of filtration.
(3) To increase the efficiency of the filters.

Experience at the three stations where double filtration is used indicates that all three of these purposes have been accomplished; for example, the maximum rate at Torresdale station before the completion of the preliminary filters was 4,000,000 gallons per acre per day, and the average yield per acre per day was 2,333,000 gallons during 1908, with an average length of run of 19.7 days, whereas with double filtration the maximum rate used on the final filters is now 6,000,000 gallons per acres per day, and the average yield has been increased to 3,960,000 gallons per acre per day for the period from March 1st to August 1st, 1909, and the average run was 46.7 days.

Undoubtedly the great argument that persuaded the people of Philadelphia to incur such a large outlay for the improvement of the city's water supply was not only the clarification of the water, but the improvement in the health of the people, and was based especially upon the reduction of typhoid fever and other diseases which were supposed to have been caused by polluted water.

As heretofore indicated, the biological and chemical aspect of treating water by filtration cannot be here discussed, but generally speaking, the experience with the filters in this city has been the complete removal of suspended matter and reduction of bacterial content of over 99 per cent. While statistics relating to the bacterial reduction are not as forceful to those persons not familiar with the biology of water, a reference to the reduction of typhoid fever rates may be readily understood by all, therefore a table showing the case and death rates for 1906 to the first half of the year 1909 follows:

TYPHOID DATA RATES PER MONTH PER 1000,000.

Year.	1906.		1907.		1908.		1909.	
Population.	1,460,344. Est.		1,490,124. Est.		1,520,488. Est.		1,551,500. Est.	
	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.
Jan.....	71.4	5.1	90.5	8.6	26.4	4.5	31.3	2.6
Feb.....	101.0	8.6	100.4	11.3	39.0	5.6	18.0	2.7
March..	87.6	11.2	65.6	11.5	30.4	5.3	14.1	2.1
April....	59.3	7.0	33.0	5.6	24.1	3.6	8.0	1.9
May....	76.1	7.1	24.9	4.7	13.9	2.8	13.5	2.0
June....	51.2	6.7	20.3	3.0	10.5	1.3	8.9	1.9
July....	25.6	3.2	17.3	2.4	8.9	1.4	7.6	0.9
Aug.....	37.4	4.5	26.5	3.3	19.9	1.6		
Sept....	28.4	4.0	20.1	2.8	23.5	3.2		
Oct.....	25.1	3.0	16.3	2.1	11.4	2.2		
Nov....	50.9	5.8	16.6	2.4	9.5	1.5		
Dec.....	52.0	6.4	18.4	2.0	10.2	1.8		
Totals.	666.0	72.6	449.9	59.7	227.7	34.8		
Fatalities	10.9%		13.2%		15.3%			

Note:—Months, January, February, April, May, July, September, October and December are considered to have in each year the same number of weekly determinations, namely 4.

Months—March, June, August and November are considered to have in each year the same number of weekly determinations, namely 5. This for purpose of comparison.

Previous to Jan. 1, 1906, Germantown, Chestnut Hill, Roxborough, Manayunk and West Philadelphia, east of 38th Street, comprised the filtered water district. Further extensions were as follows:

Jan. 16, 1906, West Philadelphia, east of 44th Street.
Jan. 30, 1906, West Philadelphia, west of 63rd Street to City Line.
Nov. 6, 1906, all of West Philadelphia.
July 15, 1907, Frankford.
Sept. 18, 1907, Kensington, east of Frankford Avenue.
April 3, 1908, west to Broad, north to Girard Avenue.
May 1, 1908, Tioga, north of Allegheny Avenue.
May 21, 1908, south to Spring Garden, Broad to 6th Street.
Oct 18, 1908, west to 22nd Street and south to Girard Avenue.
Feb. 28, 1909, introduction of filtered water to entire city completed.

It should be borne in mind that only a part of the city received filtered water during the entire period covered by this table, and at this time a small portion of the city is still receiving unfiltered water; nevertheless, it is gratifying to note the gradual and material decrease in typhoid fever cases. To sanitarians, as a rule, the exclusion of the bacterial content expressed by the percentage reduction is not so significant as the determination for the presence or non-presence of sewage bacteria. Along this line semi-weekly tests are made to determine the presence or absence of the B. Coli Communis, whose presence is indicative of contamination. While this organism is found in both the Delaware and Schuylkill river waters, it is very rarely detected in the effluent of any of the filters.

IMPORTANT ELEVATIONS

(Referred to City Datum taken as 2.25 feet above mean high water, Delaware River.)

ROXBORO—

(Lower Roxboro)

River at Roxboro pumping station		31.7
Reservoir		366.
Pre-filters		349.62
Final filters	(highest)	342.83
	(lowest)	331.83
Clear water basin		325.75

(Upper Roxboro)

Reservoir	414.
Filters	417.33
Clear water basin	410.
High service stand pipe	491.
Mt. Airy	363.

BELMONT—

River at Belmont pumping station		6.6
Reservoir		279.0
Pre-filters		267.0
Filters	(highest)	254.33
	(lowest)	248.33
Clear water basin		239.
George's Hill reservoir		212.
High service stand pipe		364.

QUEEN LANE—

River at Intake Queen Lane Station	6.6
Reservoir	238.
Pre-filters	231.25
Final filters	226.0
Clear water basin	217.0

TORRESDALE—

Delaware River at Intake (mean tide)	—5.5
Pre-filters	34.
Final filters	17.
Clear water basin	7.0
Top of Arch Pump Well, Lardner's Point Pumping Station	—10.5
Frankford reservoir	167.
Frankford high service stand pipe	300.
Oak Lane Reservoir	210.
East Park Reservoir	133.
Corinthian Reservoir	120.

PRINCIPAL DIMENSIONS OF FINAL FILTERS AND FILTERED WATER BASINS.

Filters.	Lower Roxborough.	Upper Roxborough.	Belmont.	Torresdale.	Queen Lane
Number of filters	5	8	18	65	22
Area of filters	0.53 acre.	0.70 acre.	0.735 acre.	0.75 acre.	0.76 acre.
Dimensions of filters at neat lines	109 ft. x 219 ft. 10 in.	140 ft. 8 in x 219 ft. 10 in.	8 beds, 272 ft. 8 in. x 120 ft. 2 in. 3 beds, 196 ft. 5 in. x 165 ft. 11 in. 7 beds, 242 ft. 2 in. x 135 ft. 5 in.	43 beds, 140 ft. 8 in. x 235 ft. 8 in. 22 beds, 132 ft. 2 in. x 253 ft. 2 in.	344.5 ft. x 96 ft.
Height of piers	9 ft. 1 in.	9 ft. 1 in.	9 ft. 1 in.	9 ft. 1 in.	....
Cross section of pier at top	2 ft. 10 in.	1 ft. 10 in.	1 ft. 10 in.	1 ft. 10 in.	....
Cross section of pier at base	1 ft. 10 in.	2 ft. 10 in.	2 ft. 10 in.	2 ft. 10 in.	....
Height of filters in clear	12 ft. 9 in.	12 ft. 9 in.	12 ft. 9 in.	12 ft. 9 in.	17 ft. 6 in.
Span of groined arches	14 ft.	14 ft.	13 ft. 5 in.	14 ft. and 13 ft. 2 in.	....
Rise of groined arches	3 ft.	3 ft.	3 ft.	3 ft.	....
Thickness of arch at crown	6 in.	6 in.	6 in.	6 in.	....
Thickness of floor at invert	6 in.	6 in.	6 in.	6 in.	....
Thickness of floor under pier	14 in.	14 in.	14 in.	14 in.	....
Thickness of end walls at base	4 ft. 2 in.	4 ft.	4 ft. 2 in.	4 ft. 3½ in.	2 ft. 10 in.
Thickness of end walls at spring line	18 in.	1 ft. 8 in.	1 ft. 8 in.	1 ft. 8 in.	....
Thickness of dividing wall at top	2 ft.	1 ft. 10 in.	1 ft. 10 in.	1 ft. 10 in.	3 ft. 0 in.
Thicknes of dividing wall at base	3 ft. 9 in.	2 ft. 10 in.	2 ft. 10 in.	2 ft. 10 in.	2 ft. 6 in.
Minimum thickness of puddle	12 in.	12 in.	12 in.	12 in.	....
Filtered Water Basins.					
Capacity	3,000,000 gals.	8,000,000 gals.	16,500,000 gals.	50,000,000 gals.	50,000,000 gals.
Dimensions at neat lines	159 ft. 3 in. x 190 ft. 11 in.	237 ft. 8 in. x 318 ft. 10 in.	382 ft. 2 in. x 396 ft.	601 ft. 10 in. x 762 ft. 2 in.	1056 ft. x 709 ft.
Normal depth of water	13 ft. 9 in.	15 ft.	15 ft.	15 ft.	9 ft.
Height from invert to crown	16 ft. 9 in.	18 ft.	18 ft.	18 ft.	9 ft.
Span of groined arches	14 ft.	14 ft.	14 ft.	14 ft.	13 ft. 6 in.
Rise of groined arches	3 ft.	3 ft.	3 ft.	3 ft.	3 ft. 9 in.
Dimen. of side walls at spring line	2 ft.	....	2 ft. 6 in.	2 ft. 6 in.	4 ft. 6 in.
Dimen. of side walls at base	5 ft. 6 in.	....	6 ft.	6 ft.	4 ft. 6 in.
Minimum thickness of puddle	12 in.	12 in.	12 in.	12 in.	....

Centre Square Works—1801.

A Brief History of the Water Works of Philadelphia

Philadelphia, like most other large cities, has experienced considerable difficulty in finally agreeing upon a plan for the betterment of her water supply. It has led to exhaustive study, great divergence of opinion, much investigation and considerable legislation by the City Councils.* From the very conception of the first water works to within a very recent date, the supply has been more or less unsatisfactory and numerous commissions have been appointed and surveys made with a view to ameliorating the existing conditions.

The subject first received serious attention by the public as early as 1789, after an epidemic of yellow fever, when Benjamin Franklin pointed out the necessity of going beyond the (old) City's limit for a potable supply. Certain advances were made later, and there

*As resent as 1897, Director of the Department of Public Works, Thomas M. Thompson, in a report to Councils stated, "Gentlemen of the very highest professional reputation, ability and experience such as * * * * * * and many others have united with the executive officers of our City in conscientious and laborious efforts to solve the difficult problems of securing for the City of Philadelphia a bountiful and pure water supply.

"A careful study of the reports and opinions expressed by these eminent gentlemen, compels me to state that I find them conflicting, both in their premises and conclusions, and that the data gathered from them will hardly warrant this department in presenting a report based upon their investigations."

were intervals when it was thought that the matter was settled indefinitely, but succeeding generations, owing to the City's growth and other conditions, found it necessary to make changes and extensions, and it was not until 1899 that the plans for the present system received serious consideration and were finally adopted a year later.

At the time Dr. Franklin first agitated the question of a betterment of the water supply, the City's limits were confined in the area bounded by Vine and South streets and the Delaware and Schuylkill rivers. Thus geographically located, with two rivers close at hand, which at that time could not have been polluted to any great extent, it might be supposed that this great philosopher would have given them some consideration as a source of supply, but it must be remembered that this was at a period before steam pumping plants were in use and little was known of water-power machinery. The Wissahickon Creek was strongly recommended by him, which he held could be utilized without great difficulty on account of its elevations being such as to make a gravity supply feasible. It is of interest to note, in view of the City's present boundaries, that as late as 1859, Mr. Henry P. M. Birkinbine, Chief engineer of the Water Department, considered that "the great error of the City in relation to its water works has been the rejection of this simple and perfectly feasible plan * * * * * * and to this day, an abundance of purest water would have been procured from this source, adequate for all demands."* Later, during 1875, Dr. William McFadden, Chief Engineer of the Water Department, concurred with Mr. Birkinbine, stating that "Benjamin Franklin deserved credit for arousing and educating public sentiment to the importance of a pure supply of wholesome water, but also presenting the most simple, feasible and least expensive plan for water works to attain the same."§

Councils (1797) gave serious consideration to Dr. Franklin's suggestion, but attention seemed to have been so much directed to a scheme of the Union Canal Company, that it was lost sight of.

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*History of the Water Works and Annual Report of the Chief Engineer of the Water Department, Wm. H. McFadden, presented to Councils 1860.

§Brief history and review of the water supply published with Annual Report of the Water Department for the year 1875.

This Company, a few years previously, had obtained a charter which carried with it certain rights in supplying water to citizens, etc., and it met with more or less favorable consideration. The scheme involved the construction of a reservoir at Callowhill and Broad streets and the digging of an open canal along the latter street which would supply the cross streets, necessitating at each street intersection a bridge. It was the intention to feed cisterns from this canal which were to be located in the cellars of the residences and thence pumped. Councils offered to purchase from the Company a quantity of its water, but the proposition was rejected and an attempt was then made by Councils to purchase all the Company's rights and privileges and a memorial was prepared to the State Legislature to secure enactment to provide means to carry out this project.

After much negotiating the scheme was rejected, and a year later (1798) Councils engaged Mr. Benjamin Henry Latrobe, an engineer of "superior talent and industry," the scope of whose inquiry was to cover the practicability of obtaining a supply of water within a reasonable distance of the city. Mr. Latrobe made his report during the same year, and it not only embraced suggestions for a "sufficiency of water for culinary use and an additional supply for washing the streets," but "if possible, for cooling the air."

Mr. Latrobe's first recommendation to go to Spring Mill Creek, some twelve miles distant, and deliver the water to the city by means of an aqueduct where it was to be pumped, was rejected. His next recommendation was approved and resulted in the construction of the first steam pumping plant in the United States (completed 1801). Mr. Birkinbine in his historical review of the water works referred to, comments on his (Mr. Latrobe's) failure to estimate the advantages of the Wissahickon Creek and observed "it is possible that the novel idea of raising water by steam may have so occupied his attention as to cause him to overlook this source."

It is of interest to note Mr. Latrobe's comparison of the Schuylkill and Delaware rivers as a source of water supply, especially in view of the City's recent policy to limit the quantity from the Schuylkill and make extensions on the Delaware river from which is taken at the present time approximately 70 per cent. of the total quantity consumed.*

He discussed the merits of the two rivers as follows:§

> "Against the Delaware will operate: the impurity of its waters, which is subject to a strong running flood tide, and which must be supposed to be contaminated by the decayed vegetables of the marshes over which it passes, independently of the filth, thrown from the numerous vessels lying along the wharves or running into it from the public sewers."
>
> "In favor of the Schuylkill: the principal circumstance is the uncommon purity of the water; its bed everywhere narrow and rocky, its sources lie entirely in the limestone country, and the tide opposite the center of the town does little more than raise the water by accumulation."

The accepted plan of Mr. Latrobe provided that the supply be taken from the Schuylkill river at Chestnut street wharf, and the erection of a steam pumping plant at this place to raise the water to a basin at the same location. From this basin the water was to flow by gravity through an underground conduit in Chestnut street to Centre Square, now the site of the City Hall. Here his plan provided for another pumping plant to elevate the water to wooden tanks in the top of the pumping station. The following description of these pumping plants is taken from a report to the Watering Committee by Mr. Frederick Graff, Chief Engineer and Superintendent of the Water Department, dated January 3, 1853:

> "The Center Square engine house was an exceedingly handsome building of marble, the lower story being in form a square of sixty feet, twenty-five feet high, with two por-

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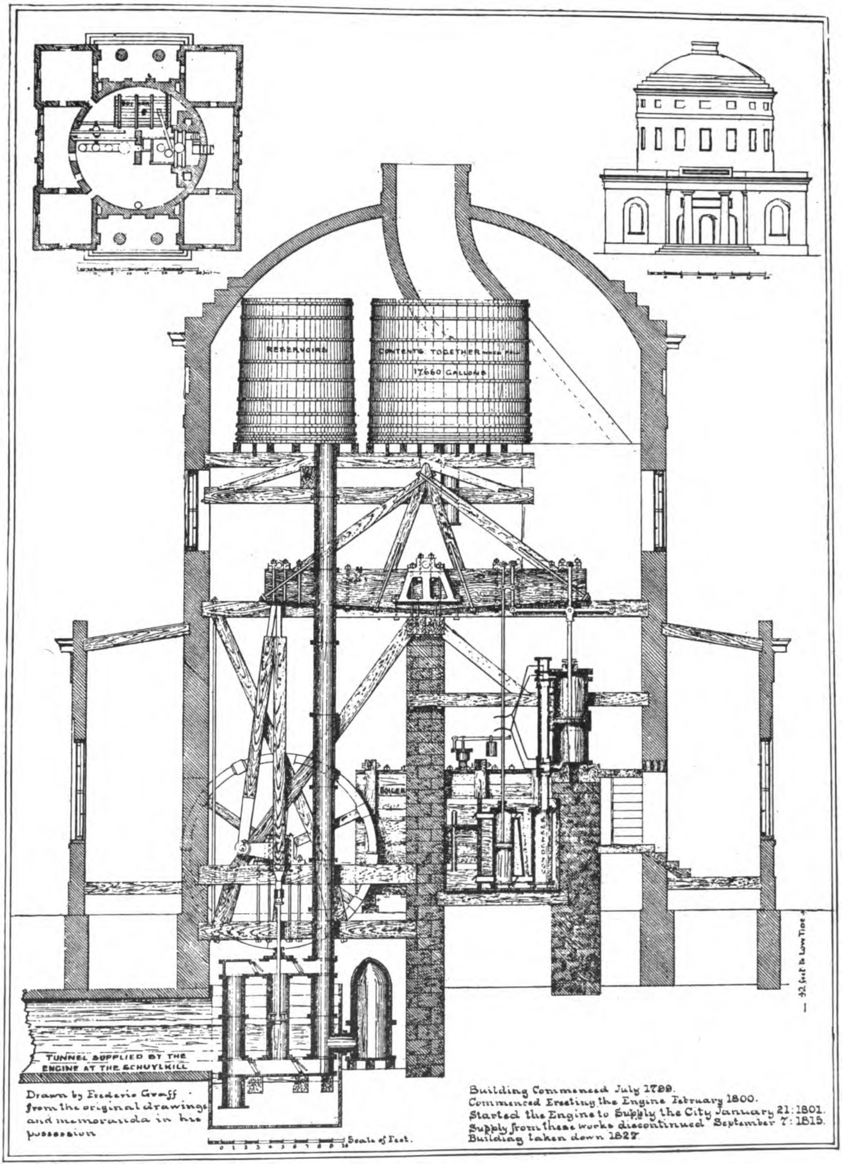
*The Commission of 1899 which formulated the general plan finally adopted and now in effect, referred to the two rivers as a source of supply and concluded that they were of the opinion that the waters of both were unfit for such purposes unless filtered. They found "the Delaware water at Lardner's Point is less turbid after rain than the Schuylkill water; is also softer and less polluted."

§Report of Mr. Latrobe December 29, 1798, printed in Report of the Committee appointed by the Common Council to inquire into the state of the Water Works 1802.



Centre Square Works—Section.

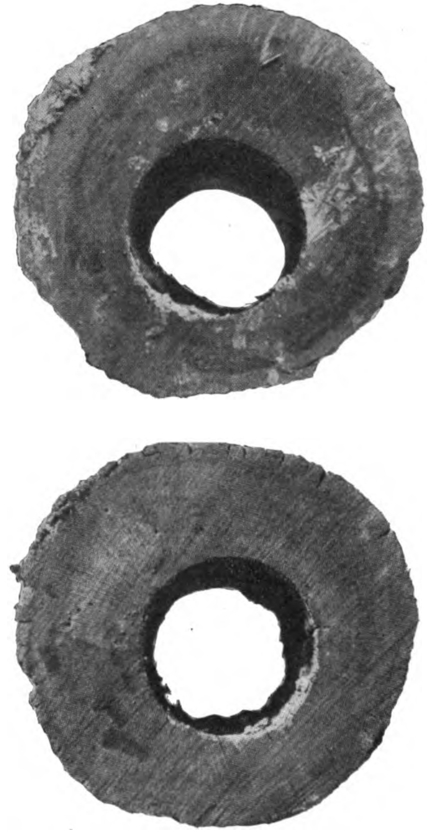
ticos containing committee rooms, offices, and engineer's room, and surrounding a circular building forty feet diameter, and sixty feet high, covered by a dome, from the centre of which was carried the chimney of the steam engines. The engines in both the buildings were very defective in every respect; the lever-beams, fly-wheel, shafts and arms, cold water pumps and cisterns, being all made of wood. The boilers to both engines were wooden boxes, nine feet high, nine feet wide and fifteen feet long; made of five-inch white pine plank, securely bolted through and braced on the outside. The fire-box inside of the boiler, was of wrought iron with vertical flues of cast iron; subsequently, a cast iron boiler was substituted. At this time, no wrought iron could be obtained in larger sheets than fifteen inches by three feet, when it was squared, which had to be done by the purchaser; all the castings were patched by gun borings, cement and hard solder; the important parts of the pumps had to be lined with sheet copper, before they could be made air-tight. The main steam cylinder of the Center Square engine, was cast in two pieces, united by copper, the joints being secured externally by a cast iron band eighteen inches wide, and although it was but six feet six inches long, and thirty-six inches in diameter, nearly four months were consumed in boring it out fit for use. The pumps were double acting force pumps, and at first were without air chambers; this necessary article was, however, added to the Centre Square pump in 1810, but could not be made useful until it was lined with sheet lead.

"The engine at Schuylkill engine house was forty inches diameter and six feet stroke; the pump attached to it being seventeen and a half inches diameter, and six feet stroke. The engine run sixteen revolutions per minute, and pumped, by actual experiment, 1,474,560 ale gallons of water in twenty-four hours, with a consumption of seventy bushels of bituminous coal. The Centre Square engine had a cylinder of thirty-six inches diameter and six feet stroke, a pump of eighteen inches diameter and six feet stroke, and by experiment pumped 962,520 gallons of water in twenty-four hours, with a consumption of fifty-five bushels of coal. The water was pumped by this engine into two wooden tanks in the top of the building, fifty feet above the bottom of the brick tunnel, leading from the Schuylkill engine house; one of these tanks was ten feet diameter and twelve feet deep, and the other, fourteen feet diameter and twelve feet deep, containing together about 17,094 ale gallons. The engine was able to pump these full in about twenty-five minutes, and they were exhausted in about the same time. Therefore, if the pumps were not constantly at work, citizens suffered for water; and from the very defective work about the engine and pump, this was frequently the case."

The construction of such pumping machinery as just described was attended with great difficulty and in view of the facilities then at hand, the very limited number of experienced mechanics and the very meagre facilities to perform such work, great credit is reflected in the undertaking which was contracted for by Nicholas Roosevelt, of New Jersey. This machinery represented the largest steam engine erected at that time, and while the development of industrial manufactories of modern times tends by comparison to make their efforts seem crude, nevertheless, the achievement was remarkable. Although these engines were defective and must have required constant attention to keep them in operation, it is almost incredible to conceive of such a combination of wood and iron performing any service whatever. However, it is a matter of record that 9,000 foot pounds were developed for the consumption of each bushel of bituminous coal.

The defects in these works made it imperative that some other method of securing the water supply should be adopted and investigations were made along these lines.

This led to further investigation of the Wissahickon and Spring Mill Creeks and Schuylkill river by Mr. John Davis and Mr. Frederick Graff during 1811. Councils finally settled on the erection of steam works at Fairmount, the construction of which was started in 1812 and put in operation in 1815. They are described in the report of the Watering Committee as follows:



Wooden Pipe laid in Market Street 1801, taken up 1901.

"A substantial stone building was erected (now occupied as a public saloon and dwelling), at the foot of the hill at Fairmount, in which was at first erected a Bolton and Watt steam engine, of forty-four-inch cylinder and six-feet stroke, working a vertical double-acting pump of twenty inches diameter, and six-feet stroke, raising the water through a sixteen-inch iron main, two hundred and thirty-nine feet long, into the reservoir, one hundred and two feet above low water in the Schuylkill. This engine had a boiler with a cast iron case, and vertical flues or heaters of wrough iron, and upon trial pumped 1,733,632 ale gallons in twenty-four hours, with seven cords of wood, carrying from two and a half to four pounds of steam pressure of steam."

* * * * * * *

Prior to the year 1817 all water mains were of wood, and considerable trouble was experienced on account of insufficient strength. The Watering Committee decided to import from England a small quantity of cast iron pipe to be laid as an experiment. The results of this experiment were "so satisfactory that from time to time iron pipe were gradually substituted for those of wood, of which there was at one time (1828) forty-five and one-half miles in use."

* * * * * * *

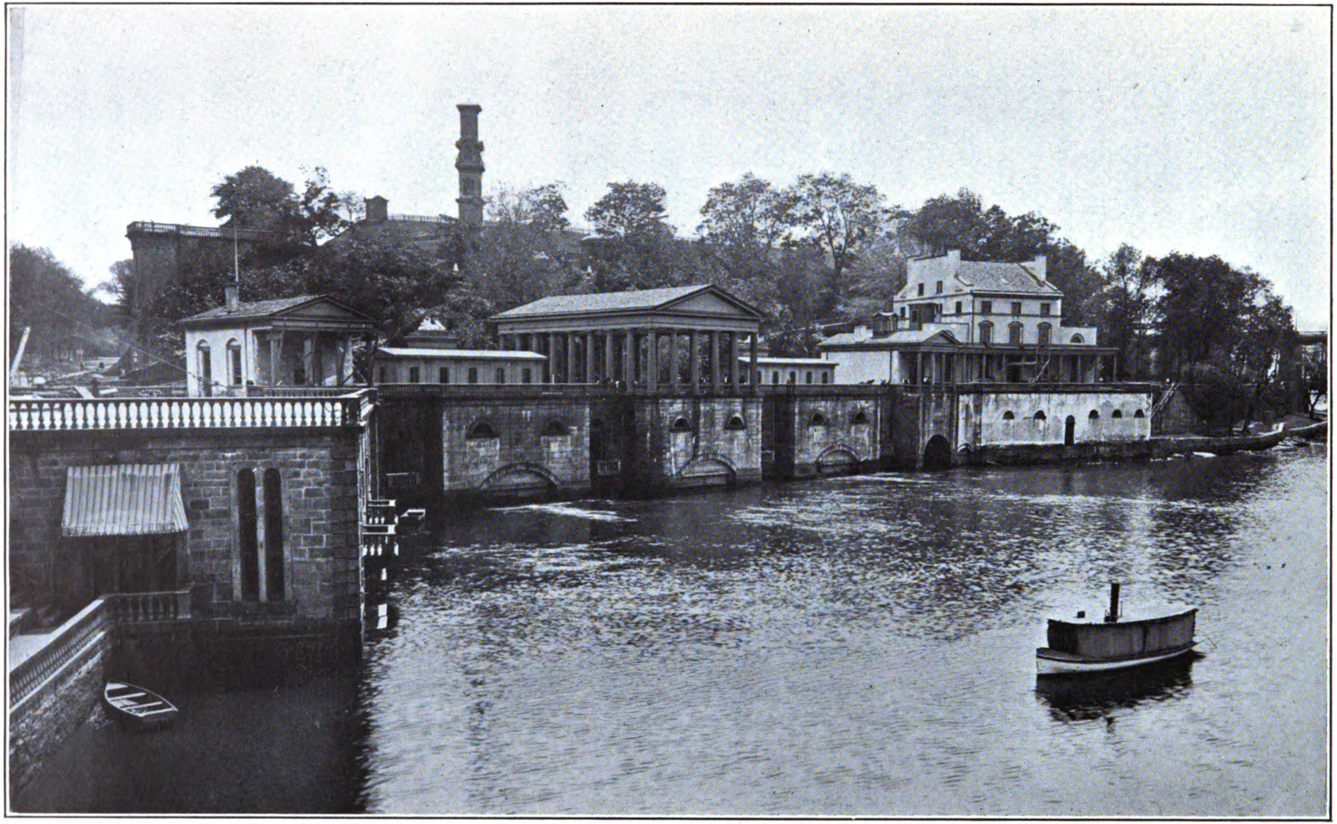
Difficulty was experienced in keeping up a sufficient supply owing to the City's rapid growth and the defective machinery then in use. These conditions combined with the very high cost of pumping led Councils to look for a water-power pumping plant on the Schuylkill river. That such a plan, however, had received some attention as early as 1807 is shown by a reservation made in a charter granted to James Kennedy by the State during that year, which allowed him the privilege to construct a dam at the Falls of Schuylkill for water-power purposes. The City was granted the right at any time to purchase from James Kennedy all his rights and improvements for the use of supplying the City with water.

The State also granted a charter to the Schuylkill Navigation Company in 1815, which carried with it the right to improve the navigation of the Schuylkill river to its mouth. Under this charter part of the work was completed, and as it was expected at that time to connect the Schuylkill and Delaware rivers by a canal, the creation of a pool in the Schuylkill river above Fairmount was thought to be a great advantage to the City's interest as well as to the said Company. The City was therefore allowed the privilege of erecting a dam at Fairmount for water-power development which was of great assistance to the Company owing to the fact that it was not then able to finance so large an undertaking.

Councils decided to erect a water-power plant at Fairmount in April, 1819, and the building of the dam was started during the same month, and by 1822 the water-power works were so far advanced that the steam plant was discontinued.

Lack of space will not permit a comprehensive description of this great undertaking; the following is taken from the report of the Watering Committee for the year 1823:

> "The whole length of the over-fall is twelve hundred and four feet; the mound dam, two hundred and seventy feet; the head arches, which will presently be mentioned, one hundred and four feet, making the whole extent of the dam, including the western pier, about sixteen hundred feet, and backing the water up the river about six miles.
>
> "On the west side of the river there is erected a head pier and guard-locks, whence there is a canal extending five hundred and sixty-nine feet to two chamber locks. On the east side of the river the whole of the bank was a solid rock, which it was necessary to excavate to the width of one hundred and forty feet, to form a race and a site for the mill-houses, running parallel with the river. The length of the mill race is four hundred and nineteen feet, the greatest depth of the excavation sixty feet. At the upper part of this excavation were erected the head arches, three in number, which extend from the east end of the mound dam to the rock of the bank, thus forming a continuation of the dam.
>
> "On the west of the excavation are erected the mill-houses, forming the west side of the race, which is supported on the other side by the rock raising above it seventy or eighty feet perpendicularly. The south end or wall of the race, is also of solid rock; and the mill-houses are founded on rock; so that nothing can be contrived more secure in all respects.



Fairmount Pumping Station; Completed 1822.

"The race is about ninety feet in width, and is furnished with water through the head arches, which allow a passage of water of sixty-eight feet in breadth, and six feet in depth, to which the race is excavated below the over-fall of the dam, and of course room is allowed for a continual passage of four hundred and eight square feet of water. These arches are on the north of the race, and the mill-buildings being on the west, the water passes from the race to the wheels, which discharge the water into the river below the dam. At the south end of the mill-buildings there is a waste gate, eight feet wide, by which (the upper gates being shut) the water can be drawn off to the bottom of the race.

"The mill-buildings are of stone, two hundred and thirty-eight feet long, and fifty-six feet wide. The lower section is divided into twelve compartments, four of which are intended for eight double forcing pumps. The other apartments are for the forebays leading to the water-wheels. The pump and forebay chambers are arched with brick, and are perfectly secure from the inclemency of the winter. The centre part of the building is one hundred and ninety feet by twenty-five feet, with circular doors to the pump chambers, and a range of circular windows over the arch ways of the wheel rooms; on a line with the cornice of the central part is the base course of two pavilions, with doric porticos, which terminate the west front. On the east front, immediately over the pumps and forebay rooms, is a terrace, two hundred and fifty-three feet long, and twenty-six feet wide, paved with brick, and railed, forming a handsome walk along the race, and leading by steps at the end, to the top of the head arches, mound dam and pier."

* * * * * * *

"The pumps were made by those ingenious engineers, Messrs. Rush and Muhlenberg, according to the designs of Mr. F. Graff, and are worked by a crank on the water-wheel, attached to a pitman connected with the piston at the end of the slides. They are fed under a natural head of water, from the forebay of the water-wheel. They are double forcing pumps, and are connected, each of them, to an iron main of sixteen inches diameter, which is carried along the bottom of the race to the rock at the foot of Fairmount, and thence up the bank into the new reservoir. At the end of the pipe there is a stop-cock, which is closed when needful for any purpose. The shortest of these mains is two hundred and eighty-four feet long, the other two are somewhat longer."

The wheels as originally constructed were of the breast pattern and remained in service many years. The first turbine was not started until 1851.

Since the construction of the Fairmount pumping station, the plan followed for increasing the water supply to meet the demands of the rapid growth in population was to construct pumping stations along the Schuylkill river and reservoirs on the near high plateaus, from which the water was supplied by gravity. Later, owing to the growing population in the northeastern section of the city, it was found necessary to construct a plant on the Delaware river.

During the year 1826 contracts were made to supply outlying districts as follows: Spring Garden, Northern Liberties and Southwark. Moyamensing and Kensington were not supplied from Fairmount until 1832 and 1833 respectively.

The construction of the Fairmount reservoir was completed in 1837, although some of the sections were completed several years prior to this date.

The next works were built by the citizens of Northern Liberties, and were known as the Schuylkill Works, situated at the foot of Thompson street, at the present site of the Spring Garden pumping station, and were put in operation July 15, 1845. Susequently the Kensington, afterwards known as the Delaware Works (1851) and the 24th Ward Works (1855) were built. The latter station was located on the site now occupied by the Zoological Gardens. The Germantown Works, abandoned in 1872, and owned by a private Company, came into the possession of the City in 1866, and during the year 1869 the Roxborough Works were put in operation. During 1872 the present Belmont Works were started, which supplanted the 24th Ward Works, and in 1878 the present Frankford

Pumping Station at Lardner's Point took the place of the Delaware Works, which were abandoned in 1890. The Queen Lane pumping station and reservoir were placed in service in 1895.

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From the construction of the first steam works at Chestnut street (1801) to the completion of the Queen Lane system (1895) as heretofore indicated, the City followed the policy of constructing large pumping stations along the Schuylkill and Delaware rivers and pumping to reservoirs, etc. However, early during this period, dissatisfaction became evident and the increasing population on the water-sheds of those rivers caused the water to become so objectionable that from year to year the citizens grew more concerned and agitated and sought relief by securing other sources of supply. This led to numerous investigations by engineers and Commissions. A brief account is here given of the various Commissions, etc., and their recommendations. The question was not finally settled until 1900, when it was decided to purify the waters of the Delaware and Schuylkill within the City limits by slow sand filtration.

During 1858 Mr. H. M. P. Birkinbine, Chief Engineer of the Water Department, drew attention to the Wissahickon Creek, Delaware and Lehigh rivers at Easton, and the Schuylkill river above Reading. After making preliminary surveys of sources near the City, started in 1864, Mr. Birkinbine in 1866 recommended the Perkiomen creek as a source of supply. The Park Commission in 1867 reported that the Schuylkill river could be relied upon for many years, if properly guarded from pollution. In 1875 a Commission was appointed to investigate the entire subject of the present and future water supply for the City, but owing to the lack of information at their disposal no recommendations as to the future supply were made.

During the year 1882, as a result of a prospective water famine, another Board of Experts was appointed. They recommended increasing the capacity of the existing works, also that a thorough investigation of the pollution of the Schuylkill river should be made, and the surveying of all sources for a future available supply. This led to the appointment of a corps of Engineers under Col. (later General) William Ludlow, Chief Engineer of the Bureau of Water, and a report was made by Mr. Rudolph Herring in 1883-86. Examinations of various areas of the country "comprised within the water shed lines of the tributaries of the Schuylkill and Delaware rivers in Pennsylvania" were made.

Again in 1899, no action having been taken on former recommendations, and the supply of water in all parts of the City being inferior in quality, and some parts scarce in quantity, a Commission of expert Engineers, consisting of Messrs. Rudolph Herring, Joseph M. Wilson, Samuel M. Gray, was appointed.

This Commission was instructed to report:

First: What was necessary for immediate relief.

Second: If the remedy be filtration, to recommend a particular method.

Third: In what direction should future extensions be made.

After availing itself of the data collected by previous Commissions and of the surveys, reports, etc., particularly those made by Mr. Rudolph Herring in 1883-86, and after making examination of the water-sheds of the Schuylkill and Delaware rivers, it was recommended to adopt "that project by which the waters of the Schuylkill and Delaware rivers, taken within the City limits, are purified by filtration."

Acting upon this recommendation, Councils in January, 1900, authorized the construction of filters within the City limits and provided funds for this purpose, also for the general improvement of the supply. The work was started immediately, following in essentials the recommendation of the Commission of 1899, and the entire City received filtered water March 1st, 1909.