PROCEEDINGS

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THE ENGINEERS' CLUB

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IMPROVEMENT, EXTENSION, AND FILTRATION OF THE WATER-SUPPLY OF PHILADELPHIA.

JOHN W. HILL.

Read February 21, 1903.

Mr. President and Gentlemen:

I have been introduced as offering a paper this evening; I regret to say that what I will give you is not in the form of a paper. The time was not available to prepare a paper such as I should like to read. So in the absence of written matter I will put on the screen a number of views of the work now in progress, and while these are being shown will endeavor to entertain you with a desultory talk about the details of the work embraced in the general improvement of the water-supply. After the views have been presented I wish to call your attention to some features of the work which cannot be represented by or do not require the aid of the lantern.

The improvement, extension, and filtration of the water-supply of Philadelphia involves four separate propositions:

1. The readjustment of sources of supply to limit the maximum consumption of water from the Schuylkill River to 150,000,000 gallons per day of twenty-four hours.

2. The readjustment of the water-distribution districts so that the present Fairmount, Corinthian, East Park, Queen Lane (in part),

and Wentz Farm, or Frankford, districts will hereafter receive their water-supply from the Delaware River, all of which, excepting the Wentz Farm district, are now supplied from the Schuylkill River.

3. The filtration of the entire water-supply from the Schuylkill and Delaware Rivers.

After these things are accomplished there will then arise the fourth proposition—viz., to meter all water services, or readjust the water rates to meet the added cost of filtering the supply.

In the reports of the experts—and wisely, it is thought—it was deemed advisable to limit the consumption of water from the Schuylkill River to 150,000,000 gallons per day, which volume of water represents about the minimum dry-weather stream-flow.

The ultimate available working capacity of the Belmont filters, as planned, will be 97,000,000 gallons per day.

The ultimate capacity of the Roxborough works will be, for:

Lower Roxborough (five filters), ...	12,000,000	gallons per day.
Upper Roxborough (seventeen filters),..	45,500,000	" "
Roxborough Service, ...	57,500,000	" "
Belmont (twenty-six filters),..........	97,000,000	" "
Total from Schuylkill River,......	154,500,000	" "

The actual capacity of the works now under contract will be, for:

Belmont (eighteen filters),............	67,000,000	gallons per day.
Lower Roxborough, ...	12,000,000	" "
Upper Roxborough (eight filters),.....	20,000,000	" "
	99,000,000	" "

or about two-thirds of the available capacity of the land taken by the city for filtration of the Schuylkill water.

The ultimate works at Belmont will embrace twenty-six filters of 0.73 acre area.

The ultimate works at Upper Roxborough may embrace seventeen 0.70-acre filters, while the works at Lower Roxborough cannot conveniently be enlarged, but will probably always remain as constructed —viz., five one-half-acre filters.

The Belmont and Lower Roxborough filters will be worked in connection with preliminary or roughing filters, while the Upper Roxborough filters, at least in their early history, will be worked only with subsided water from the Upper Roxborough reservoirs.

Experience may demonstrate the wisdom of adding a system of preliminary filters to the Upper Roxborough works, which can be done with some unimportant changes in the works as constructed, and instead of seventeen filters, the extension would probably be limited to twelve filters, or four more than the present number, working at the rate of 4,200,000 gallons per filter per day, or a total available capacity, allowing 20 per cent. for reserve, of 40,300,000 gallons, making the ultimate draft on the Schuylkill River 149,300,000 gallons per day, or nearly 150,000,000 gallons as recommended by the experts.

The wisdom of limiting the supply of Schuylkill water to the Roxborough and Belmont districts will be seen when the growth of population west of the river in the present wards, the Twenty-fourth, Twenty-seventh, Thirty-fourth, and Fortieth, is considered. The present population of West Philadelphia is estimated at 170,000, and the population fifty years hence, it is believed, will reach 450,000, which, at the present rate of consumption, will require over 90,000,000 gallons per day; or if restrictions of waste are adopted, the consumption will certainly reach 65,000,000 to 70,000,000 gallons per day. Combining the estimated minimum consumption of West Philadelphia with the estimated capacity of the Roxborough filters, there will be consumed from the Schuylkill River from 120,000,000 to 145,000,000 gallons of water per day of 24 hours.

A part of the water filtered at Roxborough will be supplied to the higher levels of the present Queen Lane district; the remainder of this district, together with the other districts mentioned, will hereafter be supplied with filtered water from the Torresdale works on the Delaware River.

With a view to presenting the more important works entering into the improvement of the water-supply, I have had lantern slides prepared from the plans and photographic views of the works, and will briefly describe these as the views are put on the screen.

Diagram of Population and Water Consumption.

The diagram (Fig. 1) shows the curves of population and water consumption from 1860 to 1900, and is offered to illustrate what many of the audience may already know—viz., that the very large per capita consumption of water has occurred entirely during the last seventeen years of the period of time embraced. Since 1885 the consumption has risen from 72 gallons per capita to 222 gallons per capita. You will observe that the increase in per capita consumption from 1860 to 1885 was 36 gallons, while from the latter year to 1900, the increase was 150 gallons. This is partly to be accounted for by the large increase during the past twenty years of the manufacturing industries in Philadelphia, partly by the almost universal use, even in the most modest dwellings and business houses, of modern sanitary appliances, and partly by increased application of water to the arts. Philadelphia is said to be a city of homes, and this

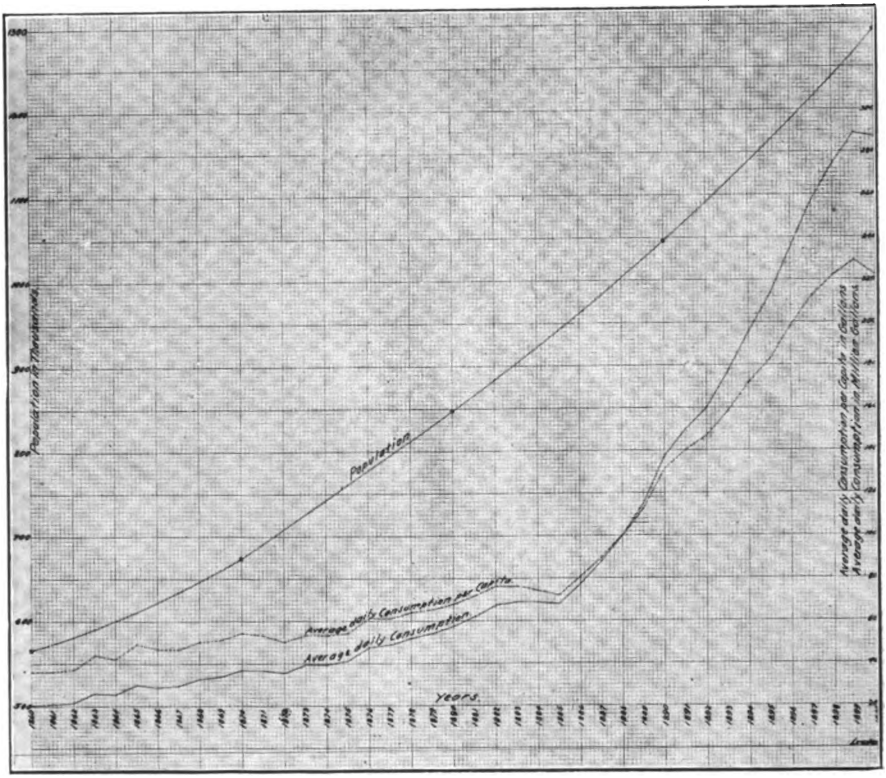

Fig. 1.—Population and Consumption of Water in Philadelphia, 1860–1900.

statement is true as compared with other large cities of the United States. Here, with a few exceptions in the older wards of Southwark, and the territory lying next to the Delaware River, the renter of limited means, instead of seeking a domicile in a barracks or tenement-house, as is the custom in New York, Cincinnati, St. Louis, Chicago, and other large cities, can obtain a separate dwelling at a cost of a few dollars per month, in which he is isolated from his neighbors, and is master of his home from the cellar to the roof and from the front to the rear of the premises. In his home, however unpretentious it may be, he will find gas, water, bath-tub, and water-closet, which are well adapted to the necessities of his family. It will thus be found that, whereas in this city a family of four or five persons will have from two to three water spigots in the house, in other large cities as many as fifty persons living on one floor of a tenement-house may have to draw water for all purposes from a single spigot; and in some so-called barracks in Cincinnati, containing three or four stories or floors, the public water is not found above the ground floor, and all tenants are compelled to carry water to their respective abodes from a single hydrant in the rear yard. Under these conditions of water-supply it can be well understood that the per capita consumption in this city is bound to be greater than in some other large cities, and the people as a whole will be cleaner in person and enjoy greater home comforts so far as these may be due to the public water-supply.

It is sometimes thought that the large per capita consumption in Philadelphia is due partly to leakage of joints in the street mains, but such information as has come to me on this point does not point to this loss as a large or even material factor. I remember a statement made a few years ago by a well-known Boston engineer, that in a system of water mains in a New England city laid under his supervision the leakage amounted to 25 per cent. of the gross consumption; but water mains are not laid in that way here.

Map of City, Showing Sketch Plan of Work.

The sketch map (Fig. 2) shows that portion of the city which lies north of Market Street and includes all the new works embraced in the improvement of the water-supply.

Beginning with the Belmont, or West Philadelphia, works, which will supply with filtered water all the city territory west of the Schuylkill River, the filtering works are located on Belmont Avenue between City Avenue and Lankenau Avenue, and occupies the tract of land bounded by Belmont Avenue, City Avenue, Monument Avenue, Lankenau Avenue, and Overbrook Avenue, in all about 57 acres, nearly all of which is occupied by the works now under construction or by the plans for future extension of the filters.

The Belmont works as they are being constructed will contain a sedimentation reservoir consisting of two divisions, with a capacity at the flow line, 279 feet above C. D. (city datum), of 72,000,000

Fig. 2.—Location of Works.

gallons; a system of preliminary filters of a daily capacity (at present) of 40,000,000 gallons, to be extended to 97,000,000 gallons to meet future consumption; eighteen plain sand filters, each of approximately 0.73 acre net sand area, and a clear-water basin of 16,500,000 gallons capacity at the flow line, 239 feet above C. D.

The raw water for the Belmont works will be pumped from the present Belmont pumping station to the sedimentation basins at the intersection of Belmont Avenue and City Avenue, two new lines of 36-inch rising main having been recently laid through West Park and Belmont Avenue for that purpose.

The Roxborough works consist of two sets of filters, one on Dearnley Avenue west of the Lower Roxborough reservoir, and the other on Port Royal Avenue and Hagy Mill Road. The Lower Roxborough works consist of five one-half-acre filters, and a clear-water basin of 3,000,000 gallons capacity, to which will shortly be added a system of preliminary filters of 12,000,000 gallons daily capacity, which will be the ultimate working capacity of the Lower Roxborough station.

The Upper Roxborough works consist of eight filters, each of about 0.70 acre net sand area, and a clear-water basin of 8,000,000 gallons capacity. No preliminary filters are at present contemplated for the Upper Roxborough station.

The Lower Roxborough filters are placed at an elevation from which 60,000 to 80,000 population can readily be supplied by gravity. The elevations of the works at this station are as follows:

Lower Roxborough subsiding reservoir, ...	366.00	C. D.
Level of water in preliminary filters, ...	350.00	"
Level of water, filter No. 5, ...	343.00	"
Level of water, filter No. 4, ...	340.25	"
Level of water, filter No. 3, ...	337.50	"
Level of water, filter No. 2, ...	334.75	"
Level of water, filter No. 1, ...	332.00	"
Level of water, clear-water basin, ...	325.75	"

The filters at Lower Roxborough, by reason of the topography, are arranged in terraces, each filter rising 2 feet 9 inches above the next below. By the adoption of Lower Roxborough reservoir as a subsiding basin the pumpage of 12,000,000 gallons per day through an added head of 48 feet is avoided. In the plans of the experts this reservoir was to be abandoned entirely, and all pumpage from the Shawmont station was to be to the Upper Roxborough reservoirs at elevation 414 feet C. D., but careful study of the general problem indicated the advantage of utilizing the Lower Roxborough reservoir as a subsiding basin for a system of filters designed to supply all of the Twenty-first Ward lying below elevations 250 C. D., and parts of the Twenty-second and Thirty-eighth Wards. At the present time these works are supplying from 6,000,000 to 7,000,000 gallons of filtered water per day, of the following quality, as shown by the weekly report of the Testing Station for the week ending February 14th:

Bacteria per cubic centimeter, clear-water basin, ...	52.0
Turbidity, parts per million, silica standard, ...	5.0

The average of the effluents flowing from the five filters to the clear-water basin was as follows:

Bacteria, per cubic centimeter, ...	77.0
Turbidity, silica standard, ...	4.4

showing a marked reduction in the bacterial content of the filter effluents while passing through the clear-water basin. The reason for this is supposed to be the lack of food material for the support of bacterial life in the filtered water.

The presence or absence of fish in water has been mentioned as a test of quality. Certain species of fish, like the carp, for instance, are often found to flourish in waters polluted by organic wastes, while other kinds, like the mountain trout, more fastidious in their tastes, are never found in any but the clearest and naturally purest upland waters. In all cases, however, there must be enough organic matter in any water to support even fish life, and an estimate of the quality of a water-supply for domestic purposes, from the presence or absence of any particular fish, can only be relative. A water wholly destitute of organic matter could not support fish life, while in a water heavily polluted with sewage certain kinds of fish would die, possibly for lack of oxygen.

It has been stated that, since the introduction of the filtered water into Manayunk, goldfish cannot live in it, which is an indication that some, if not quite all, of the sewage wastes have been removed by plain sand filtration from the Schuylkill water.

The accepted standard of water purification by the filters of Europe is 100 bacteria per cubic centimeter of effluent. No turbidity standard for potable water, so far as I am aware, has ever been set either here or abroad, but the nearest approach to this has come from the Medical Society of the District of Columbia, which, as I am informed by

Colonel Miller, in charge of the Washington aqueduct, has expressed the opinion that a filtered water showing by the platinum wire standard a turbidity of 0.025, corresponding to about 6.25 parts per million by the silica standard, would meet all reasonable requirements.

The Upper Roxborough filters will supply parts of the Twenty-first and Twenty-second Wards by gravity, and through the Roxborough auxiliary pumping station will furnish filtered water to Mt. Airy, Chestnut Hill, and all the higher elevations in the Roxborough district. The elevations of the works at this station are as follows:

Upper Roxborough reservoirs,	414.00 C. D.
All filters at uniform elevation,	419.00 "
Clear-water basin,	410.00 "

The filters at Upper Roxborough are completed, lacking the filtering materials, which are now being placed, and within a few months this station will be put in service with an early capacity of 15,000,000 gallons per day, which will gradually be increased to over 20,000,000 gallons, as the new purveying districts have been adjusted to a proper consumption of the combined capacity of the Upper and Lower Roxborough stations.

The complete service at Lower Roxborough will be the pumpage of raw water from the Schuylkill River at Shawmont to the Lower Roxborough subsiding reservoir, from which it will be drawn continuously by gravity to the preliminary filters, thence to the final filters, thence to the clear-water basin, and thence to the distribution districts, through a double line of 30-inch cast-iron pipes; one, line "B," leading to the Manayunk district, Twenty-first Ward, and one, line "A," leading to the Germantown district, Twenty-second Ward.

The complete service at Upper Roxborough will be the pumpage of the raw Schuylkill River water to the Upper Roxborough subsiding basins, thence by gravity to the low-service pumping station on Eva Street near Shawmont Avenue, from which the subsided water will be lifted by centrifugal pumping machinery to the filters; thence to the clear-water basin at Port Royal Avenue and Hagy Mill Road, and thence through a single line of 48-inch cast-iron pipe by gravity to the Roxborough auxiliary (high-service) pumping station, where the supply for Chestnut Hill and Mt. Airy will be taken off and the remainder flow by gravity to levels in the Twenty-first and Twenty-second Wards, which are too high to be supplied from the Lower Roxborough filters. The clear-water basin of the filters at Upper Roxborough is at an elevation 84.25 feet higher than the clear-water basin at Lower Roxborough.

The Upper Roxborough filters have a flow line 5 feet higher than the flow line of the subsiding reservoirs, and hence the necessity for the second low-service pumping lift just mentioned. In the subsiding basins at both Upper and Lower Roxborough the process of sedimentation will be continuous; that is, the water-level will be maintained at an approximately constant elevation, and the rate of pumpage to the basins will also be the rate of filtration at the two stations.

The capacity of the Lower Roxborough subsiding basin at flow line is about 13,000,000 gallons, or slightly more than one day's work of the filters when the preliminary filters have been completed. The capacity of the Upper Roxborough subsiding reservoirs is 147,000,000 gallons, or about seven times the easy capacity of the filters. In the early history of this station it could not be worked above 15,000,000 gallons per day because of the limited distribution district to be supplied previous to the completion of the Torresdale filters and readjustment of the supply to the present Queen Lane district.

The Torresdale filters, located on the west bank of the Delaware River, north of Pennypack Creek, are intended to supply a present population of 1,100,000, comprising the present Fairmount, East Park, Queen Lane (in part), and Wentz Farm districts. The filter capacity intended by the experts to be located at the Queen Lane reservoirs has in the plans been combined with the Torresdale works.

At the present time the work of construction at Torresdale embraces fifty-five three-quarter-acre filters, and a clear-water basin of 50,000,000 gallons capacity. The plans contemplate an addition of ten filters, each of three-quarter-acre net sand area, to provide for the supply of filtered water to the Queen Lane district.

The total capacity of the Torresdale works, based on sixty-five filters, with preliminary filtration of the water, will be 248,000,000 gallons per day of twenty-four hours.

From the clear-water basin at Torresdale the filtered water will flow by gravity to shaft No. 1, of the Torresdale conduit, thence through the conduit to shaft No. 11 at Lardner's Point, where it will rise and be distributed to the old and new pumping stations. (See Fig. 19.) These stations will have a combined daily pumping capacity, when completed, of 290,000,000 gallons, of which 240,000,000 gallons will be assembled in the two new engine houses.

From the Lardner's Point pumping station the filtered water will be pumped into the Lardner's Point pipe distribution system, and conveyed to Frankford Avenue and Frankford Creek, whence the water will flow partly southward through mains on Frankford Avenue and partly westward and southwardly through mains to be laid from the intersection of Torresdale and Kensington Avenues.

The Lardner's Point pipe distribution system consists of four lines of 60-inch cast-iron pipe in Robbins Street, from Delaware Avenue to Tacony Street, and three lines of the same size and kind of pipe in Tacony Street, from Robbins Street to its junction with Torresdale Avenue; thence as three lines of pipe, the same as before, in Torresdale Avenue to Kensington Avenue. The three lines of pipe cross Frankford Creek between Frankford and Kensington Avenues. The fourth line of 60-inch pipe will in the future be laid in Robbins Street from Tacony Street to Torresdale Avenue and in Torresdale Avenue from Robbins Street to Kensington Avenue, provision being made in all the valve chambers west of Tacony Street for ultimate connection with the fourth line of pipe when laid.

From valve chambers Nos. 5, 6, and 7, at Torresdale Avenue and Frankford Avenue, three lines of 48-inch pipe will be laid southward on Frankford Avenue, and from valve chambers Nos. 8, 9, and 10, at Torresdale and Kensington Avenues, four lines of 48-inch pipe will be laid westwardly on Torresdale Avenue, and two lines of 48-inch pipe southwardly on Kensington Avenue, to lead into and connect with the principal mains in the present Queen Lane and East Park distribution districts.

The Oak Lane reservoir of 70,000,000 gallons capacity, at elevation 210.00 C. D., forms part of the Torresdale works and is intended as a compensating reservoir for filtered water, and to fix the head against which the Lardner's Point pumps will in the future work. This basin is now under construction, on the site lying between Third and Fifth Streets and Medary Avenue and Sixty-fifth Avenue North, adjacent to the suburb of Oak Lane.

The 48-inch rising main which will connect this with the Queen Lane and East Park distribution systems will be laid in Fifth Street from Erie Avenue to Chelten Avenue, where it will connect with the reservoir gate chamber.

The total land appropriated for the filters and other works comprises 462.502 acres, divided as follows:

Upper Roxborough station,	34.518 acres.
Belmont station,	60.572 "
Torresdale station,	343.500 "
Oak Lane reservoir,	20.823 "
Lardner's Point pumping station,	3.089 "

The Belmont Works.

Figure 3 shows the general plan of the Belmont works, which embraces the two settling basins, preliminary filters, plain sand filters, and clear-water basin, as the principal features, and as auxiliaries an administration building, containing offices for the management of the works, boiler-room, engine-room, and laboratory for the analytical examination of the water samples, pumping machinery to supply water to the sand washers and ejectors, and to pump water drained from filters taken out of service into filters which are in service, together with electrical generators to supply light to the filters, gate and regulator houses, and administration building.

Referring to figure 3, showing the Belmont subsiding basins, it will be noticed that the raw water from the Schuylkill River will flow through a 48-inch pipe lying on the bottom of the reservoir to the northeast corner, where it will issue through the open branches of "tees" in the pipe, and not through the end, which will be plugged.

The water rises from the bottom to the top of the easterly compartment of the basin and is drawn from the surface by a floating pipe connected with another 48-inch pipe on the floor of the westerly compartment of the basin, from which it is discharged at the northwest corner of the basin through the open tees near the end of the pipe; the end of the pipe being plugged as it is in the easterly compartment of the basin. The water then rises from the bottom to the top of the westerly compartment and is drawn from the surface by a floating pipe through the gate chamber to the preliminary filters south of Ford Road. It will thus be seen that during the period of continuous subsidence in the reservoirs the raw water passes from end to end, and from the bottom to the top, of each division of the reservoir before it is drawn off to the filters.

Figure 4 shows the operations in the west division of the Belmont sedimentation basins, which indicates the character of material which the contractors were required to remove; much of the excava-

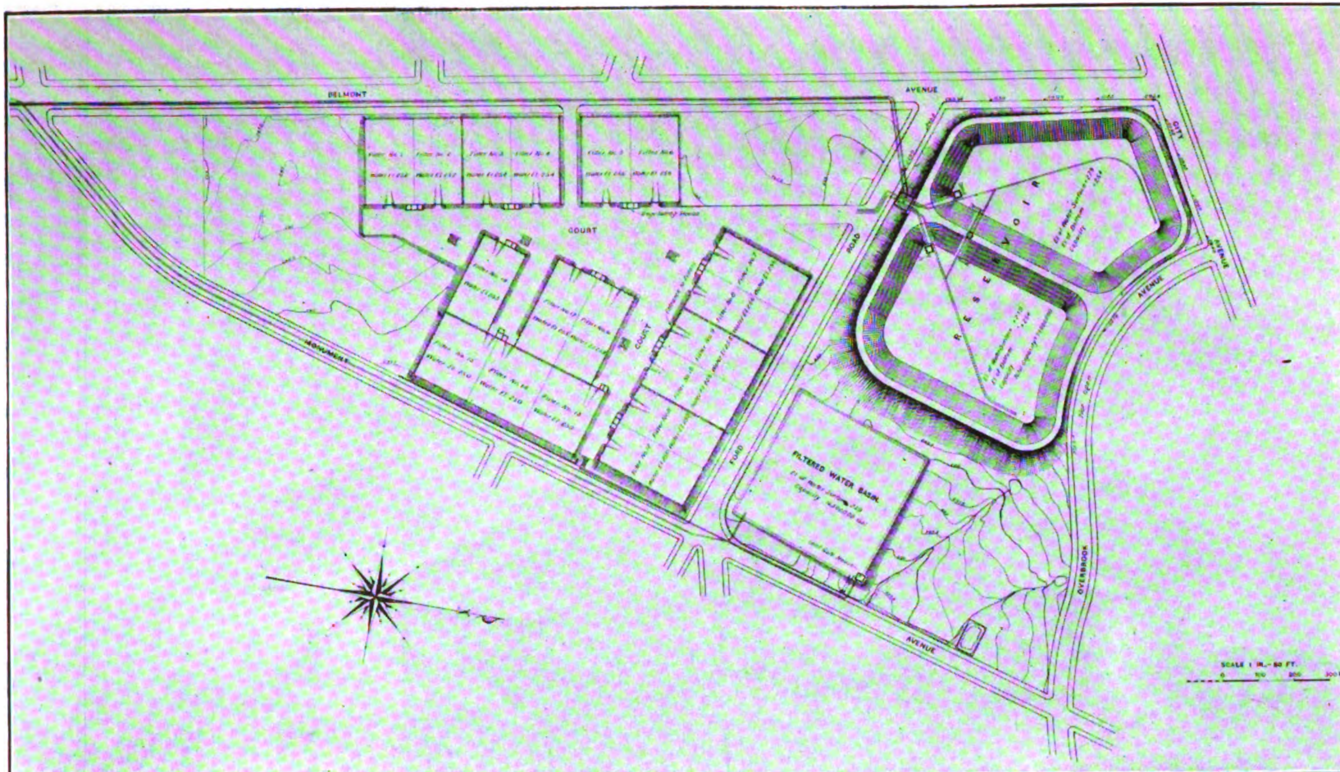

Fig. 3.—Belmont Filters and Reservoir.

tion, as will be noticed, is in solid rock, sometimes as hard as quartz. While rock was shown by the diamond drill borings to constitute a large part of the excavation, it was not thought that so much blasting as was really required would be necessary in moving the material. All the excavation for both divisions of the reservoir is now completed, the puddle lining placed and rolled over part of the floor of the east division, and with the advent of spring the leveling up of the floor of the west division, and trimming of all the inside slopes,

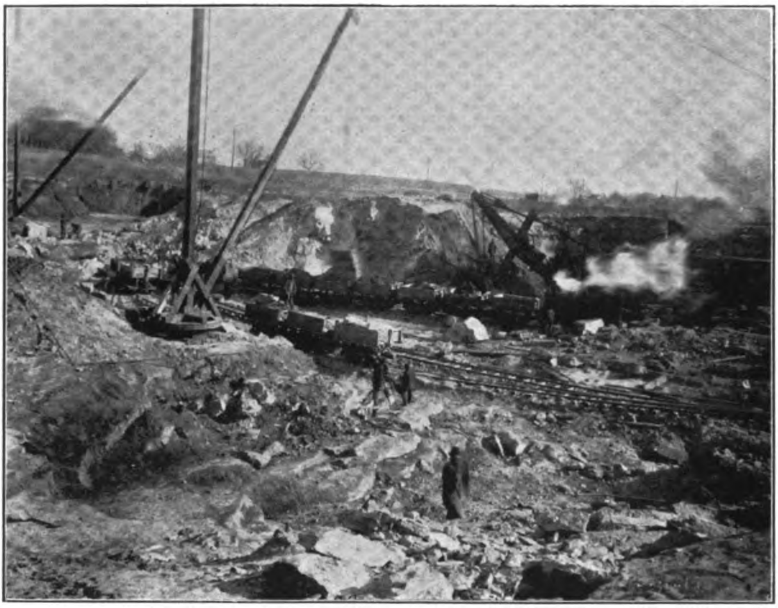

FIG. 4.—BELMONT RESERVOIR EXCAVATION—WEST BASIN.

will be commenced with a view to the early completion of this detail of the work.

Figure 5 shows in detail the method of paving the floor and slopes of the reservoir. After the floor has been brought to sub-grade, by excavation and filling with concrete and rough stones in mortar, a layer of clay puddle 18 inches thick is placed and rolled in 6-inch layers over the floor; above this is placed an 8-inch paving of concrete rammed in place, and over this a layer or sheet of asphaltic mastic consisting of Neuchâtel or other equal imported rock asphalt, with Bermudez asphalt as a flux and binder, mixed with granolithic grit.

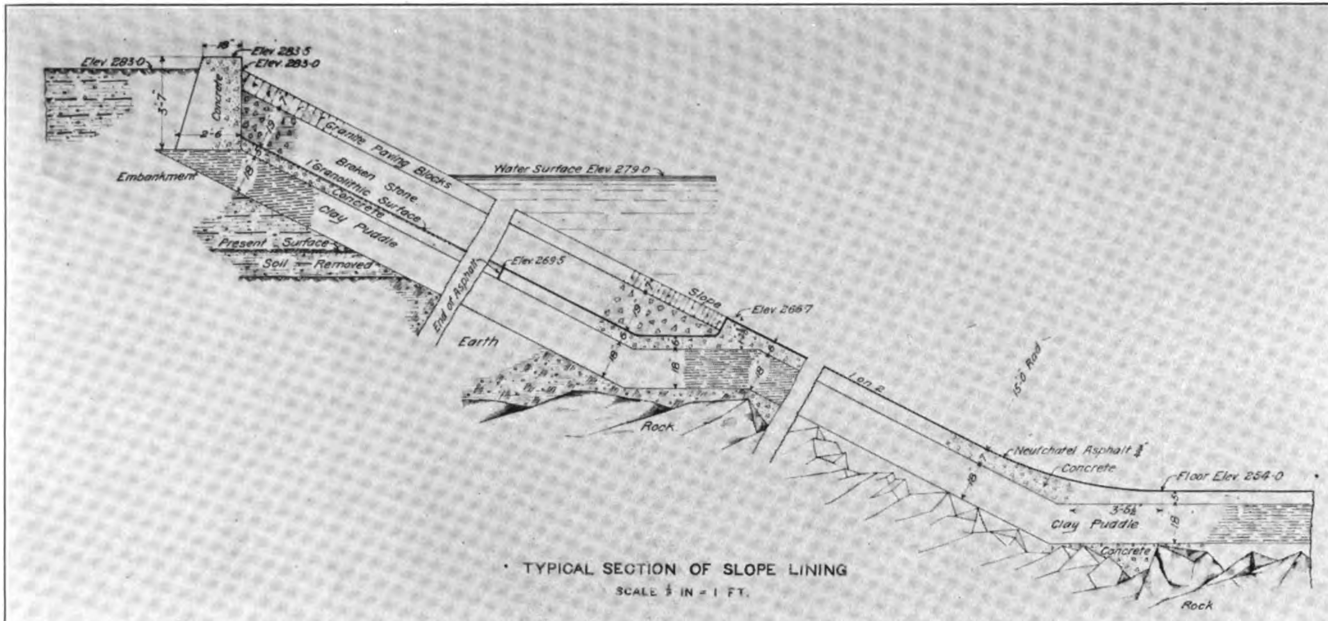

FIG. 5.—BELMONT RESERVOIR—SECTIONS OF EMBANKMENT AND LINING.

The proportions set out in the specifications are 70 parts by weight of rock asphalt, 10 parts of Bermudez asphalt, and 20 parts of sharp grit and sand. These proportions may be varied, if the city should deem it advisable, to secure a water-tight lining. The thickness of puddle is the same on the slope as on the floor, but the concrete paving varies from a thickness of 7 inches at the bottom of the slope to 6 inches at the berm, from which point to the top of the slope the thickness is continued as 6 inches. Above the berm is shown a dry paving of Belgian blocks, pavement size, backed with broken stone.

FIG. 6.—BELMONT RESERVOIR—INLET AND OUTLET GATE HOUSE.

In the original plans this was thought to be necessary as a protection from the frost to the puddle; but when the studies were being made for the paving of the slopes of the Oak Lane reservoir, it was not thought essential to repeat this construction, and it has been about decided to omit it in the Belmont basins as a superfluous detail.

The clay puddle used throughout the work, except at Lower Roxborough, consists of equal parts of a strong Delaware or New Jersey clay, Swedeland clay, and graded gravel or broken stone, mixed and wetted in a horizontal screw puddle pug mill, and rolled with horse and steam rollers on the floor, and with horse rollers on the slopes, in thin layers. The imperviousness of this puddle is such that when placed in a 12-inch layer under the concrete inverts (6 inches thick at the center) of the filters at Upper Roxborough and at Belmont, some of the filters showed no leakage after weeks of test, the level of the water being taken with a hook gauge and proper corrections being made for the weather conditions.

Figure 6 shows the gate house of the Belmont reservoirs, which contains, with the exception of one 48-inch gate in the division em-

FIG. 7.—BELMONT FILTERS—FILTER NO. 1.

bankment, all the gates to control the flow of water into either compartment of the reservoir, and draw the subsided water through either effluent pipe from the reservoir to the preliminary filters, or, if it should be so desired, draw it to the plain sand filters. Thirteen 48-inch stop-valves are located in the basement or pit of the gate house.

Figure 7 shows the concrete piers of one of the Belmont filters, which were made as separate monoliths in two sections and set on the pier seats with the aid of a derrick. All other piers at Belmont, Roxborough, and Torresdale were built, or are being built, in place.

From the subsiding basins the water will flow by gravity to the preliminary filters to be located in the angle between Belmont Avenue and Ford Road. The plans for these filters are now well advanced and the work will be put under contract early this season. These are being planned for an immediate capacity of 40,000,000 gallons per day, to be increased by additions of other filters to keep pace with the increasing consumption of water from this station. From the preliminary filters the water will flow by gravity to the plain sand filters, thence by gravity to the clear-water basin, from which, until the consumption has increased to more than 40,000,000 gallons per day, the filtered water will flow into the West Philadelphia distribution system through a 48-inch cast-iron main laid in Monument Avenue and Belmont Avenue to an intersection with the present rising mains from the Belmont pumping station at Belmont and Montgomery Avenues.

After the Belmont filters have been started, the old 30-inch and 36-inch rising mains will be closed at the points where they cross Belmont Avenue, in a manner to effectually prevent a transfer of unfiltered water to that portion of the pipes laid west of the intersection with the new 48-inch pipe in Belmont Avenue supplying filtered water to the system.

From the intersection of the 48-inch filtered water main with the old rising mains the distribution of filtered water will be effected through the present system of mains.

The service at Belmont will embrace but one lift of the water from the Schuylkill River at Belmont pumping station to the subsiding reservoirs.

The elevations of the Belmont works are as follows:

Flow line, subsiding reservoirs, ...	279.00	C. D
Flow line, preliminary filters, ...	267.00	"
Water-level, filters Nos. 1 and 2, ...	250.00	"
Water-level, filters Nos. 3 and 4, ...	252.00	"
Water-level, filters Nos. 5, 6, 7, and 8, ...	254.00	"
Water-level, filters Nos. 9, 10, 16, 17, and 18,......	251.00	"
Water-level, filters Nos. 11, 12, 13, 14, and 15,......	248.00	"
Flow line, clear-water basin,.....................	239.00	"

The elevation of the flow line of George's Hill reservoir is 212.00 C. D., or 27 feet below the flow line of the new Belmont clear-water basin.

The varying elevations of the filters is due to the topography of the land taken. The ideal arrangement, of course, is filters at uniform elevations, as at Upper Roxborough and Torresdale; but a balancing of the fixed charges on the extra cost of constructing the Belmont filters at uniform elevation against the money value of the extra head pumped against, represented by the difference between the highest and lowest filters in the series,—viz., 6 feet,—indicated the least cost in adapting, with some limitations, the filters to the natural topography of the site.

Filters Nos. 11, 12, 13, 14, and 15 are partly or wholly built on filled ground, rolled in thin layers with a steam roller weighing 3333 pounds per foot width of roller, while all other filters are built entirely in excavation. A careful balancing of cut and fill admitted of a reduction of the pumping head actually lost by the terracing of the filters to 6 feet.

The clear-water basin at Belmont has a capacity of 16,500,000 gallons with a depth of 15 feet. The subsiding reservoirs have a capacity of 72,000,000 gallons with a depth of 25 feet. All filters at Belmont, and all other stations, have a depth of 9 feet 9 inches from the center of the invert in the floor to the spring line of the arched vaulting, with a rise of 3 feet to the arch.

Upper Roxborough Filters.

Figure 8 shows in plan the Upper Roxborough filters. These works comprise eight ¾-acre filters, measured at the sand line, and a clear-water basin of 8,000,000 gallons capacity. The filters are all at uniform elevation—viz., 419.00 C. D. at the high-water line. The general plans contemplate an addition of four filters to the rear or north of filters Nos. 1, 2, 3, and 4, and, should it be demanded in the future, five or six more filters can be located north of filters Nos. 7 to 12, on the property acquired by the city. It is not thought that the consumption of water from this station will require an addition to the filters for the next ten or fifteen years, but the size and arrangement of raw-water supply-pipes, and filtered effluents, have been based on the maximum work of the station.

It has been stated that the Upper Roxborough filters are expected to work entirely with subsided water, which, with the early capacity of the works, will represent from seven to ten days' subsidence in the Upper Roxborough reservoirs, and which it is thought will admit of working these filters at a 4,500,000-gallon rate per acre without preliminary filtration. In due time, as the consumption of filtered

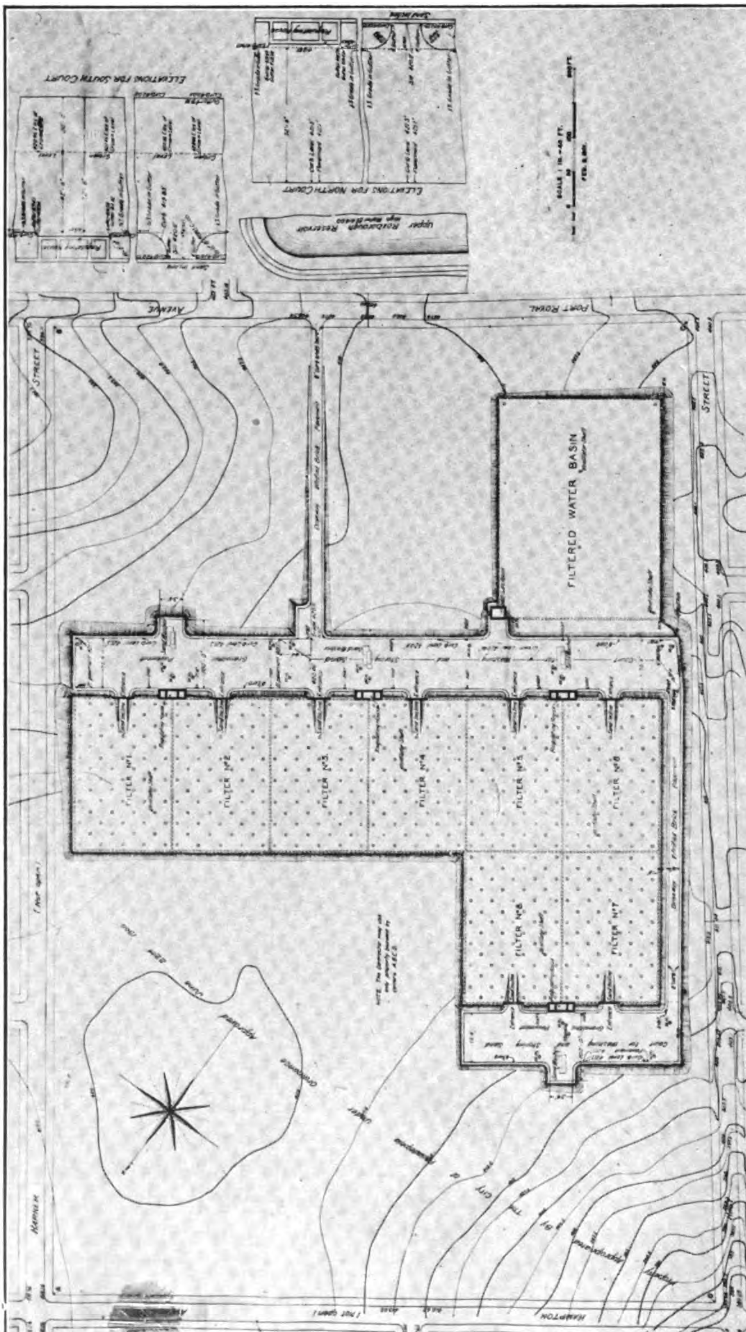

Fig. 8.—Upper Roxborough Filters.

water increases, it will doubtless be found advisable and more economical to construct preliminary filters as an auxiliary to the Upper Roxborough station, and raise the rate of filtration to 6,000,000 gallons per acre per day rather than add to the number of plain sand filters.

Figure 9 shows the regulator house for two of the Upper Roxborough filters, which is typical of the regulator houses of all the filters, except that each filter at Lower Roxborough, as well as filters Nos. 13 and 18 at Belmont, has a separate house.

In the double house shown in plan by figure 10, there is a central dry chamber in which are placed the pipes and valves which control

FIG. 9.—UPPER ROXBOROUGH FILTERS—FILTER ENTRANCE AND REGULATOR HOUSE.

the flow of water into the filter, and for the drainage of water from above the sand-level, when the filter is taken out of service for scraping, and two wet chambers, one for each filter of the pair, which contains the effluent regulating and measuring weir, the pipes and valves to disconnect the filter from the main effluent pipe and to refill the filter after sand scraping, from below. The wet chambers also contain pipes and valves for the complete drainage of the filter. The floating weir used in the filters is modeled after that used by Mr. Lindley

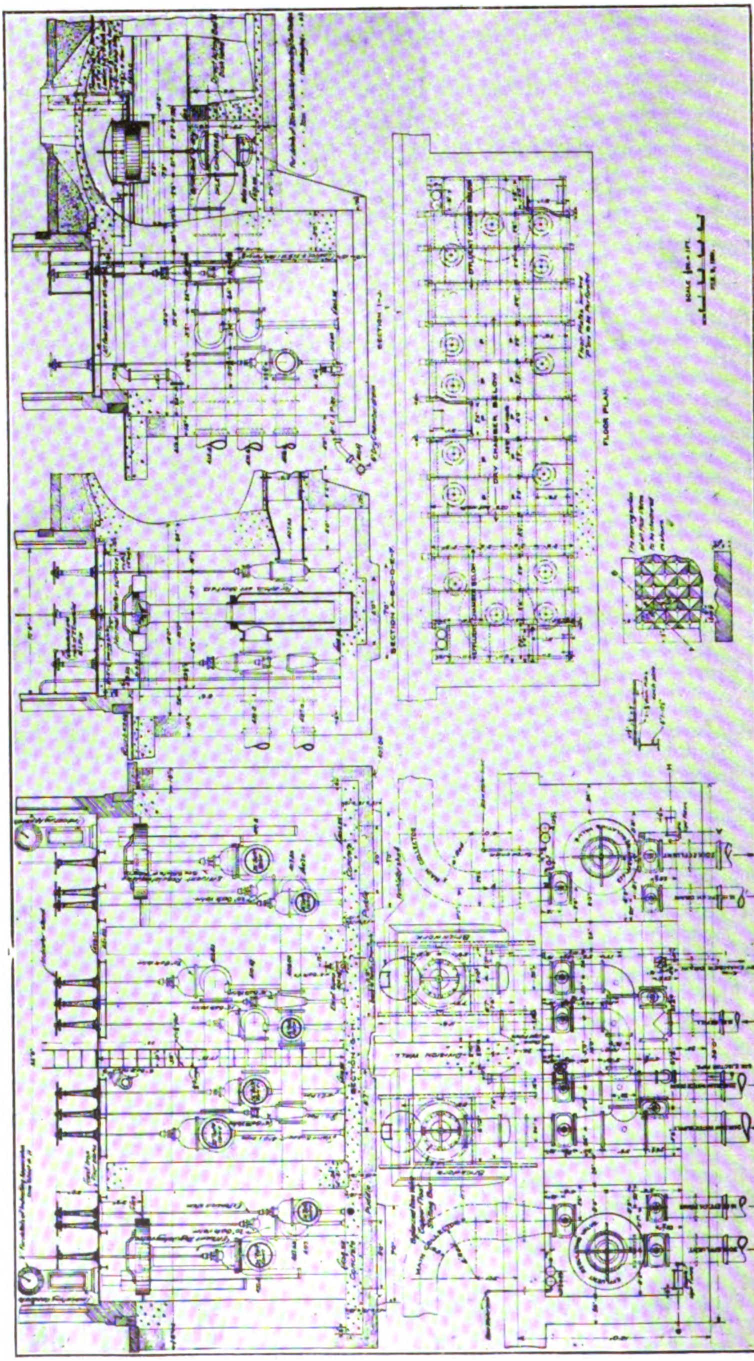

FIG. 10.—UPPER ROXBOROUGH FILTERS—REGULATOR AND INLET CHAMBERS.

in the filters of Warsaw, but is made adjustable to regulate the flow from the filter without changing the position of the copper float.

The filter entrance shown in figure 10 is typical of all the filters. Each entrance is provided with two inclined sand runs for wheeling the washed sand from the courts back into the filters. The entrance is closed with double doors, which in summer-time are usually left open to aid in the ventilation of the filters. In winter, when the temperature of the air is 32° F. or less, the doors are always closed when the sand beds are laid dry, to prevent freezing at the surface of the sand.

LOWER ROXBOROUGH FILTERS.

Figure 11 shows in plan the filters at Lower Roxborough which have been in service since last August. This station contains five ½-acre filters, measured at the sand line, and a clear-water basin of 3,000,000 gallons capacity. The present filtering capacity is from 6,000,000 to 7,000,000 gallons per day, which will be raised to 12,000,000 gallons per day when the preliminary filters now under construction have been completed and started in service.

Figure 12 shows the puddle lining under the concrete floor and back of the side and end walls. The inverts constituting the floor sections are 6 inches thick at the center and 14 inches thick at the pier seats. The concrete was made and placed without any special precautions to insure water-tightness, reliance being had entirely on the puddle. Considering that these tanks will be filled only with filtered water after the sand and underdrains have been placed, the structure must be made water-tight when built, or perhaps it will never by use become tight. Certain of the filters show no leakage, and the maximum allowable leakage on a ¾-acre filter is 1000 gallons in twenty-four hours, which represents from 0.022 to 0.030 per cent. of the daily capacity of the filter. Data on the water-tightness of structures of this character are not forthcoming, but it was thought in this instance that a leakage of a concrete tank 200 feet long, 150 feet wide, and 9 feet deep, surrounded by a lining of puddle from 12 to 18 inches thick, not in excess of 0.04 per cent. of the volume of water daily passing through, was allowable. Absolute water-tightness can be had with a glass bottle or a pressed-tin cup, but it is very difficult to insure in large masonry tanks. The puddle was placed over the entire floor of all filters, regulator houses, and water basins, and carried up outside the side and end walls for a height 1 foot above the water line.

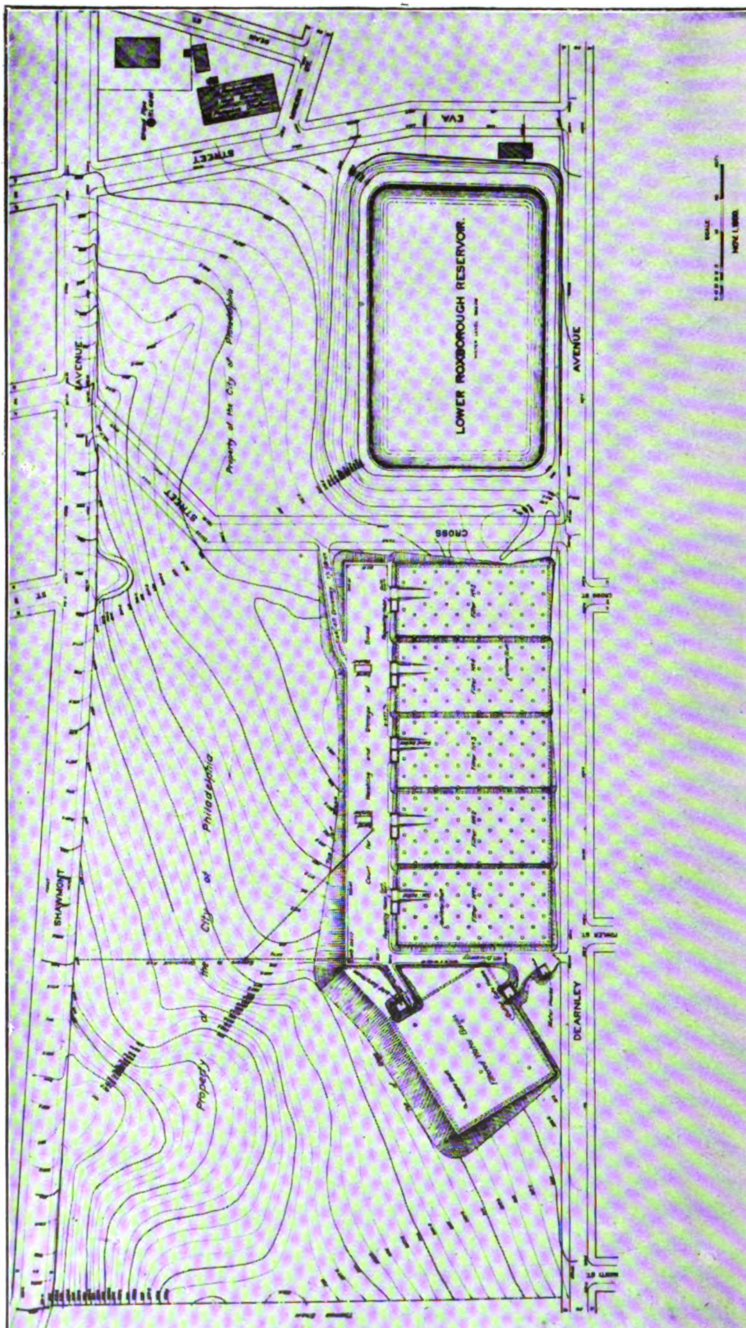

FIG. 11.—LOWER ROXBOROUGH FILTERS.

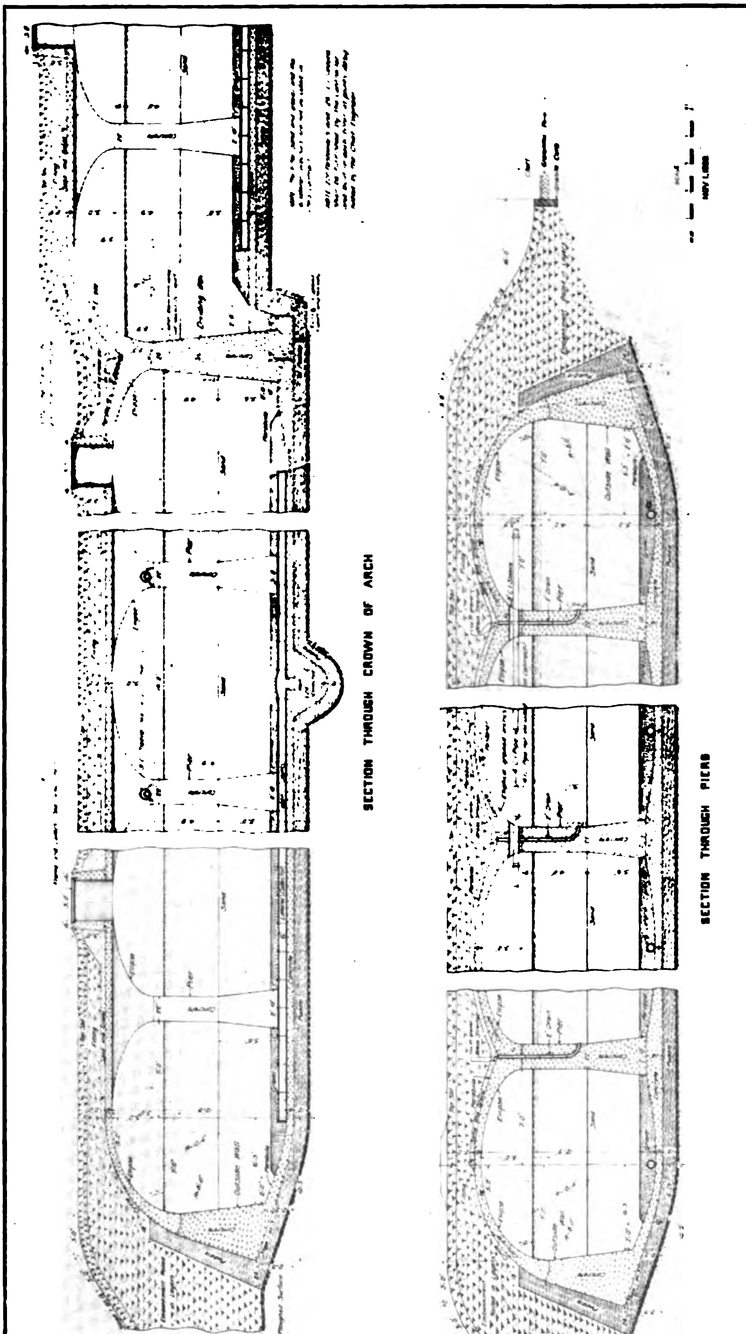

FIG. 12.—LOWER ROXBOROUGH FILTERS—SECTIONS OF FILTERS.

Over the arches of the filters is placed a filling 3 feet deep, partly of gravel or broken stone and partly of earth, covered with a layer of top soil, grass seeded to form a turf. Water collected on the earth covering of a filter percolates through the material and finally passes down the side of the concrete pier through a small opening left in the roof. Over the clear-water basins the depressions between the arches are filled and rolled level with the top of the arches, with clay puddle, above which is placed a covering of earth rolled in place, top-soiled and seeded. Water absorbed by the filling is carried off by a system of subsoil drains.

The two bottles on the President's desk show the character of water flowing to-day in the Schuylkill River at the pumping station and the kind of water now coming from the Lower Roxborough filters. The raw water contains a turbidity of 140 parts per million by the silica standard and a bacterial content of 25,000 per cubic centimeter, while the filtered water contains 2 parts turbidity by the silica standard and 45 bacteria per cubic centimeter.

Preliminary Filters—Lower Roxborough.

Two and one-half years' experience at the Spring Garden and Harrison Mansion testing stations, on the Schuylkill and Delaware River waters, demonstrated the advantage—in fact, the necessity—of preliminary treatment of the raw river or subsided water by rough filtration, through beds of coarse material, gravel or sand, at rates varying from 40,000,000 to 120,000,000 gallons per day per acre of filtering area, before the water is applied to the plain sand filters. The advantages of preliminary filtration are threefold:

1. It prolongs the life of the filter and increases the yield between scrapings from 50 to 200 per cent. over the plain sand filter working only with subsided water.

2. It makes it possible to operate the plain sand filter at rates twice that accepted abroad as the proper rate; viz., to raise the rate from 3,000,000 gallons per acre to 6,000,000 gallons per acre per day.

3. It insures a uniformly better quality of effluent from the filters. The operation of plain sand filters with a preliminary roughing filter is not a new thought. Such filters working on the water from the River Maas have been used at Schiedam, Holland, for more than seventeen years; but the system used there is not quite like that which we have been working with here on the Schuylkill and Delaware

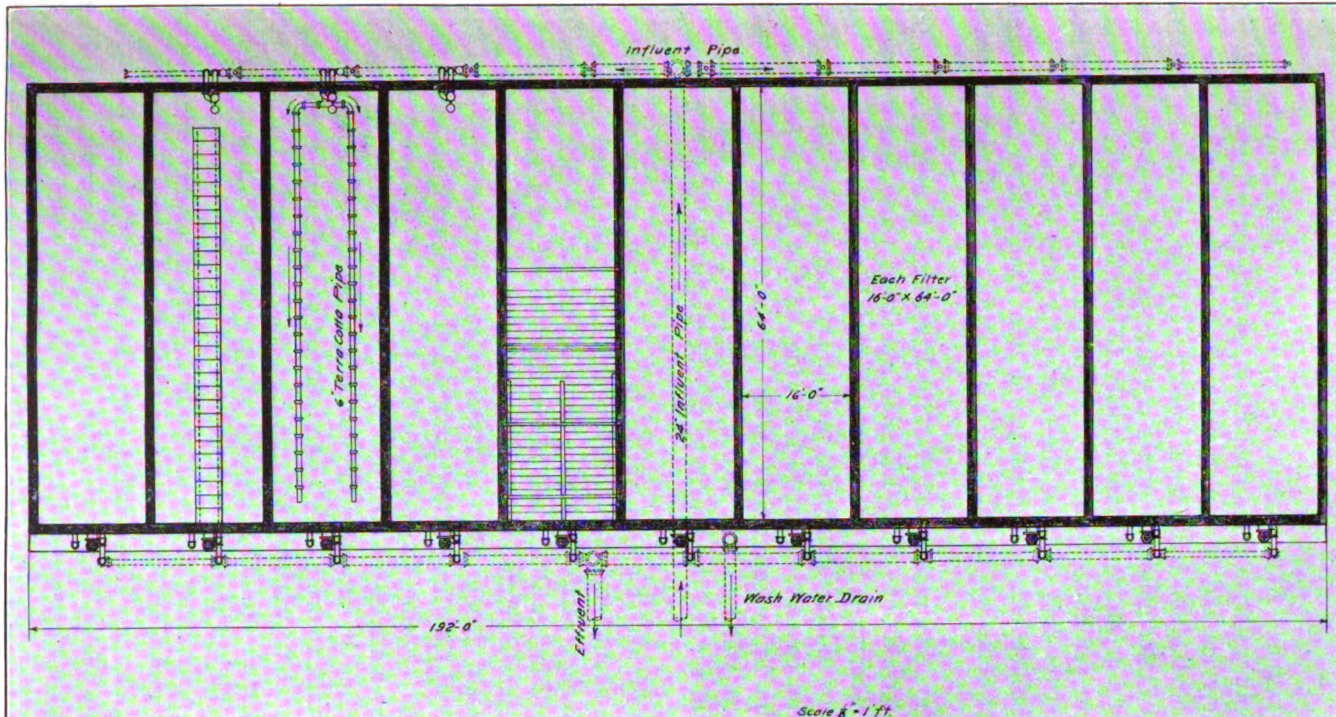

Fig. 13.—Plan of Preliminary Filters, Lower Roxborough.

River waters. At Schiedam one preliminary filter may be required to supply water to three final filters, or two preliminary filters may be in service and supplying water to three final filters. The final plain sand filters have been worked at rates as high as 5,000,000 United States gallons of water per acre per day, and the maximum yield of a preliminary filter has been 15,000,000 United States gallons per acre per day. Ordinarily the preliminary filters work at from one and one-half to twice the rate of the final filters.

In proportions and construction the "vor" filter and "sand" filter at Schiedam are alike, except the former is filled with coarser sand.

It should be understood that the River Maas is tidal at Schiedam, and the conditions there resemble somewhat those that will prevail at the Torresdale filters on the Delaware River.

At Lower Roxborough the preliminary filters (Fig. 13) will consist of eleven concrete tanks 16 feet wide, 64 feet long, 5 feet 6 inches deep, inside measurements. When all the filters are in service, the acre rate will be about 40,000,000 gallons per day, and with eight filters in service the acre rate will be about 60,000,000 gallons per day.

These tanks (Fig. 14) will contain a layer of coarse gravel at the bottom about 5 inches thick; above this a layer of crushed and screened furnace slag, particles ranging from 1½ inches to ¾ inch in diameter, about 10 inches thick, and above this a layer of slag particles ¾ to ¼ inch diameter, 24 inches thick, and above this a layer of 9 inches compressed sponge as a mattress pressed down on the slag. The water will pass from below upward and is drawn from the tanks at the top. During the more turbid periods of the river water the granular material and the mattress are partially freed from the collected mud by stopping the flow and allowing the water contained in the tank to drain off. From four to five times a year the mattress is taken out, washed in a machine, and replaced. Once or twice each year the granular material requires flushing with a strong hose-stream played through a nozzle.

The preliminary filters will do in a short time what would require a very great, and in most cases inadmissible, length of time with settling basins. Thus, within a very few hours there can be removed from the Schuylkill and Delaware River waters by preliminary filters an amount of suspended matter which would require from three to four weeks to remove by storage of the water in sedimentation basins,

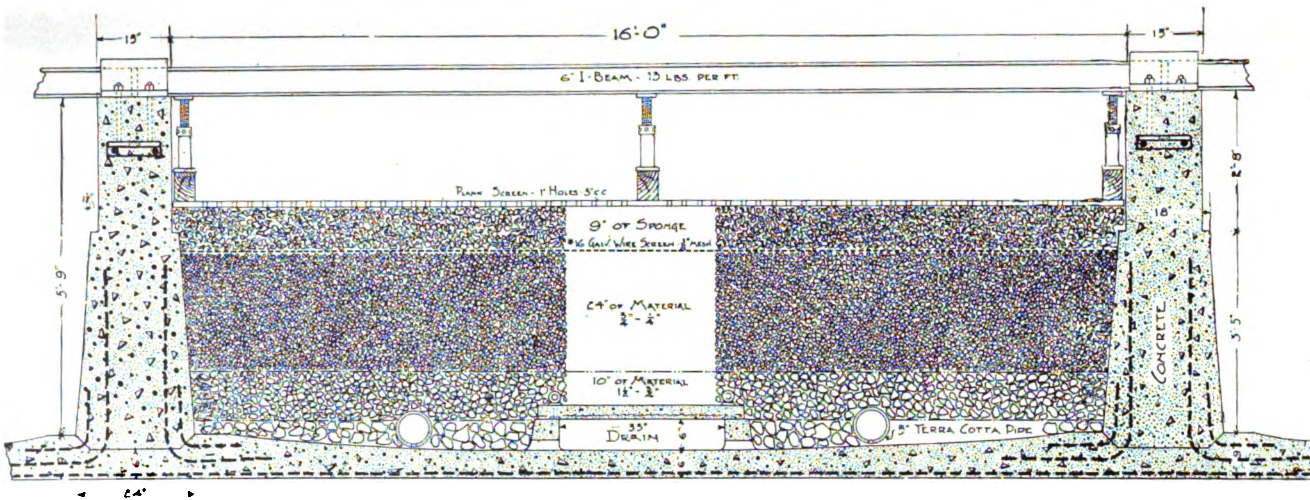

Fig. 14.—Cross-section through Preliminary Filter, Lower Roxborough.

and a comparison of the cost of the two methods of preparing water for plain sand filters indicates that $1,000,000 in preliminary filters will accomplish as much as $20,000,000 in settling basins, without considering the larger cost within the city limits of land for the latter structures.

Upon the completion of the preliminary filters at Lower Roxborough about 4,000,000 gallons per day will go to Manayunk and 8,000,000 gallons to Germantown.

Referring to the clear-water basin at Lower Roxborough and the other stations, these are not intended for storage, but to compensate for the varying rates of hourly consumption during the day. The filters will be operated at nearly uniform rate, but the consumption of water, of course, will vary from hour to hour throughout the day.

Torresdale Filters.

Figure 15 shows in plan the first installation of fifty-five filters at the Torresdale station. As will be noticed, these works consist of five banks of eleven filters each, with a wide court between for the sand washers and temporary storage of washed sand. North of the upper bank of filters ten other filters are planned which will provide for a part of the present Queen Lane consumption and increase the present capacity of these works to 248,000,000 gallons per day.

The present contract, known as contract No. 25, embraces the first fifty-five filters, the clear-water basin, all sewers, main conduits, and supply pipes proportioned for the future extensions of this station.

The additional items required to complete the Torresdale filters are principally the low-service pumping station and machinery, preliminary filters, sand washers and pumps, electric lighting system, coal-handling machinery and pockets, and a spur track from the New York division of the Pennsylvania Railroad.

The sewerage system for this station is planned to care for the drainage from a considerable area of tributary property in addition to the overflow and waste from the filters and sand washers and the sewage collected at the station. The outfall is in Pennypack Creek, which empties into the Delaware River, at the south line of the property taken for construction of the filters and their auxiliary works.

In the early discussion of the filters at Torresdale a sewage disposal works, capable of dealing with the sewage of a semi-urban population of 45,000, was considered as an essential, when the territory draining into the Pennypack Creek begins to grow in population, to

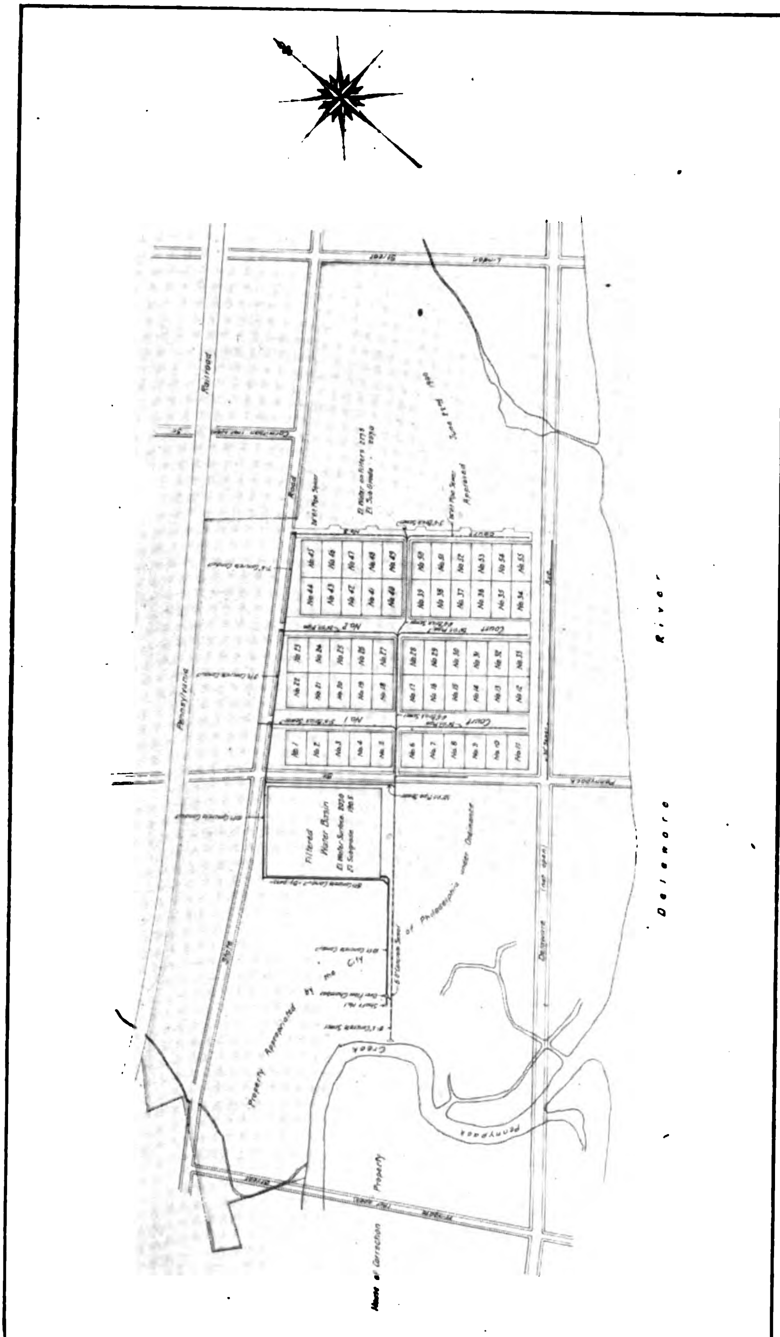

FIG. 15.—TORRESDALE FILTERS.

guard against the delivery of fresh sewage too near the intake for the filters. No steps have been taken to reduce the sewage disposal works to a definite plan, and doubtless the time is far distant when these will be needed.

Figure 16 shows a section of the main conduit placed at the west

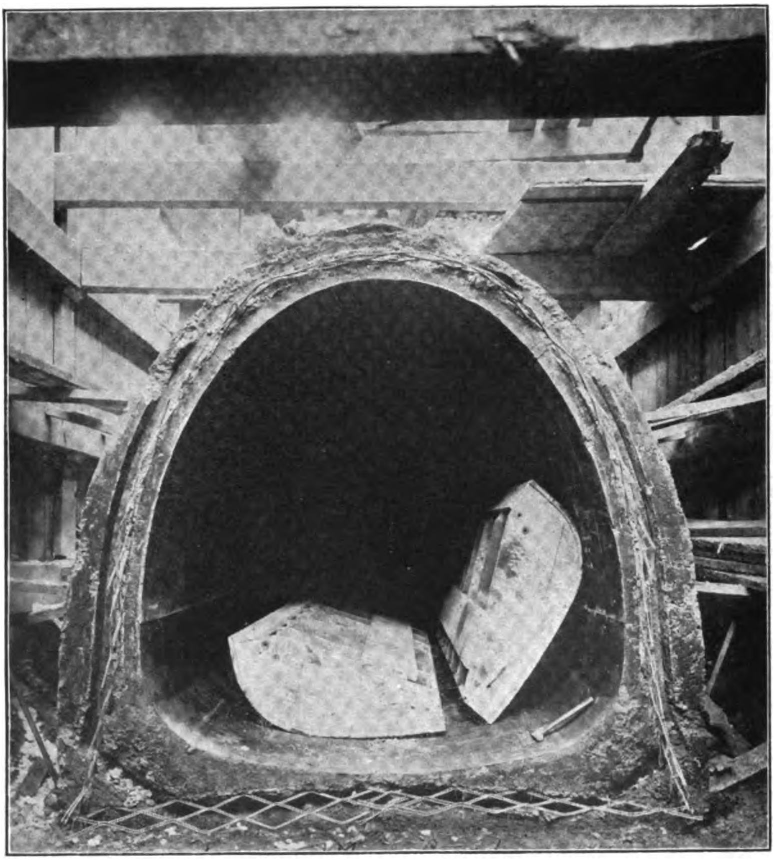

Fig. 16.—Torresdale Filters—Section of Main Conduit.

end of the filters to conduct the water from the filters to the clear-water basin. This conduit, varying from 9 feet diameter at the clear-water basin to 7 feet 6 inches diameter at court No. 3, is constructed of concrete, reinforced with expanded metal, and is supplied with water from the several groups of filters through a cast-iron main varying from 60 inches diameter at the conduit to 24 inches diameter at the most remote filter of each group. One of these cast-iron compound mains lies on each side of each court and serves one group of eleven filters. This conduit is typical in form and materials of construction of all the large conduits at this station.

The general elevations of the Torresdale filters and the Torresdale

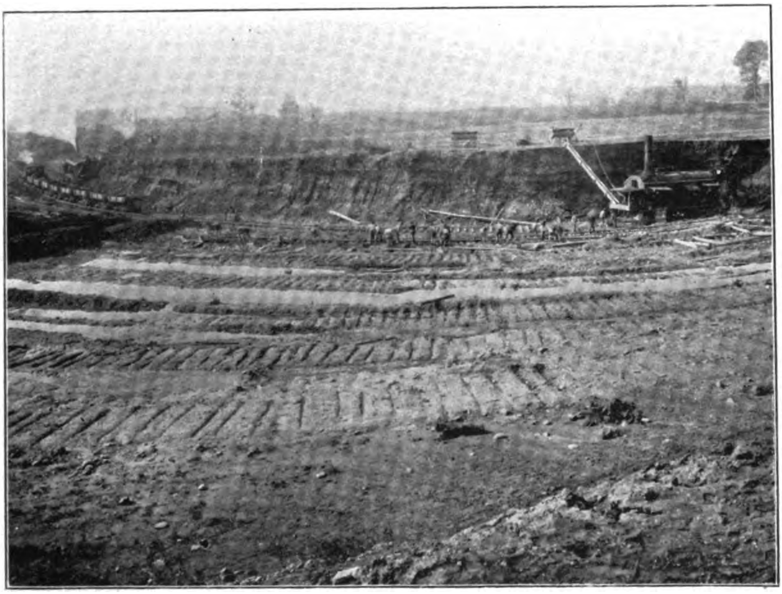

FIG. 17.—TORRESDALE FILTERS—EXCAVATION FOR CLEAR-WATER BASIN.

conduit, referred to Torresdale datum, which is 200 feet below city datum, are here given:

Flow line of all filters,	215.00 T. D.
Flow line of clear-water basin,	207.00 "
Head of shaft No. 1,	216.46 "
Center of conduit, shaft No. 1,	104.32 "
Center of conduit, shaft No. 11,	114.66 "
Head of shaft No. 11,	216.46 "
Center of conduit from clear-water basin to shaft No. 1, where it connects with the shaft,	186.50 "

The clear-water basin is wholly in excavation, and figure 17 shows the steam shovel at work excavating materials at about sub-grade. The material is chiefly river deposit of mixed gravel and sand. At some spots the material, when excavated to sub-grade, has been found very unstable and not adapted to receive the floor loads of the basin when completed, which, under the piers, will reach about four tons per square foot. To remedy this condition the soft material has been excavated for depths ranging from a few inches to 3 feet or more, and replaced with layers of sand and gravel, and boulders rolled in place, to create a hard, unyielding floor upon which the inverts of the floor will be laid. The least elevation of the base of these excavated portions below sub-grade is about 187.50, or more than 5 feet below mean low water in the Delaware River and 3 feet below extreme low water. The artificial foundation thus made is as solid after rolling as the natural materials.

At Belmont, where soft spots were found in the materials of the clear-water basin at sub-grade for the floor, layers of stone spawls were brought on and rolled in place, and to avoid possible injurious settlement under the piers which carry the concrete roof arches and load of earth filling, excavations were made to depths of 5 and 6 feet below sub-grade, a timber grillage placed, and concrete sub-piers carried up to sub-grade; over the piers, as well as elsewhere throughout the floor, a 12-inch layer of clay puddle was rolled in 6-inch (finished) layers, in order that the compression of the puddle by the floor, roof, and water loads should be as nearly as possible uniform over the whole area.

TORRESDALE CONDUIT.

The water from the clear-water basin of the Torresdale filters flows through a concrete conduit of horseshoe section, equal in area to a circle 10 feet diameter, to shaft No. 1 of the Torresdale conduit, and down shaft No. 1, through the tunnel, and up shaft No. 11 at the Lardner's Point pumping station, to the pump wells in the engine-houses. The two end shafts and the tunnel constitute a large inverted siphon blasted through the gneiss rock and lined with stretcher brick (Fig. 18). The general depth of the tunnel part of the siphon is about 100 feet below mean ground-level. Shaft No. 1, shown on figures 15 and 19, is uniformly 10 feet 6 inches diameter from top to bottom (Fig. 19). While shaft No. 11 (Fig. 20) has the same diameter as No. 1 from the tunnel to a point about 50 feet below ground-level, and from this elevation to the head of the shaft, 10 feet above ground-level, the diameter is enlarged to 21 feet to reduce the velocity of the water before its flow is changed at right angles, to enter the conduit which connects the effluent shaft with the pump wells at Lardner's

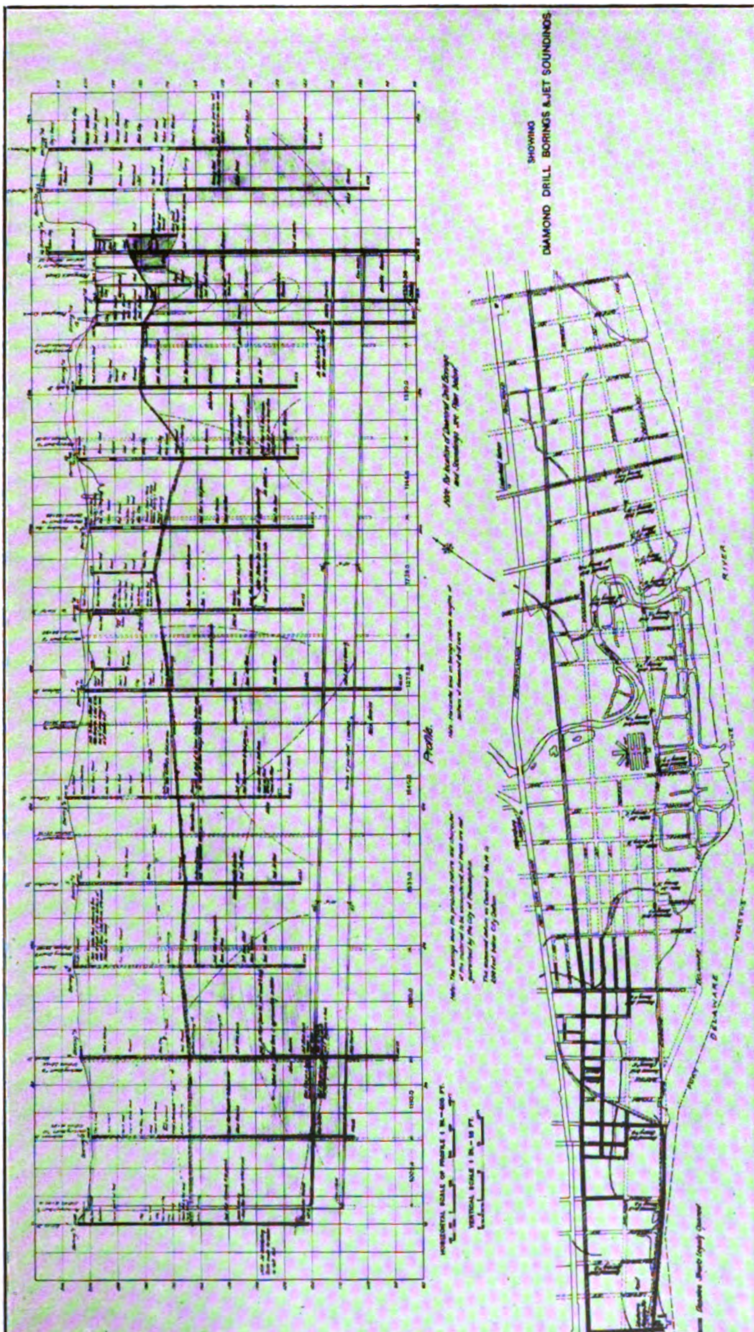

FIG. 18.—TORRESDALE CONDUIT—PLAN AND PROFILE.

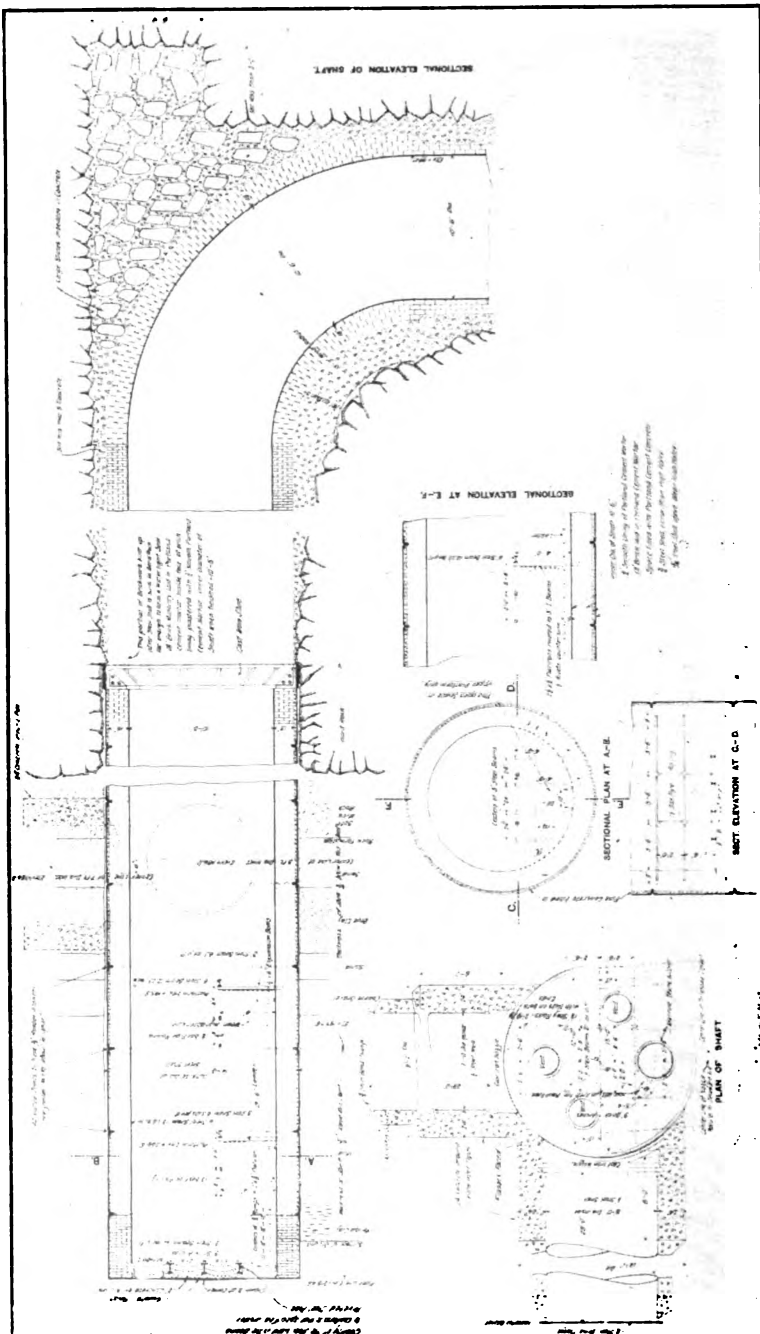

Fig. 19.—Torrendale Conduit—Shaft No. 1.

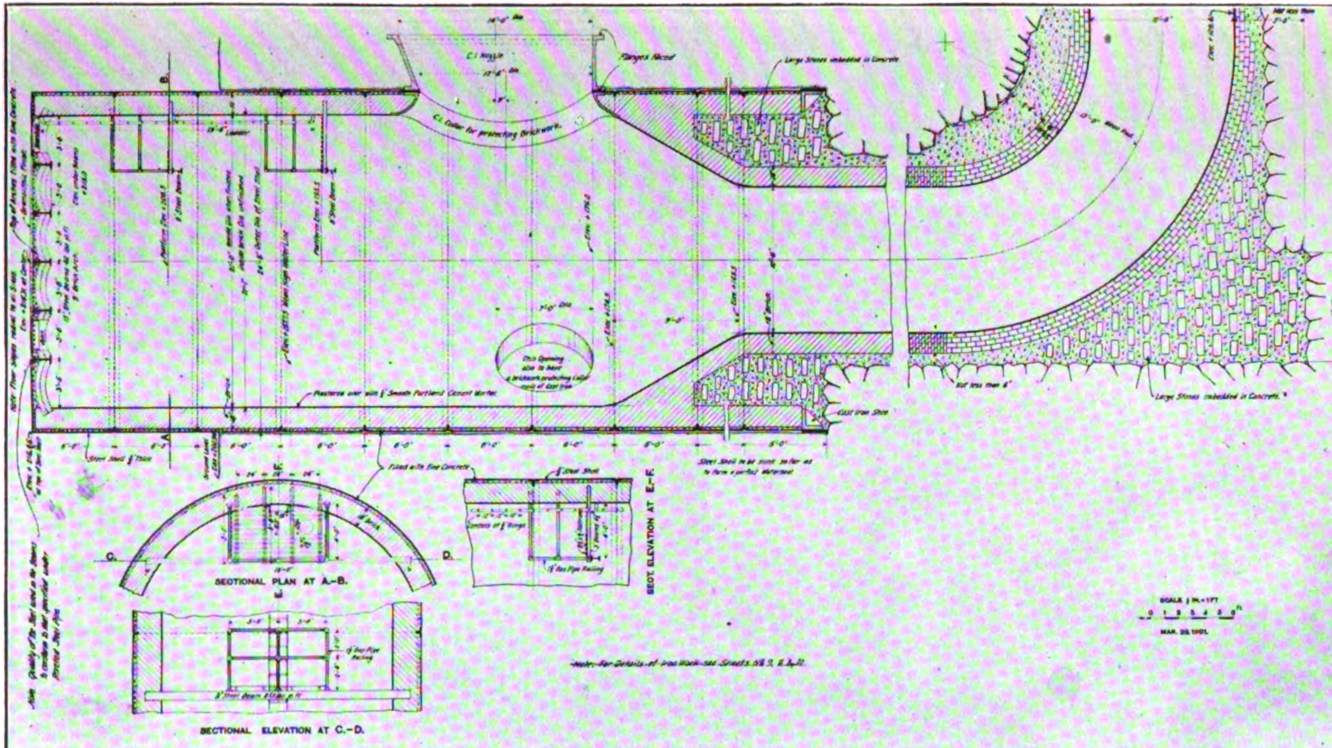

FIG. 20.—TORRESDALE CONDUIT—SHAFT NO. 11.

Point. The conduit is uniformly 10 feet 6 inches diameter from shaft No. 1 to shaft No. 11. The total length of conduit, including end shafts to elevation 215.46 T. D., is 14,035 linear feet.

Each shaft is joined to the tunnel by a concrete 90-degree bend, of the same internal diameter as the shaft—viz., 10 feet 6 inches. The bends are turned on a radius, center line of 15 feet 9 inches. The inner surfaces have a granolithic finish 1 inch thick.

The only deep rock operations from which information could be derived upon the probable character of the materials to be encountered in driving the headings for the northerly end of the Torresdale conduit are found near the House of Correction and north of Pennypack Creek. Here the rock excavated in the deep quarry is very hard, with few seams or fissures flowing water, and the typical sections showing excavation for the conduit were partially based on this information.

Experience has shown that the character of the rock in this quarry is not maintained for the whole length of the conduit, and that a great change in the hardness and stability of the material takes place in going from the north to the south end of the work. The treacherous material, however, is not continuous, but occurs in reaches of the work, sometimes being abreast of and sometimes crossing the line of the tunnel.

The diamond drill borings which preceded the preparation of the detail plan indicated the varying nature of the work, but the rapidity with which some of the material would deteriorate upon contact with the air in the tunnel was not fully suspected.

The conduit is constructed with nine working and two permanent (end) shafts. All shafts are opened to full depth and lined to the solid rock, and over 12,500 linear feet of heading has been driven. The working as well as the permanent shafts are constructed with steel shells sunk into hard rock and sealed, the interior being lined with an 18-inch ring of hard-burned stretcher brick laid in cement mortar. The sinking and lining of the steel shells for the end shafts was much more carefully executed than it was for the working shafts, because the latter in due time will be closed with brick arches sprung from abutments cut in the rock at the sides of the shaft above the arch of the conduit, above which will be constructed in each shaft one or two relieving arches to take a part of the weight of the backfill of shaft off the arch of the conduit. From the arch of the conduit to ground-level the working shafts will be solidly backfilled when the conduit has been completed.

Figure 21 shows tunnel excavation in solid rock, where the material was sound and required no timbering. About 86 per cent. of the entire excavation is in material which requires no support; but in the north end of the conduit, while the rock is very satisfactory for tunnel work, the flow of water into the workings has been a source of annoyance. The reach of the conduit between shafts Nos. 4 and 7 presents excellent material for shaft and tunnel excavation, and the flow of water has not imposed any serious hardships on the contractors.

Figure 22 shows some of the work in treacherous ground, in the

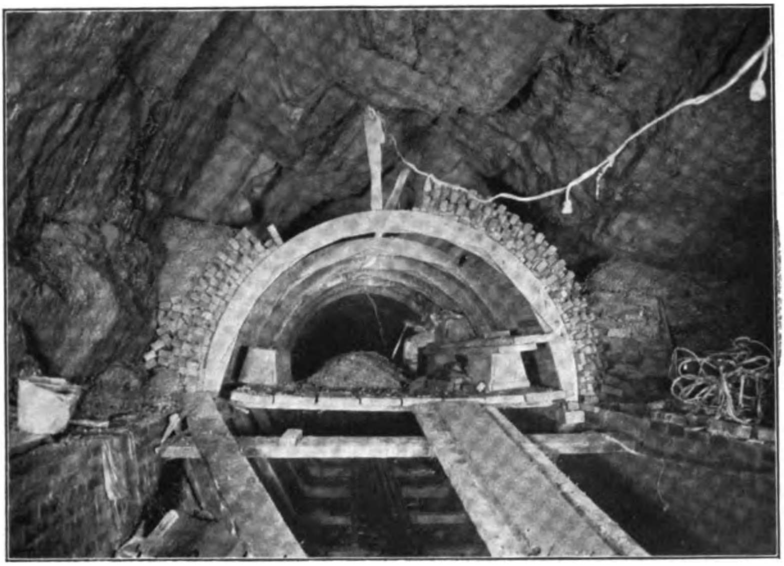

Fig. 21.—Torresdale Conduit—South Heading, Shaft No. 10.

north heading of shaft No. 8, and indicates the character of the falls following the blasts. The inscribed lines show the outer surface of the brick invert and arch of standard sections, but in all localities where the material over the arch is liable to move after the timber supports have been drawn, the thickness of the arch is being increased by one or two rings of brickwork.

For several hundred feet in the north heading of shaft No. 9, opposite the Disston Saw Works, the collar beams and posts supporting the roof abut against each other to prevent dangerous falls and possible injury to valuable surface structures.

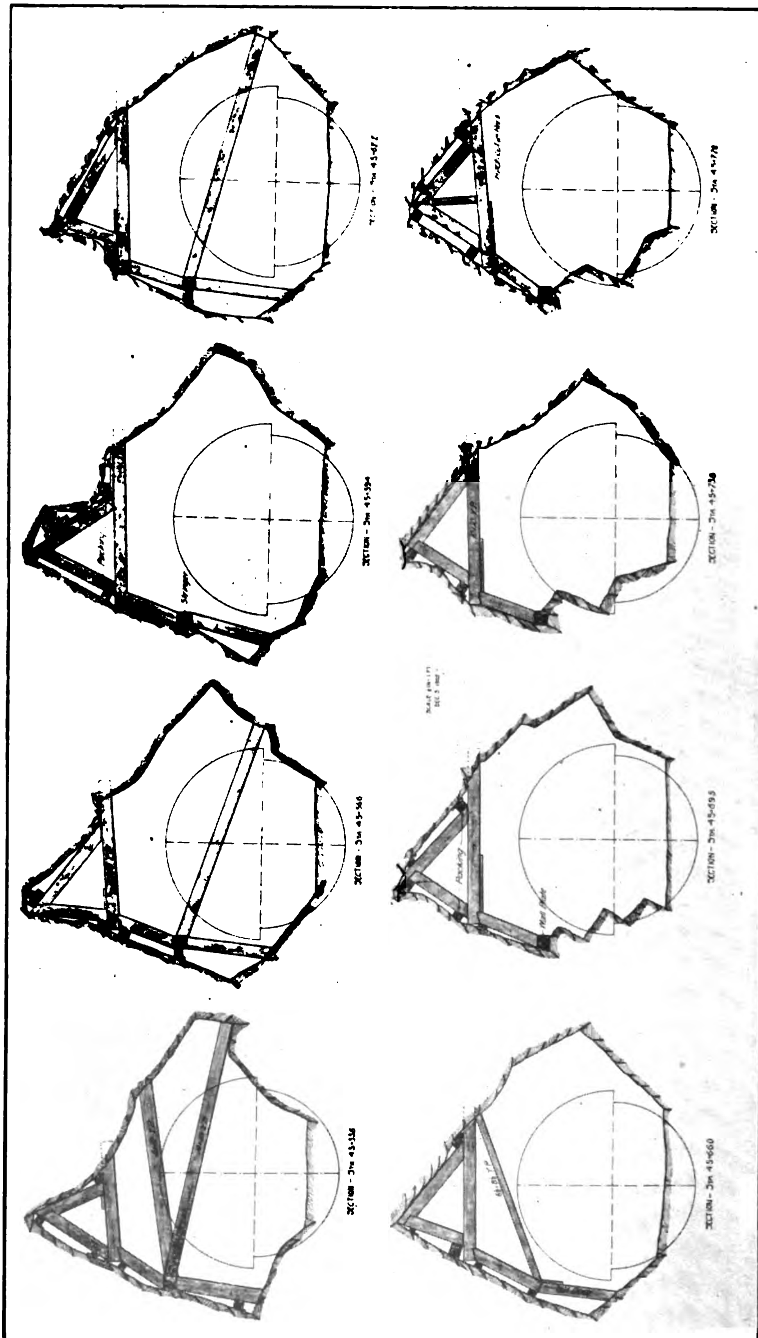

FIG. 22.—TORRESDALE CONDUIT—TIMBER SETS, NORTH HEADING, SHAFT NO. 8.

The conduit is graded upward at the rate of 9 inches per 1000 feet from the influent shaft No. 1 to the effluent shaft No. 11, to prevent the tunnel becoming air-bound (Fig. 18). Air which may be carried down shaft No. 1 will either be carried into the tunnel or rise through the water in the shaft. Such air as may be carried into the tunnel will flow with the water and be vented at shaft No. 11, the upward inclination of the tunnel from the influent to the effluent shaft preventing the accumulation of air, which might be a cause of interference with the operation of a horizontal tunnel. Should there ever be any indications of air sticking, as it were, in the conduit, it is believed that it can readily be removed by increasing the speed of the pumping machinery at Lardner's Point, lowering the level of water temporarily in the pump wells, and creating an increased velocity of flow through the conduit. The conditions under which the water is conducted to the influent shaft, and the upward gradient of the tunnel from the influent to the effluent shafts, are thought to be effectual safeguards against the introduction of any considerable quantity of air into the conduit, or of any impairment of its capacity by an accumulation of air at any point along the roof.

The capacity of the conduit was originally calculated as 300,000,000 gallons per day, with a loss of head 8.6 feet between the level of water in shaft No. 1 at Torresdale and shaft No. 11 at Lardner's Point, but of course the carrying capacity will largely depend upon the accuracy with which the lining is constructed and the evenness and smoothness of the plaster finish on the interior face of the brickwork. Late investigations of the hydraulic conditions of the conduit suggest a capacity of 320,000,000 gallons per day with such lining as the plans require, and with exceptionally excellent work on the part of the bricklayers, engineers, and inspectors, the capacity may reach 340,000,000 gallons per day, with the loss of head mentioned above.

The pump wells and pumping engines will admit of lowering the level at Lardner's Point considerably more than 8.6 feet, and it is not doubted that in this way the conduit can be made to carry 350,000,000 gallons daily from the Torresdale filters to the Lardner's Point pumping station. Such capacity will not be required for many years,—certainly fifty years or more,—and it can be safely assumed that this single conduit will not be overtaxed during that length of time.

Lardner's Point Pumping Station.

The Lardner's Point pumping station will consist of engine- and boiler-house No. 2 (now under construction as contract No. 29), engine- and boiler-house No. 3, of same dimensions, to be constructed immediately north of engine-house No. 2, and the present Frankford pumping station, known as engine- and boiler-house No. 1.

Each of the new engine-houses, of which the plan of engine- and boiler-house No. 2 is shown on figure 23, will contain six 20,000,000-gallon (daily) pumping engines, and each of the new boiler-houses will contain six batteries of internally fired marine boilers of 800 horse-power each. The first set of three 20,000,000-gallon (daily) pumping engines, for engine-house No. 2, are now being built by the Holly Manufacturing Company, of Lockport, N. Y., and will be completed, so far as the work in the shops can be done, before the engine-house will be ready to receive them.

The engines are of vertical crank and fly-wheel triple expansion type, with a single-acting water plunger and duplex suction and discharge water chambers. Each water chamber is provided with independent removable cast-steel valve-decks. The capacity is based on twenty revolutions per minute, and the contract duty based on the coal actually burned in the boilers is 130,000,000 foot-pounds per 100 pounds of coal. The combined rating of the engines in the two new houses and in the present Frankford station is over 13,000 horse-power.

The system of conduits or aqueducts for the distribution of the filtered water to the pumping station (Fig. 24) embraces two main conduits leading from shaft No. 11, with inverts placed at elevation 176.00 C. D., the larger of which consists partly of a circular riveted steel pipe 14 feet diameter, 28 feet long, joined to the flange of a cast-iron nozzle attached to the steel shell of the shaft, and to a horseshoe section concrete and steel conduit equal in area of waterway to a 14-feet diameter circle. The cast-iron nozzle which connects this conduit to the shell of the shaft is a flange offset reducer 12 feet 6 inches diameter at the shaft, and 14 feet diameter at the joint with the steel pipe. This connection is intended for a daily discharge of 300,000,000 gallons when required in the future.

The smaller conduit, 7 feet diameter, consists of a riveted steel pipe 28 feet long, which, at one end, is connected with the shell of the shaft through a cast-iron nozzle of same diameter, and at the other end to a horseshoe-shape concrete and steel conduit equal in

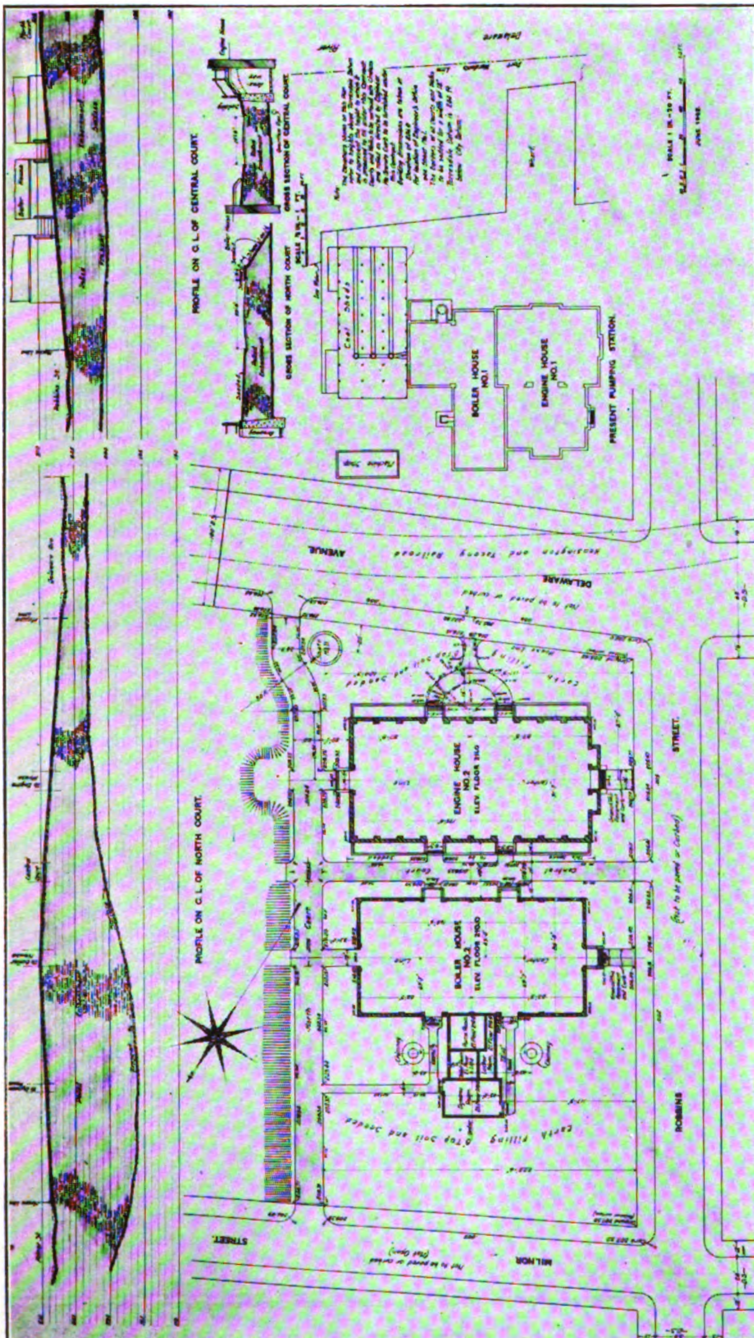

FIG. 23.—LARDNER'S POINT PUMPING STATION—PLAN OF BUILDINGS AND COURTS.

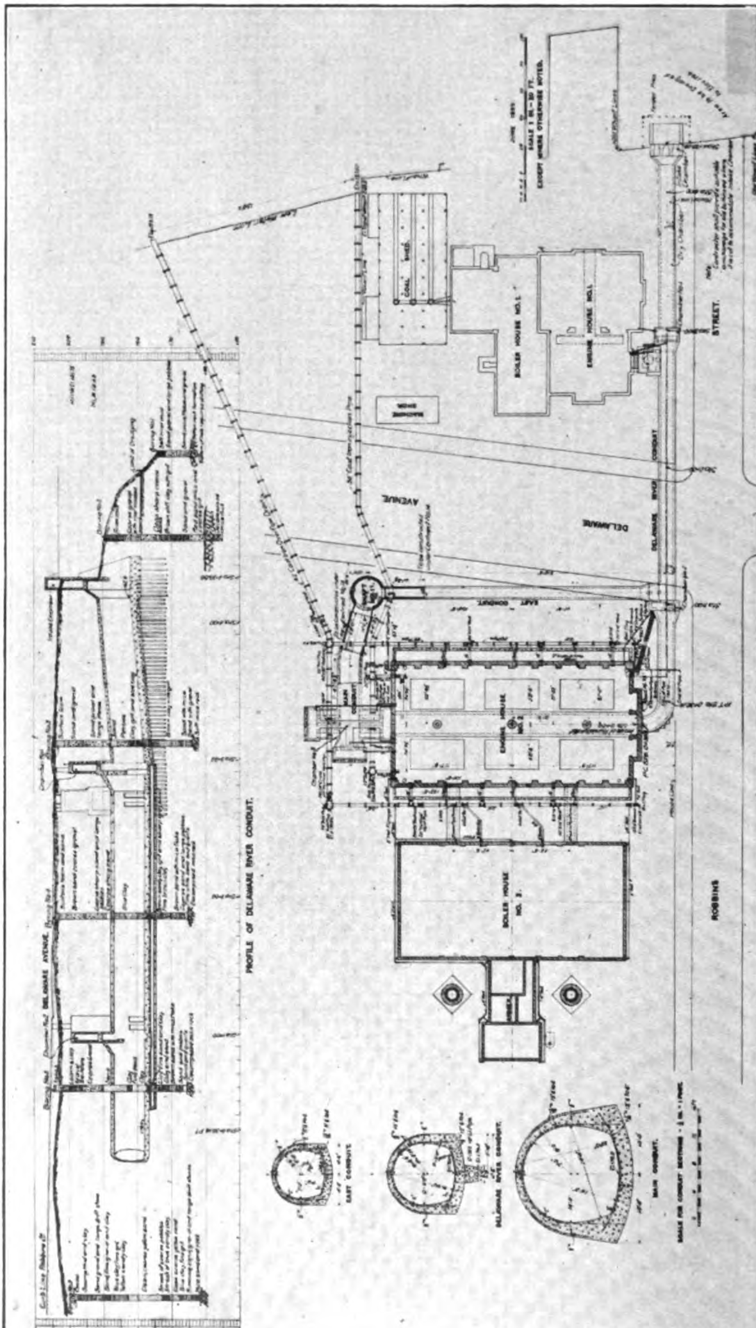

Fig. 24.—Lardner's Point Pumping Station—Conduits and Piping.

area to a circle 7 feet diameter. This conduit is intended to supply water to the present pumping station termed engine-house No. 1.

The pump well of engine house No. 2, and the smaller conduit from shaft No. 11, connect into another concrete and steel conduit of horseshoe section equal in area to a circle 9 feet diameter, which is extended eastward on Robbins Street to a gate chamber in the Delaware River. The latter conduit, known in the plans as the Delaware River connection, is provided with a double gate chamber to admit of taking water direct from the river into the pump well of engine-house No. 2 and to the engines in engine-house No. 1, until such time as the water is brought from the Torresdale filters, after which the sluice gates in both chambers will be closed and the section of conduit between them becomes a so-called dry chamber, from which water leaking through the gates from the river, or from the filtered water portion of the conduit, will be pumped into the sewers from a well provided in engine-house No. 2. Attention to the level of water leaking into the dry chamber will prevent any pollution of the filtered water in the conduits and pump wells by leakage through the gates at the river end of the Delaware River connection.

The gate chamber, which is supplied with water through the 14 feet conduit, is built with three sets of sluice gates to control the flow of water to the pump well of engine-houses Nos. 2 and 3, and to a future engine-house which will be located at the intersection of Milnor and Levick Streets, west of the proposed location for engine- and boiler-houses No. 3.

I regret that I am unable to present a view of the elevations and finished appearance of the new pumping stations, which it is thought will compare favorably with any modern pumping houses built by other cities, and in view of their great size and very elaborate substructures will not be unusually expensive structures for the purpose.

Lardner's Point Pipe Distribution System.

From the pumping stations at Lardner's Point the filtered water will serve the Queen Lane and East Park distribution districts through a system of 60-inch and 48-inch cast-iron mains (Fig. 25).

Each of the four sets of 20,000,000-gallon pumping engines will discharge their water through a short line of 48-inch cast-iron pipe into four lines of 60-inch pipe in Robbins Street, uniting with these pipes in gate chamber No. 1.

The four lines of 60-inch pipe will be laid in Robbins Street from

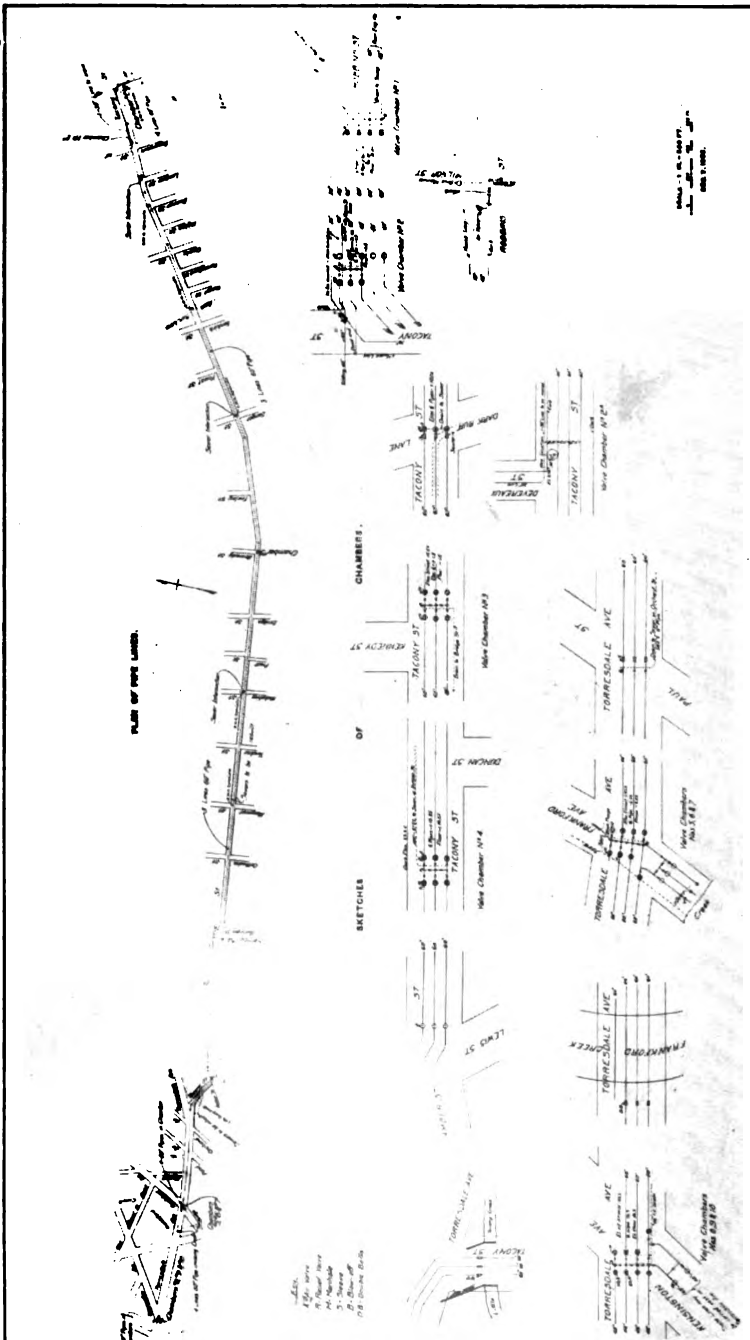

Fig. 25.—Lardner's Point Pipe Distribution System—General Plan.

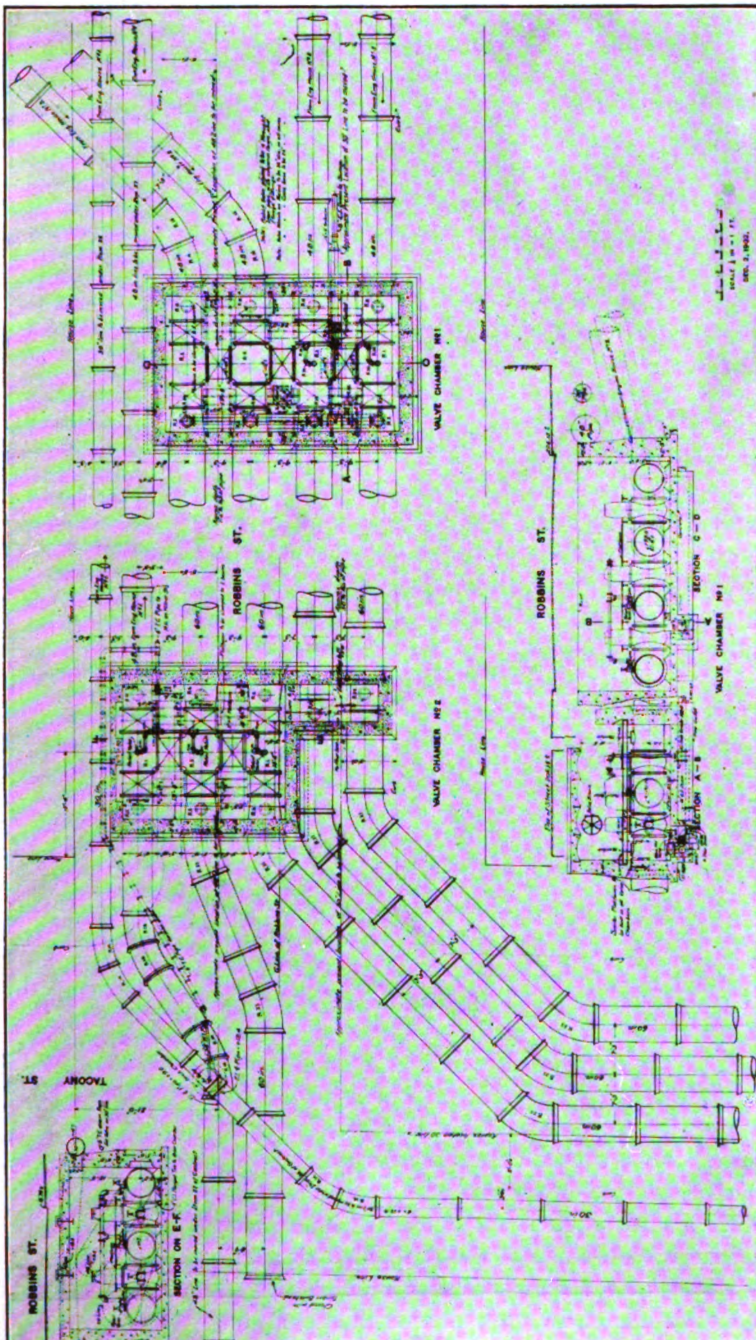

Fig. 26.—Lardner's Point Pipe Distribution System—Valve Chambers Nos. 1 and 2.

gate chamber No. 1, near Milnor Street (Fig. 26), to Tacony Street or Old State Road; at this point the north line of pipe will be temporarily stopped to be continued in the future on Robbins Street to Torresdale Avenue, thence on Torresdale Avenue to Kensington Avenue, passing through gate chambers Nos. 5 and 8 (Fig. 27). The other three lines will be laid in Tacony Street from Robbins Street to the intersection with Torresdale Avenue, and thence in Torresdale Avenue to Kensington Avenue, where the four lines of 60-inch pipe will end in gate chamber No. 8.

The three lines of pipe in Tacony Street occupy the roadway nearly from curb to curb, and together with the short length of the fourth line, now to be laid under contract No. 28, comprises nearly 45,000 linear feet of 60-inch pipe. From the terminus of the four lines of 60-inch pipe, nine lines of 48-inch pipe will lead into the Queen Lane and East Park districts, to complete the main feeders for the supply of filtered water from the Lardner's Point pumping station.

At the two terminal points, and at distances apart of about 4000 feet, masonry valve chambers will be built (Figs. 26 and 27), in which will be placed the special castings and stop-valves to control the flow of water in the event of injury to either line of pipe, and avoid the temporary loss of the use of more than 4000 feet of one line of pipe while repairs are being made. To prevent, as far as possible, injury to these large pipes, each line is provided with a pop relief valve in each gate chamber, set to blow at 125 pounds, in addition to relief valves on the discharge pipes of the pumping engines at Lardner's Point, set to blow at 120 pounds per square inch.

Figure 27 shows the location of the gate chambers, earlier mentioned, along the lines of 60-inch distribution mains on Robbins and Tacony Streets and Torresdale Avenue. The stop-valves and all special castings built in the chambers are flanged work. Each line of 60-inch pipe enters and leaves the chamber through a 60-inch to 48-inch hub and flange reducer. All valves are 48 inches diameter, partly to reduce the cost of the work and partly to limit the depth of excavation at the chambers. A 48-inch stop-valve is a well-exploited detail of waterworks construction, involves no risk when properly proportioned for the pressure under which it will work, is much less expensive, and requires less depth of chamber than a 60-inch valve. A careful investigation of the probable extra loss of head by the use of 48-inch valves compared with 60-inch valves indicates less than 0.30 foot for the entire number in each line of pipe. The cost of over-

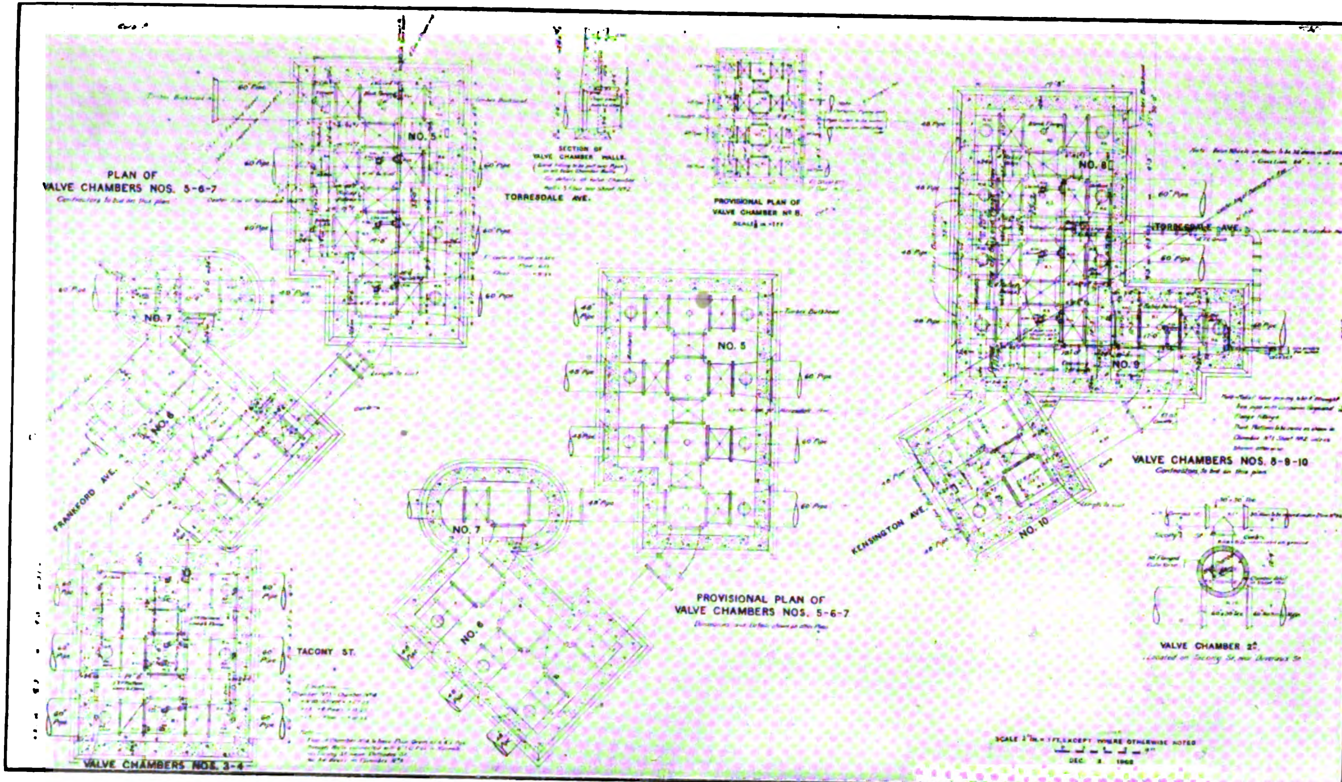

FIG. 27.—LARDNER'S POINT PIPE DISTRIBUTION SYSTEM—VALVE CHAMBERS NOS. 3-4 AND 5-6-7, AND 8-9-10.

4

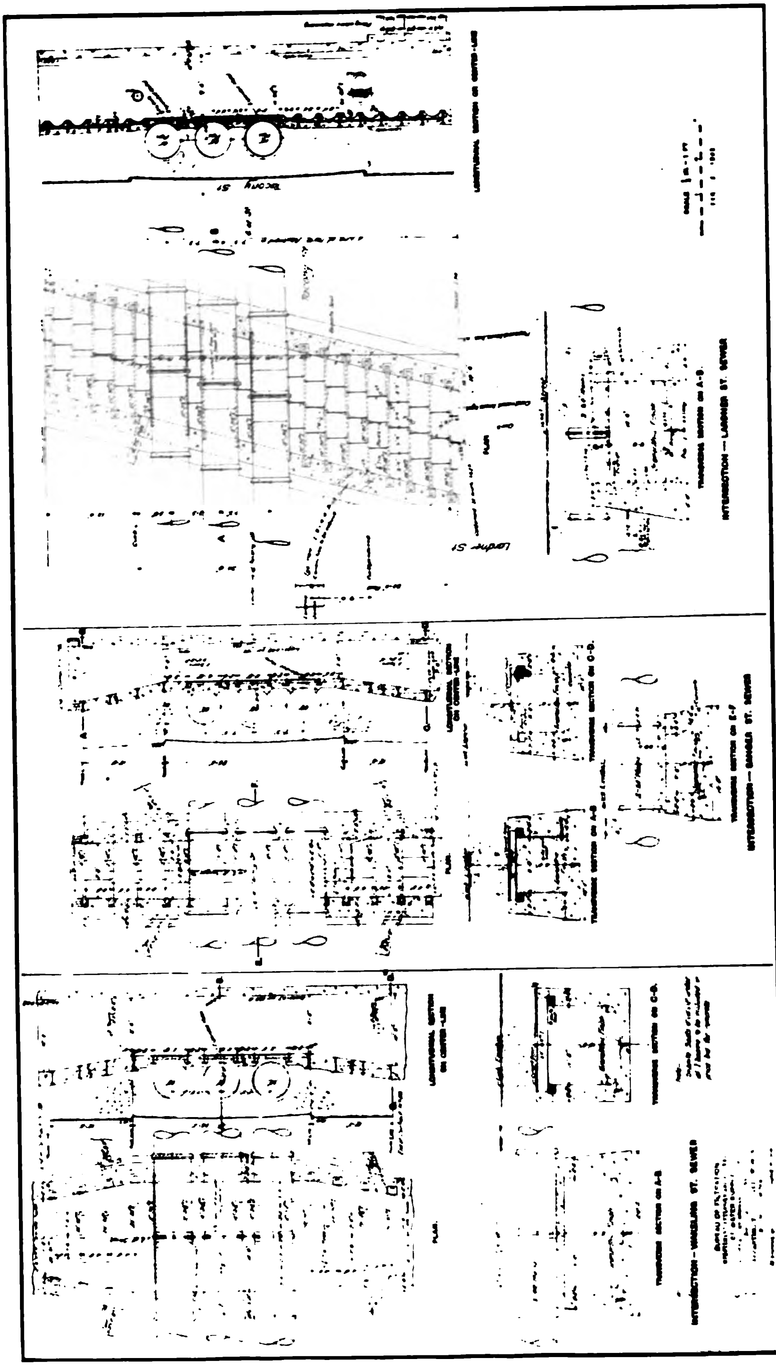

FIG. 28.—LARDNER'S POINT PIPE DISTRIBUTION SYSTEM—SEWER INTERSECTIONS.

coming this additional loss of head by the pumping machinery at Lardner's Point was very much less than the annual fixed charges on the additional cost of the work of construction if 60-inch instead of 48-inch stop-valves had been used.

Figure 28 shows three large sewer intersections at Lardner, Sanger, and Frankford Streets, where the 60-inch pipes are carried over concrete chambers with inverts at the same grade and elevation as the sewers, but with the crowns or roofs depressed to admit of sufficient cover for the pipes above. In laying the pipes the principle held that, however remote the probability of accident, ample provision should be made for certain, convenient and quick repairs, and shallow trenches and placing of pipes above important intersected sewers were early decided upon.

The sewer chambers have roofs in all cases below the elevation of mean high water in the Delaware River, but the channels are of such sectional area as to provide a velocity of flow not less than that of the connected sewer. At Lardner and Frankford Streets the chambers are of such width as to require the use of two lengths of flange pipe to span the opening. In these cases the pipes are treated as beams to carry part of the street load, and transmit it to the side walls of the chambers. The roofs of the chambers consist of concrete arches supported on the flanges of steel beams.

Plan of Oak Lane Reservoir.

Figure 29 shows in plan the Oak Lane reservoir, which is intended solely for compensation for the varying hourly rates of water consumption, and to limit the head on the Lardner's Point pumping machinery. The flow line is at elevation 210.00 C. D., with a water depth of 20 feet 6 inches. In the construction of this basin provision has been made for covering it, if it shall be found that exposure of the filtered water in such volume (70,000,000 gallons) to the light and air is attended with any ill effects. Such experience as we have had with filtered Schuylkill River water does not indicate appreciable deterioration through considerable lengths of time by exposure in clear bottles to the light, but this experience may not apply with equal force to the filtered Delaware River water which will be pumped to the Oak Lane reservoir; and if it is found desirable that this basin should be covered, the plans have been worked out to provide for a covering by the addition of the necessary piers, and a steel and timber or concrete vaulted arch roof. The preponderance of available data seems to indicate

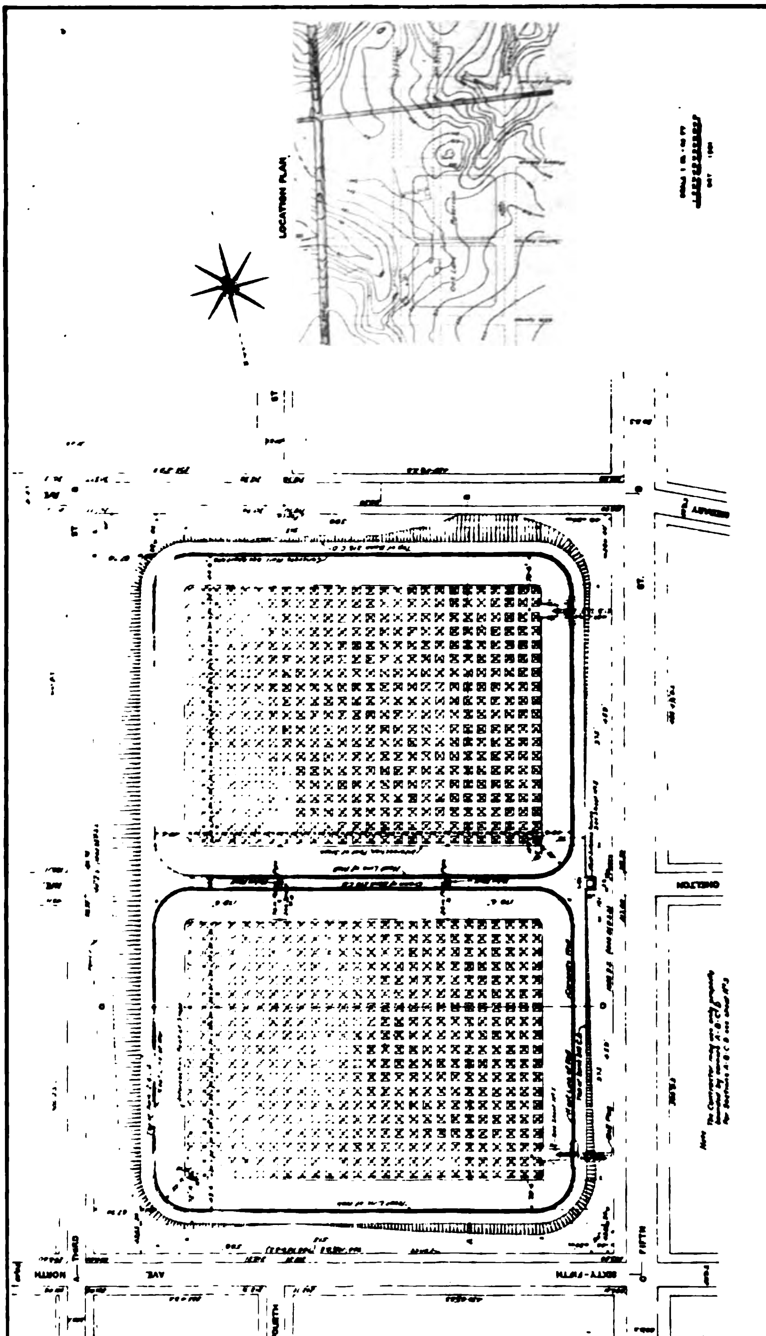

FIG. 29.—OAK LANE RESERVOIR—GENERAL PLAN.

that a covering is not essential, and in its early history the reservoir will be worked as an open basin.

The Lawrence (Mass.) reservoir, receiving filtered water from the Merrimac River, contains about thirteen days' storage and is uncovered; no ill effects to the filtered water by the exposure, so far as I am aware, have been reported from Lawrence. Upon the other hand, the Quincy (Ill.) reservoir receiving filtered Mississippi River water, holding about the same number of days' supply, required covering to prevent an objectionable growth of algæ in the water. There is, however, this difference in the two instances cited: at Lawrence the water is filtered through plain sand filters, without the aid of alum or other chemicals, while at Quincy rapid mechanical filters with a coagulant containing alum or iron as the astringent are used. How much, if at all, the use of a chemical in the filtration of water at Quincy may have caused deterioration in the water when exposed to the light and air for twelve to thirteen days in an uncovered reservoir, I do not know; but it is possible that the dissolved chemical in the filtered water might have stimulated the growth of certain species of algæ.

Capacity of Works.

The capacity of the works, as planned and generally under contract, may be recapitulated as follows:

		Gallons per Day.
Torresdale Filters.		
Fifty-five filters, Torresdale contingent and preliminary filters,	210,000,000	
Ten filters, Queen Lane contingent and preliminary filters,	38,000,000	
Total of Torresdale,	248,000,000	
Belmont Filters.		
Eighteen filters and preliminary filters,	67,000,000	
Roxborough Filters.		
Lower Roxborough, five filters and preliminary filters,	12,000,000	
Upper Roxborough, eight filters and subsided water,	20,000,000	
Total,		347,000,000

Upon the assumption that upon the completion of the works the city may adopt water meters, or some other remedy for the unnecessary waste, and that an average allowance of 150 gallons per capita per diem will meet all reasonable requirements of consumption, the capacity of the works as planned and now under contract (excepting Queen Lane contingent of ten filters at Torresdale) will be as follows:

Torresdale capacity will serve a population of........	1,680,000
Belmont capacity will serve a population of..........	420,000
Roxborough capacity will serve a population of......	213,300
Total, ...	3,313,300

It is estimated that the population of the city in 1950 will not exceed 3,500,000, and upon this basis the present works of filtration are projected from forty to fifty years in the future.

POPULATION SUPPLIED AND CONSUMPTION OF WATER IN NINETEEN OF THE LARGEST AMERICAN CITIES.

CITIES.	POPULATION SUPPLIED.	CONSUMPTION. GALLONS DAILY.	GALLONS PER CAPITA.
Philadelphia, ...	1,254,000	287,188,000	229
New York,..............	2,049,000	245,700,000	120
Chicago, ...	1,698,600	323,000,000	190
Brooklyn, ...	1,110,000	95,900,000	86
Boston,.................	560,900	80,000,000	143
Cleveland, ...	420,000	66,900,000	159
Buffalo, ...	400,000	92,365,000	233
St. Louis,...............	400,000	63,530,000	159
San Francisco,...........	342,800	25,000,000	73
Cincinnati, ...	325,900	39,600,000	121
Detroit, ...	306,055	44,800,000	146
Milwaukee,..............	300,000	24,000,000	80
New Orleans, ...	287,104	13,820,000	48
Pittsburg, ...	234,000	54,000,000	231
Minneapolis, ...	202,718	18,813,000	93
Providence, ...	187,300	10,130,000	54
Indianapolis, ...	169,164	13,400,000	79
Allegheny, ...	130,000	39,000,000	300
Denver, ...	100,000	30,000,000	300

The proposition to so restrict the needless wastes and reduce the per capita daily consumption of water possibly to 150 gallons is sustained by reference to certain cities in the following table of water consumption in nineteen of the principal cities of the country for the year 1902. Cincinnati, Cleveland, Milwaukee, Providence, and St. Louis are thus all manufacturing cities, in which, excepting Milwaukee and Providence, meters are not generally used, and the consumption of water is regarded as excessive, and the same complaint of water waste with the two exceptions noted is made there as it is in New York, Boston, and other cities not generally metered.

Denver is supplied partly from gravity sources in the South Platte Valley, or by water-power pumping from the Platte River, a small portion of the water from Cherry Creek being also pumped. At Pittsburg several years ago I was informed by the superintendent of the waterworks that in his opinion the large apparent consumption was due to leaks in the street mains, and that his experience in making connections and repairs revealed a considerable loss from bad joints.

Assuming that the general introduction of water such as is now coming from the Lower Roxborough filters will have an effect to reduce by 80 per cent. the typhoid fever rates, the direct money value to the city of this reduction is estimated at $2,284,000 per year, an amount which, capitalized at 5.5 per cent., the fixed charges on the bonds issued for construction of the works, for thirty years, equals $33,195,656, which I consider as the present value of the general filtration of the public water-supply.

The following total quantities apply to the contracts executed to date:

Excavation,	2,371,000	cu. yds.	
Rolled earth fill,	259,000	"	
Rolled embankment,	595,000	"	
Puddle,	228,000	"	
Concrete masonry,	315,500	"	
Rubble masonry,	2,200	"	*
Brick masonry,	23,000	"	†
Cast-iron water-pipe,	72,000	tons.	
Special castings,	2,850	"	
Structural steel,	3,362,000	pounds.	‡
Cast-iron fixtures,	1,163,000	"	‡
Wrought iron,	101,000	"	
Stop-valves,	1,259		
Check-valves,	130		
Rotary valves,	18		
Regulator houses,	49		
Gate houses,	9		
Valve Chambers,	15		
Administration buildings,	3		
High-lift pumping stations,	2		
Low-lift pumping stations,	3		

* Does not include inverts of sewers, contracts No. 25 and No. 29.

† Does not include regulator or gate houses, sewers, and manholes.

‡ Does not include manhole frames and covers, fasteners in vaulting, sewer inlets, filter ventilators, nor appurtenances to piping.

Enough has been shown to-night to indicate in a vague manner the magnitude of these works. Many of the details are worthy of much more time for their proper presentation than I have taken to briefly sketch out the whole system. Many interesting problems have arisen in developing the plans and constructing the work which I sincerely hope have been properly worked out. The amount and varying character of the detail are such that nothing short of a volume such as Mr. Edward Wegman, C.E., has so admirably written of the old and new Croton aqueducts can properly present it to engineers interested in works of its character, and I cannot hope that my brief talk this evening, together with the lantern slides shown, can do more than give you an inkling of this great work.

The readjustment of sources of supply, costing as it does a large sum of money, aside from the cost of the works of filtration at Torresdale, possesses several points of vital interest. At the present time there is pumped from the Schuylkill River for the city supply a daily average of 283,429,000 gallons, while the Delaware River furnishes 30,160,000 gallons, or a total, as shown by the report of the Bureau of Water for 1902, of 313,589,000 gallons. The Schuylkill River thus furnishes at the present time over 90 per cent. of the water consumed. By the new plans based on the present daily consumption the Schuylkill River will furnish about 20 per cent. of the water and the Delaware River will supply the remainder. In view of the large substitution of the Delaware for Schuylkill water, some inquiry is bound to arise as to the relative merits for domestic and other purposes of the two sources of supply.

From a table showing the weekly averages for 1902 of the leading data from the chemical and bacteriological examinations of the two rivers, I quote the following upon the condition of the raw waters:

TURBIDITY IN PARTS PER 1,000,000 BY THE SILICA STANDARD.

Delaware River, average for year,	53
Schuylkill River, average for year,	100
Delaware River, maximum for year,	460
Schuylkill River, maximum for year,	1,100
Delaware River, minimum for year,	9
Schuylkill River, minimum for year,	9

BACTERIA PER CUBIC CENTIMETER.

Delaware River, average for year,	6,405
Schuylkill River, average for year,	14,160
Delaware River, maximum for year,	24,000

Schuylkill River, maximum for year,	86,000
Delaware River, minimum for year,	550
Schuylkill River, minimum for year,	630

Color by the Platinum Cobalt Standard.

Delaware River, average for year,	0.19
Schuylkill River, average for year,	0.09
Delaware River, maximum for year,	0.40
Schuylkill River, maximum for year,	0.22
Delaware River, minimum for year,	0.10
Schuylkill River, minimum for year,	0.04

Hardness, Equivalent to Carbonate of Lime.

Delaware River, average for year,	51.00
Schuylkill River, average for year,	87.00
Delaware River, maximum for year,	94.00
Schuylkill River, maximum for year,	124.00
Delaware River, minimum for year,	26.00
Schuylkill River, minimum for year,	44.00

It will be noticed from the data quoted that in all respects other than color the Delaware River furnishes the better natural water. Considering filtration of the two waters, the data quoted and the experimental results at the testing stations indicate the Delaware as the most favorable water to work with. Considering the color, the filtered Delaware water, when viewed in a clear glass beaker alone, would not to an unpractised observer suggest color, but when compared with filtered Schuylkill water the darker appearance of the water is then evident.

Plain sand filtration cannot be relied upon to remove or largely reduce color where, as in the Delaware River water, it is due to vegetable stain. But so far as I am aware the dissolved matter which imparts color to either the Schuylkill or Delaware water is not inimical to health.

The increased color found in the water of the Delaware River is probably due to the swamp water from the Rancocas and other creeks flowing into the river from New Jersey.

Omitting this single condition of color, which I do not know to be objectionable from a sanitary standpoint, I think it is fair to assume the Delaware River water as the better of the two sources.

Comparison of Experts' Estimates and Actual Cost.

With reference to the cost of the work: The report of the experts aggregates a gross outlay of $14,569,989, or, in round numbers, say

$14,570,000, based upon works to supply 200,000,000 gallons daily of filtered water. The general plan of the experts, however, as I have since been informed by members of the commission, contemplated some improvements that were not incorporated in their summary of cost. For example, a basin which would have had the same function as the Oak Lane reservoir (contract No. 27) now under construction is known in the experts' report as the Olney Avenue reservoir. This reservoir, it was thought, would be required for compensation and limited storage in the event of gravity supplies being brought into the city. Upon further study of the general subject it appeared to be advisable to incorporate in the Torresdale plans such a reservoir at an elevation higher than the Wentz Farm reservoir to aid in the distribution of water from the Torresdale filters. The amount estimated for the Olney Avenue reservoir was $1,000,000 (page 81 of the experts' report).

In developing the Belmont scheme it was thought by the experts that the additional reservoir at George's Hill, planned by the Bureau of Water, at an estimated cost of $500,000, which, pro rated upon the cost of the settling basin for the Belmont works (contract No. 16), would have cost to construct about $790,000, would have been made a part of the plans as proposed by them. That is to say, as I understand, the experts believed that the George's Hill reservoir would be increased in capacity by 85,000,000 gallons, and that it was desirable to pump first to subsiding basins at George's Hill and then pump the water again to the filters at Belmont Avenue and Ford Road. The value of this reservoir is essentially a part of the cost of the improvements proposed by the experts, but was not incorporated in their summary.

The filters at the Torresdale station were connected with the distribution system by one line of 48-inch pipe, and one line of 30-inch pipe, extending southward on State Road as far as Robbins Street, where they intersected the present 48-inch and 30-inch rising mains from the Frankford pumping station. The capacity of these pipes, with the same loss of head as is allowed for in the Torresdale conduit, is about 30,000,000 gallons per day of twenty-four hours, or less than the capacity of the filters planned for the Torresdale station. By substituting the Torresdale conduit for the cast-iron mains mentioned in the experts' report we have provided a daily capacity of over 300,000,000 gallons with the same loss of head between the Torresdale filters and Lardner's Point as that allowed for the cast-iron mains for a carrying capacity of 30,000,000 gallons per day, and making provision for the ultimate capacity of the Torresdale station as estimated for by the experts. This detail involves an increased cost of $1,350,000.

Another feature of the experts' report to which your attention can properly be called is that the 200,000,000 gallons daily consumption was based upon the general metering of all water services, and no allowance is made in the summary for the cost of installing the meters. The adoption of a meter system was clearly regarded by them as an essential part of the improvement. I am not calling attention to this with a view to criticizing the report of the experts, which, after three years' study, and considering the limited time at their disposal, I believe is in all respects admirable, but to show why the actual cost of the work constructed is bound to be greater than the figures written in their report.

Another condition which must be considered is the difference between the cost of labor and materials in 1899 and during the years 1901, 1902, and at present. All materials for waterworks constructions and labor command higher prices to-day, and with reference to common labor and some skilled labor the amount of work performed at the higher prices is actually less than that which was performed at the prices prevailing in 1899; this is bound to have a marked influence upon the figures made by the contractors who assume the responsibility for constructing the work, and is a contingency which it would be unfair to assume that the experts provided for.

DISCUSSION.

THE PRESIDENT.—The paper is open for discussion, gentlemen. I am sure that Mr. Hill will be glad to answer any questions that suggest themselves to you.

JAMES CHRISTIE.—Mr. President, while offering a resolution of thanks to Mr. Hill for the paper he has presented to us this evening, I wish to preface it by expressing the satisfaction that Philadelphians should feel, that after so many years of agitation, extending over the last quarter of a century; after an extended discussion of all sorts of schemes for the solution of the question of pure water, we have at length nearing completion a comprehensive system which utilizes the impure water passing by the city and will distribute it to us in a satisfactory condition.

I think it is now generally recognized that no surface water anywhere is in the proper condition for drinking without passing through some process of purification. So no matter where we would have gone for water-supply, if we had taken surface water, the necessity for filtration would be almost as great as for that we have at hand. In addition to such diseases as typhoid and cholera, which affect the alimentary system of the human adult, it is known that infantile mortality is largely augmented by the presence of injurious organisms in milk and water. Wasting diseases resulting in inanition and atrophy are responsible for much of the mortality in young children. The good results that have followed from proper systems of sterilization for milk and water have demonstrated this. Pure water supplied to infants will tend to reduce the summer ailments in children, and the loss of a promising infant is certainly a greater calamity than the removal of a bad man.

Those of us who have found it convenient to frequently visit the filtration plants described by Mr. Hill realize the magnitude and immensity of the work and the great skill that has been displayed by the engineers and contractors in its execution. The work has been admirably handled and will rank with the best of its character anywhere.

We hope, Mr. President, that at some future evening some member of Mr. Hill's staff may be able to present to us a description of the methods used by the contractors in prosecuting this work. I move a vote of thanks to Mr. Hill for the trouble he has taken in the presentation of the subject before us this evening. (The motion was put and carried unanimously.)

The President.—The meeting is open to further discussion.

Samuel S. Sadtler.—May I ask, Mr. Hill, how nearly the bacteria are removed from the filtered water?

Mr. Hill.—The last two weekly reports from the Lower Roxborough filters show an average bacterial content of the effluent water of all the filters for the week ending last Saturday, February 14, 1903, as less than fifty colonies of bacteria per cubic centimeter of water, ranging from thirty-nine to sixty-five colonies of bacteria per cubic centimeter of water. For the week previous to that the average bacterial content was about sixty colonies per cubic centimeter of water. With the exception of about four weeks during the winter, when the water was very bad and wholly unprepared by sedimentation or preliminary filtration before going to the filters, the average bacterial content of the filter effluents rarely exceeded thirty colonies per cubic centimeter of water. Some of the filters have delivered the water with as few as three colonies per cubic centimeter of water—almost sterile water; but until the preliminary filters have been completed to prepare the water for the Lower Roxborough filters, the best work of these filters cannot be shown. Our standard of bacteria per cubic centimeter of filtered water is fifty. So long as the bacteria in the filtered water are not in excess of the standard I do not trouble the man who is in charge of the filters. When, however, the numbers exceed the standard, an investigation is made to locate the cause and remedy the increased bacterial content of the filter effluents.

I can confirm Mr. Christie's opinion that there is no surface water anywhere flowing in rivers or lakes that is naturally fit to go to the consumer for dietetic or potable purposes. To-day, if the water were coming from the Blue Mountains, as proposed by Mr. Hering in his report of investigations during the years 1884 and 1885, there is no doubt in my mind that the city would be building, or perhaps have already built, works of filtration. Those familiar with the works proposed by Sir Alexander Binnie for the supply of water from the Welsh mountains to London understand that the water is to be gathered in impounding reservoirs in Wales and be passed through plain sand filters before it reaches London. I think Mr. Christie is quite correct in the opinion that no water from natural surface sources should be used for dietetic purposes unless it is first filtered.

THE PRESIDENT.—I am glad that Mr. Hill and Mr. Christie have called attention to the necessity of the filtration of any domestic water-supply, no matter where gathered, whether from flowing streams or from surface springs. If I am not mistaken, in Germany it is subject to governmental control.

MR. HILL.—Yes, it is.

THE PRESIDENT.—And no municipality or water company, if such exists in Germany, is allowed to furnish the water of flowing streams for domestic uses without filtration.

I have long known the Schuylkill River and its sources of pollution and I am persuaded in my own mind that a domestic supply from this source is not fit for use without filtration. I hold to the same opinion in regard to the supply from the Delaware River. The difference in the supply from the two streams is only relative, the governing factor in the purity of the two sources being that the Delaware, which is more than four times the size of the Schuylkill in drainage area and volume of flow, has the advantage of greater dilution. In other words, the pollution of the Delaware water is not so apparent to the senses as it is in the lower pools of the Schuylkill.

Nevertheless, there are no regularly sewered cities and towns in the Schuylkill watershed. There are, it is true, isolated cases of public sewers, all of them on a comparatively small scale, in towns and villages, not including the city of Reading, which has expended a large sum of money upon a separate sewage system, for the chemical treatment and filtration of the outflow from the first and second sewer districts of the city, which is the only portion of the system as yet completed. On the other hand, the Delaware River flows through a district part of which is thickly populated. Within a distance of sixty miles of Philadelphia there are five large cities and towns, all of which are sewered, the effluent passing directly to the river, without treatment.

It is therefore necessary to filter the supply from both the Delaware and the Schuylkill. It is the only safe plan to pursue, and the only one which will insure a supply of water safe for use for domestic purposes. With the introduction of filtered water in this city, I feel satisfied that the statement just made by Mr. Hill, that the death-rate from typhoid fever will be reduced 80 per cent., will prove to be entirely correct. Indeed, from such an admirably planned and well-executed plant, a greater reduction in the typhoid rate may be looked for. Surely the community is under obligations to the gentlemen who are carrying on this work so assiduously, for it is in many ways a difficult undertaking and one calling for the largest exercise of engineering skill.

I have in my hands a letter received from Mr. John C. Trautwine, Jr., a member of the Club, which opens up a question which I think he would like to have answered. Mr. Trautwine is not able to be with us to-night. He says in part of his letter:

"It is naturally gratifying to find the work now being carried on upon these lines, the authorities installing filters and advocating the introduction of meters.

"It seems regrettable that waste restriction, which would have reduced the cost of the filters at least one-half, was not installed first.

"Possibly Mr. Hill can indicate why the natural order of procedure has been reversed."

Mr. Hill.—Three years ago, when this work was begun,—that is, the construction features of the work,—it seemed to me that we ought to give serious attention to the matter of water meters, and one of the earliest steps that were taken was to ascertain the probable number of service connections and the cost of installing a general meter system for the city. It was found there would be required about 250,000 meters, of which 92 per cent. represented meters on domestic service pipes; and upon the average cost of $18 per meter, set and connected in the service pipe, the gross cost was found to be $4,500,000. When the matter was talked over with my assistants, as well as with the Mayor, a statement was made that, if we began by metering such water as is in the second bottle (pointing to the unfiltered Schuylkill water in the bottle on the President's table), we would be liable to be strung up to lamp-posts; that the people might be willing to have good water metered, but not such water as that. (Laughter.) The consensus of opinion of the officials was that we should first filter the water and then take up the matter of adjusting meters to the service pipes. I have the promise of Mayor Ashbridge that he will incorporate in his last message to Councils, which will be prepared within a few weeks, a strong paragraph recommending the use of meters as a means of restricting unnecessary and reckless waste of water from the city mains.

While describing the lantern slides, I overlooked a sketch which, with your permission, I would like to describe at this time. (Mr. Hill turned to a large sketch hanging upon the wall and said:) This is a section of a filter, and I wish to say a few words about the construction of the main collector shown in the center of this filter. (Mr. Hill explained the design.) In the Roxborough filters the construction of the main collectors was the cause of an unexpected leakage through the cracks formed between the main collector walls and the floors of the filters. The water passed through these cracks into the puddle, and doubtless to some extent through the puddle. So in the filters at Belmont and at Torresdale we are building a main collector like this (indicating). In this construction of main collector the walls are built of concrete, with openings through the sides for the reception of the lateral collectors. From each side of the main collector 8-inch perforated terra-cotta pipes are run nearly to the side walls of the filters, the aggregate area of perforations in each length being equal to the area of the pipe.

I consider the perforated pipe to be superior to the unperforated pipe, because it is calculated to effect a more nearly uniform rate of percolation through the gravel underdrains and superimposed sand beds for the whole length of the lateral collector. The perforated lateral collectors, as we are using them in the Philadelphia filters, were first proposed by Mr. James P. Kirkwood in the filters planned by him for the city of St. Louis, nearly forty years ago. So far as I am aware, this city is the first to adopt Mr. Kirkwood's suggestion.

The depth of gravel in the underdrains is 16 inches at the center of the filter bay, divided as follows: At the bottom, 6 inches in depth of gravel, varying in size from 3-inch to 1½-inch diameters; next above, a depth of 4 inches of gravel, varying in size from 1½ to ¾-inch diameters; next above a depth of 3 inches, varying in size from ¾-inch to ¼-inch diameters; next above, a depth of 2 inches of gravel, varying in size from ¼-inch diameter to particles that will be retained on a No. 14 sieve; and finally, at the top of the system of underdrains, a layer of coarse sand 1 inch thick, composed of particles which will pass a No. 14 sieve and be retained on a No. 20 sieve.

The average thickness of the bed of filter sand placed above the gravel underdrains, both in the filters now running at Lower Roxborough and in the filters in which the filtering materials are now being placed at Upper Roxborough, is 36 inches. The construction of the filters is such that the depth or thickness of the sand bed may be varied between wide limits, although the information gained thus far from the practical operation of the filters at Lower Roxborough suggests a maximum depth of sand bed of 40 inches, and a minimum depth, after repeated scraping, of 20 inches.

After a filter has run until the difference between the level of the water over the sand bed and the level of the water in the effluent chamber at the end of the filter approximates 4 or 5 feet, the inflow of water is stopped and the water on the sand bed drawn off through the collectors until the level is 10 or 12 inches below the surface of the sand, after which operation the upper ¾ inch of dirty sand is scraped off, washed, and stored in the court for future use. When a sand bed, by repeated scrapings, has been reduced to a thickness of 20 inches, one more scraping is made and then the previously scraped and washed sand is brought back into the filter and the sand bed restored to its original thickness of 36 inches, more or less.

L. Y. SCHERMERHORN.—What are the physical characteristics of sand suitable for filtration purposes?

MR. HILL.—It does not seem to be much affected by the shape of the sand grain, but it is affected by the size. If there is too much of fine material, the bed will be too dense for practical filtration. If there is too much of coarse material, the water goes through too freely and without proper filtration. The sand in the Lower and Upper Roxborough filters consists of particles which will readily pass a brass wire sieve of four meshes to the linear inch, and of which no appreciable part will pass a brass wire sieve of eighty meshes per linear inch. Such material, by the standard adopted by the Massachusetts State Board of Health, would have an effective size varying between 0.30 mm. and 0.35 mm., and a uniformity coefficient varying between 2.00 and 2.60. The sand contracted for for the Belmont and Torresdale filters will have a slightly larger effective size and slightly smaller average uniformity coefficient. The effective size is 0.30 mm. to 0.38 mm., and uniformity coefficient 1.70 to 2.60.

The particles of sand may be pure silica, quartz, or any other material not soluble in water. No chemical action takes place between the grains of sand and the water passing around them. The sand might be replaced with particles of anthracite coal of the same size, and the operation of the filter, in my opinion, would be quite the same, although the use of anthracite coal as a filtering medium would probably increase the sulphuric acid found in the effluent.

Some of the refuse iron sand from the concentrating plant at Edison, N. J., was tested in one of the experimental filters at the Spring Garden testing station, but no special advantage for this was found.

EDGAR MARBURG.—In the construction of these filters, very large quantities of concrete were used. The question as to the best mixing of concrete, especially with reference to the proportion of water, is one concerning which there is still a good deal of difference of opinion. I should like to ask Mr. Hill to tell us something about the specifications for concrete, and whether they led to satisfactory results.

I should also like to inquire more particularly as to the character of the sponge layer at the top of the preliminary filters. That is to say, whether different substances were experimented with, and what determined the final selection.

MR. HILL.—With reference to concrete, we have adhered rigidly to the specifications as to quality and proportions of materials. There has been a reasonably wide variation in the "wetness" and "dryness" of concrete used, depending upon the location of concrete and the condition of the weather. We have made many cubes and slabs of "wet" and "dry" concrete, and these have been specially tested for strength and water-tightness, and it appears that dry concrete is equally as water-tight as wet concrete, and, on the whole, of greater strength. One objection to the use of wet concrete in the piers of the filters was observed early in the work at Lower Roxborough; viz., upon dumping wet concrete into the tall, narrow forms, the heavier ballast seemed to fall to the bottom as each barrow-load was put in, and when the forms were taken away there was found a layer of stone with very little mortar about it at the bottom and then a layer of finer ballast and mortar above. The amount of water in the concrete was then reduced until the mixture was reasonably homogeneous when placed in the work. The amount of water used has been varied to suit conditions. As a rule the concrete is made as wet as the nature of the work will permit, but always stiff enough to allow the rammers to walk over freshly laid material without sinking in it for more than a fraction of an inch.

Concerning the layer of sponge in the preliminary filters at Lower Roxborough, this layer is 9 inches in thickness, loose, compressed to 6 inches in thickness, equivalent to about 5 pounds per square foot of surface. Other material than sponge has been tried for the elastic layer at the top of the preliminary filters, but on the whole the sponge is less expensive in use, and apparently gives a more uniform efficiency than Holland peat moss. The chief objection to the latter material is that the loss in removing, washing, and replacing is too large to admit of its use in a practical way.

We have frequently washed the dirty sponge from the experimental preliminary filters at the Spring Garden testing station, and the loss of materia, does not exceed 5 per cent. of the original weight, and it is believed that in practice the loss may be kept within 2 or 3 per cent.

An attempt was made to have the manufacturers of mechanical filters make a proposition for the Lower Roxborough preliminary filters, and the specification was so drawn as to admit of a tender on these filters, to operate, of coursel without coagulants; but the bidder was required to incorporate in his proposal a guarantee of efficiency and cost of operation of the filters he offered, and not merely to offer so many filters at a price per filter. I regret to state that the manufacturers of mechanical filters were unwilling to make a proposition on this work unless permitted to use a coagulant, and, of course, their tender in this way could not be entertained, because the use of a coagulant was, by the terms of the contract, excluded.

I am now reminded of a remark made by his Honor, Mayor Ashbridge, when I came to Philadelphia three years ago to take charge of the plans for the improvement, extension, and filtration of the water-supply, to the effect that "We propose to filter the water of this city, and we propose to filter it without alum; and if you think you can do that, I will hire you; and if not, you can go back to Cincinnati." (Laughter and applause.)

EDW'D S. HUTCHINSON.—I think I understood Mr. Hill to say that the water of the Schuylkill was somewhat harder than that of the Delaware. I would be glad if he could give us some relative figures on that, if possible.

MR. HILL.—A comparison of the hardness of the waters of the two rivers from the 4th of January to the 27th of December, 1902, shows 51 parts carbonate of lime per million for the Delaware River and 87 parts for the Schuylkill River. It will thus be seen that the Schuylkill water is about 70 per cent. harder than the Delaware water.

EUGENE M. NICHOLS.—The sponge, Mr. Hill, is it the ordinary sea sponge?

MR. HILL.—It is the clippings of the ordinary sea sponge. In preparing the Florida and Cuba sponges for the market, large quantities of the sponge are clipped off to give the sponge proper shape. The trimmed sponge is worth ten to twelve cents per pound, while the clippings are sold at five cents per pound. These sponge clippings when compressed *en masse* constitute the elastic layer at the surface or top of the preliminary filter.

MR. NICHOLS.—What would be the ordinary life of any piece?

MR. HILL.—Our experience indicates that the life or durability of the sponge in service will be about nine or ten years. It is thought that the loss will be about 10 per cent. per year, including the waste in handling.

MR. NICHOLS.—Well, is not the whole sponge layer calculated, then, as represented by the probable life of a sponge?

MR. HILL.—Yes; assuming the sponge to have a life or service of eight to ten years, we would be compelled to renew the layer as an entirety in this length of time, due to the natural wear and tear and loss in handling the material.

A MEMBER.—I would like Mr. Hill to tell us how the sand first deposited in the filter bed is treated to prepare it to receive the first inflow of water from the river.

MR. HILL.—The sand, whether obtained from the Delaware River or from the banks in New Jersey, is washed until the turbidity of the filtered or distilled water in which the sample has been shaken is, by the silica standard, from 200 to 400 parts per million. For this test 100 grams of washed sand are shaken in a beaker containing 1 liter of water. After the filter has been filled to the proper depth with sand of this quality it is worked for one or two weeks at the start to remove matter that cannot be removed by the usual process of washing; the changes which occur in the sand bed may be due, in part, to bacterial action. It is thought that the bacteria which have a natural habitat in the sand may be displaced by certain species of bacteria in the water before the sand bed is ready for the proper filtration of the water. This is simply a thought. What is well known, however, is that a sand bed improves with age for a period of use of from one to two years, after which the continued use of the sand may show no further improvement, or, as it is sometimes termed, no further "ripening."

A MEMBER.—Is the water passed from the top down, or from the bottom up, in the first filtration?

MR. HILL.—In the final filter?

A MEMBER.—No, in first entering the filter.

MR. HILL.—In charging a plain sand filter originally, and after each scraping of the sand, the water passes from below upward. In the preliminary or roughing filters at Lower Roxborough the water will continuously pass from below upward, the accumulated mud or other suspended matter being partially removed by daily or more frequent flushings. It is not expected of the preliminary filters to deliver or furnish an effluent fit for use, but that it will assist materially in adapting the water for filtration in the final plain sand filter.

MR. HUTCHINSON.—I suppose that crushed quartz will do as well as natural sand?

MR. HILL.—Yes, that would answer the purpose just as well as natural sand.

MR. HUTCHINSON.—I did not know that it was used before.

MR. HILL.—Probably the expense has been the only drawback to its use.

MR. HUTCHINSON.—I have thought that probably the irregularity of the surface of the crushed quartz might give it an advantage over water-worn sand.

MR. HILL.—In a plain sand filter the smoothness or roughness of the grains of sand is of less consequence than the grading of the grains from "coarse to fine." In the sample of sand being used in filters all of the samples should pass a No. 4 and No. 6 sieve, very little should pass a No. 80 sieve, while the size of grain should grade regularly from the coarser to the finer sieve. Each sieve thus in a series, from No. 4 to No. 80, should intercept its proper proportion of the whole sample.

In a preliminary high-rate filter the rough particles of filtering materials are preferable to smooth particles. In the bed of a plain sand filter it does not appear necessary that the grains should be sharp or rough.

MR. SADTLER.—Mr. President, I would like to ask Mr. Hill whether the scum that is formed on the layer of sand is largely suspended matter, or is a fixation of the albuminoid of the constituents of the water; and then, how that scum is removed from the sand.

MR. HILL.—The muddy layer, or *Schmutzdecke*, at the surface of the sand, is largely suspended matter intercepted mechanically. In addition to the mechanical interception of the suspended matter at the surface of the sand there appears to be a useful work going on in the materials of the *Schmutzdecke*, due to the vital activity of the organisms that are intercepted at the surface of the sand and caught in the suspended matter. The *Schmutzdecke* is removed periodically by scraping the bed with wide, flat shovels. The shovel has a flat blade about 12 inches wide by 14 inches long, and is attached to the handle at such an angle with reference to the height of a man that he can push it along horizontally, and we find that men can readily be trained to scrape off a given thickness with very great precision. Usually the scraping is ½ inch thick; sometimes it is much thicker than ½ inch when the applied water is very high in suspended matter.

W. F. Ballinger.—Mr. Hill, as I understand you with reference to bacteria, there is an average of from 11,000 to 16,000 bacteria per cubic centimeter in unfiltered water, and fifty is the standard in the filtered water.

Mr. Hill.—An average for the year 1902 for the Schuylkill River was 14,000 per cubic centimeter of water, and for the Delaware River 6400 per cubic centimeter of water. Fifty bacteria per cubic centimeter of water is the standard we are working to.

Mr. Ballinger.—Then you take out 99.7 per cent.?

Mr. Hill.—It would be so, of course, when the original counts are as high as 16,000; but the percentage would not be quite so great when the number of bacteria contained in the raw water is lower. We are satisfied if the bacterial content of the filtered water can be kept at fifty colonies per cubic centimeter, or less, no matter how few may be in the water originally, and we want it to be no more than fifty no matter how many may be in the water originally; and while the percentages of bacterial and turbidity reduction are stated in the reports of the filters, they are not given the same weight as the actual numbers found upon analysis of the filter effluents. From a careful review of the work of the Spring Garden testing station, reaching back more than two and a half years; of the Torresdale testing station, for one and a half years, and of the Lower Roxborough filters, for the past six months, I feel that there will be no great difficulty in maintaining a bacterial content of the effluent not in excess of fifty colonies per cubic centimeter. Some of our filters at Lower Roxborough are running to-night with a bacterial content of the effluents not in excess of thirty-five colonies per cubic centimeter, and the average of all the filters to-day is very close to fifty colonies.

Emile G. Perrot.—I would like to ask Mr. Hill if a certain thickness of the scum on the top of the sand does not prevent the water from filtering. Is there not a certain limit to the thickness of the scum that would prevent the water from filtering through the sand? And if the pressure is increased on the scum, would not that make the water infectious by carrying it into the filtered water so that it would carry disease?

Mr. Hill.—If, in the operation of the filters, we were to break the *Schmutzdecke* and permit the unfiltered water to pass through the bed, it would be very objectionable; and to guard against this condition the utmost care is displayed in distributing the sand when first placed in the filter. If there be negligence in placing the sand in the filter, and a condition of the effluent should arise indicating the passage of unfiltered water from the top to the bottom of the sand bed, there probably would be only one remedy for this—viz., to take the filter out of service, remove and properly replace the sand. The placing of the sand in the filters has been as rigorous as the testing of cement, steel, or other materials offered for use in the construction of these works.

I fully realize the danger inferred in the question, and have taken every possible precaution, first, to bring about a sand bed of uniform density throughout; second, to so guard the operation of the filters as to avoid disturbance of the sand bed while in use.

Considering the homogeneity of the sand, I do not think the *Schmutzdecke* could be broken by the pressure due to the maximum rate of filtration which we may employ. In the operation of the filters it is run until the loss of head becomes so great that it cannot be operated at a profitable rate of delivery.