tains, and damming the valley through which the river flowed, would be the means of retaining a vast lake of more than 1,000,000,000 cubic mètres capacity, much above the amount furnished by the greatest floods. The excavation from the cutting through the dividing ridge would be utilized for the formation of the dam. It was needless in addressing such an assembly, which counted among its members the best engineers in England, to urge that dams were well known works and were constructed everywhere.

In conclusion, he thanked them for the attention with which they had received his brief explanation of an enterprise that interested the whole world, and England in particular.

(*Paper No. 1625.*)

"Abingdon Sewerage."[1]

By CHARLES FOOTE GOWER, M. INST. C.E.

THE Corporation of Abingdon, being under notice from the Conservators of the Thames to desist from discharging sewage into the river, called upon Mr. Bailey Denton, M. Inst. C.E., in the autumn of 1874, to advise them as to the best means of sewering the town of Abingdon, and of disposing of its sewage, and at the same time to report on the question of supplying the town with water.

Mr. Denton accordingly, with the assistance of the Author, made the necessary inspection of the town and neighbourhood, and advised the acquisition of 20 acres of land upon the banks of the Thames, about $\frac{3}{4}$ mile below Abingdon, for the purification of the sewage by intermittent downward filtration, combined with wide irrigation. The report gave a description of a general scheme for sewering the town, of the outfall sewer, and of the situation of the pumping station necessary for raising the sewage to the land.

The population, at the time of Mr. Denton's report, was 6,000. The amount of sewage to be ultimately dealt with was estimated at 25 gallons per head for a prospective population of 10,000 persons—that is, 250,000 gallons per day as the dry-weather flow.

The drainage area comprised within the borough boundary is about 287 acres, of which 200 acres may be taken as tributary to the sewerage system. The surface of the ground is slightly undulatory, rising gradually from the River Thames on the east, and

[1] The discussion upon this Paper was taken in conjunction with that upon the following one.

from the River Ock on the south. The soil is sand and gravel, with occasional beds of clay; these deposits overlie the Kimmeridge clay, or where that is wanting, the Coral Rag and Calcareous Grit. Subjacent to the latter is the Oxford clay, which crops out between Abingdon and Oxford; while some of the hills both north and south of Abingdon are capped by the Lower Green Sand formation.

The ordinary summer level of the Thames at Abingdon is 162 feet above Ordnance datum, though in floods it reaches 167 feet, or nearly so. The River Ock, on the south side of the town, is kept up at 168 feet for working mills. The higher parts of Abingdon attain a level of 200 feet, while the lower parts vary from 168 to 175 feet in elevation. The water in the subsoil in that part of the town bordering the Thames is regulated by the level of the water in that river; but in other parts of the town it was, previously to the carrying out of the sewerage works, regulated by the height of the Ock mill stream, which is 5 or 6 feet higher than the Thames. This caused the subsoil water to rise in winter almost to the surface of the streets in certain localities, and was a source of great inconvenience, as well as of injury to health; fever and diarrhœa being prevalent in those parts of the borough, as stated in Dr. Thorne Thorne's report, dated March 1873.

The sewers in Abingdon, when Mr. Denton made his report, were very inadequate. Many of the streets were unprovided with sewers. Those then in use consisted for the most part of culverts, 18 inches or 24 inches in diameter, and $4\frac{1}{2}$ inches thick, while in one street a watercourse was arched over and used as a sewer. These conduits, with a few lengths of piping intended principally to carry off surface waters, were all that existed. What was wanting in sewerage was made up by cesspools, the contents of which, in such a soil as that of Abingdon, no doubt mingled with the water from the shallow wells used by the inhabitants.

The land selected for the purification and utilization of the sewage is from 165 to 168 feet above Ordnance datum. It will be seen, from the heights already given, that it was not possible to bring the sewage from the lower parts of the borough to the land without lifting; and though it would have been possible to bring that from the higher portion by gravitation, such portion would not exceed one-third part of the area of the borough. It was found, moreover, that the cost of such a division would be greater than the saving to be effected in pumping the sewage would warrant. It was therefore determined to carry the whole of the

sewage to a pumping station, and there lift it to the height necessary to command the entire surface of the land selected.

In the design for the sewerage of the borough, the following principles were adhered to: That all surface waters should be excluded from the new sewers, as far as possible, by retaining the existing sewers for surface drainage only; the rainfall, however, upon back roofs and yards, which it would be difficult to deal with separately, was to be admitted, with certain restrictions, into the new sewers, so that the dilution of the sewage in rainy weather —such a source of expense in pumping, and of difficulty in disposal—should be kept within moderate limits.

That the level of the subsoil water in Ock Street, and the low neighbourhood adjoining, should be reduced as much as possible by laying open-jointed drains beneath the sewers, or in other places, so as to render the foundations and cellars of buildings dry and healthy.

That, as it was necessary to pump the whole of the sewage from the outfall sewer on to the land, storage capacity to hold the limited quantity of sewage that might flow during the night, as well as to regulate the working of the engines, should be provided.

That, to avoid all objection on the score of health from the collection of the night discharge, the storage reservoir should be placed outside the inhabited district, with provision, by air-shafts and check-valves, to prevent sewer gas from being driven upwards towards the town.

That, by means of one or more storm overflows, the sewage should not be allowed to head back above a certain height in the outfall sewer, which it otherwise might do on occasions of heavy rains, floods, or accident to the engines.

That all the sewers should be watertight, so as to prevent the ingress of subsoil water, which would, in some parts of the town, have greatly increased the quantity of diluted sewage to be pumped.

That all the pipe sewers should be laid in straight lines, and that at each change of direction or inclination, and sometimes at intermediate points, air-shafts should be constructed, so as to ventilate, and provide for the inspection of, the entire sewerage system.

That, the town being without a public water supply, provision for flushing the sewers should in the meantime be made by inlets from the Thames, the Ock, and other streams in the town.

That, as the work proceeded, private connections should be made with the new sewers by the contractor, and the old connections

cut off as soon as possible. All cesspools were to be filled up when the works were sufficiently advanced to receive the sewage and to discharge it upon the land.

Lastly, that the engine-power should be in duplicate, each engine to be capable of lifting 50 per cent. more than the sewage when undiluted with surface water. The possibility of adding to the engine-power at a future time, should it be necessary, was considered sufficient to justify a provision which, though ample for the present, might not be sufficient for all prospective requirements.

The works which have been executed in conformity with these principles may be briefly described.

The reservoir portion of the outfall sewer is circular, 3 feet 6 inches in diameter, and 500 yards in length. It has a capacity, with the pump-well chamber, of 100,000 gallons, being somewhat more than one-third of the prospective dry-weather flow of sewage. The main sewer, from the reservoir up to the town, is 18 inches in diameter; it is capable of discharging 2,000,000 gallons in twenty-four hours, being eight times the estimated dry-weather flow. There is thus an ample margin in the discharging power of the outfall sewer for any increase of flow arising from rainfall upon back yards and roofs.

The secondary sewers are nearly in proportion to the outfall sewer, consisting of 15-inch, 12-inch, and 9-inch pipes, according to the duty required of them.

The level of the invert of the sewer at the pumping station is 154·3 feet above Ordnance datum, or about 8 feet below the ordinary summer level of the Thames at Abingdon.

From the pumping station the sewer rises with a gradient of 1 in 880 for the length of the reservoir portion, and from thence the 18-inch-pipe sewer has gradients of 1 in 754 and 1 in 528. It was originally intended to construct a storm overflow in close proximity to the town. This was afterwards, however, placed at the pumping station, at a level of 162·5 feet above Ordnance datum, or 6 inches above the ordinary river level.

The outfall sewer is subject at times to considerable internal pressure from the sewage collected in it, as well as to external pressure from the subsoil water outside. It was therefore strongly and carefully built. It is constructed with two rings of brickwork surrounded with concrete at least 6 inches thick. A ring of cement is interposed between the brickwork and concrete, and between the two rings of brickwork, so as to render the work watertight. Beneath the sewer is a 9-inch drain, which communicated with a

sump. From this sump the subsoil water was continuously pumped, during the construction of the works, by an 8-HP. engine and chain pump.

The lower half of the sewer is for the most part in clay, above which are free sand and gravel, charged with water nearly up to the surface of the ground. The sewer trench nowhere exceeded 14 feet in depth. It was timbered with poling boards in the usual way, the gravel standing well, in spite of the large quantity of water that was continually being pumped out. The pumping went on day and night, the flow of water from the pumps amounting at times to 600 gallons per minute.

At its junction with the reservoir portion of the main sewer, the 18-inch-pipe sewer is provided with a flap valve, for the purpose of preventing sewer gas from passing onwards toward the town. This last-mentioned sewer consists of glazed socket-pipes, carefully jointed and caulked with tarred hemp, and afterwards filled round with Portland cement mixed in equal parts with fine clean sand. As this portion of the sewer is below water-level, the pipes were surrounded with about 6 inches of concrete, and where the sewer passes through clay, with clay puddle, so as to make them watertight. The subsoil drain is laid at a depth of 6 inches beneath the sewer, 9-inch socket-pipes being used for the purpose.

On its course towards the town, the outfall sewer passes under the Wilts and Berks canal, the lower river Ock and the mill head. In crossing the canal the water was drawn off, and 18-inch cast-iron pipes were laid and jointed; the trench was then refilled, and the bottom and banks of the canal carefully reinstated. The other two crossings were effected without difficulty by constructing dams and diverting the water.

At the lower Ock a second sump was established in connection with the subsoil drain, and another engine was kept going, the distance from the first engine being too great to keep down the water effectually. From this second sump the subsoil drain was continued forward beneath the main sewer, as well as for a considerable distance beneath the branch sewers in the town. By means of a communication from the subsoil drain into the lower Ock, the drainage of the low-lying portion of the borough has been considerably improved, as it thus obtains an outlet 5 or 6 feet lower than formerly, when it was maintained at the level of the mill head.

This lowering of the subsoil water greatly facilitated the construction of the sewers in the lower parts of the town, and affected

the water in the wells. It was afterwards found necessary to sink some of the wells a few feet deeper to obtain water.

The manholes (Plate 3) are circular, tapering upwards, the lower part generally of concrete, the upper part of brickwork; they are furnished with cast-iron covers and dirt boxes, with apertures for ventilation. Every second or third manhole is provided with a flushing board fitting into a groove, or with a flap valve.

The flushing inlets consist of 6-inch pipes laid from any convenient manhole to the river, or other source of water-supply. The sewers being watertight, any portion of a sewer above a manhole can be filled so as to serve as a tank to flush the length below. Manholes, capable of holding several hundred gallons, serve to flush the smaller sewers. These manholes are provided with overflows to prevent them from being filled beyond a safe quantity.

The contract for the main sewers was let to Mr. Henry Potter early in 1876; the works were commenced in May, and were pushed on vigorously during the following summer. Wet weather setting in early in the autumn retarded progress; and during the winter of 1876–7 the floods were so continuous that but little advance was made with the work. The sewerage contract was, however, practically completed, and some of the private sewers were connected, in the autumn of 1877, within the stipulated period of eighteen months. The total cost of the outfall and main sewers was £8,750; this sum includes engineer's charges, as well as the cost of a portion of the minor connecting sewers, which were executed by the contractor at schedule prices, up to the boundaries of private property on both sides of the streets.

The work to be done in pumping was fixed at raising 400 gallons per minute 20 feet high. There are two engines, each capable of doing this amount of duty, their aggregate power being equal to about half the maximum quantity that the sewers are calculated to deliver in twenty-four hours. The contract for the engines, independent of buildings, was let to Mr. Frederick Mason, of Ipswich, for £826 8*s.* 9*d.*; they are high-pressure condensing engines, with double action sewage pumps fixed horizontally in line with the cylinder, all on one bed-plate. The buildings were let to Mr. Potter, the contractor for the sewerage works, as an extra work upon schedule prices. Their cost, including sewage screens, well for water, weighing machine, fencing, yard, &c., has been £1,674, making the total cost of the pumping station and engines, £2,500. The coal consumed by the engines is ordinarily rather less than 1 ton per week, and the total annual cost of pumping for the past two years has been somewhat less than £150.

The principal materials used in the construction of the works were, bricks, brought by canal from Swindon, from Slough, and from Reading, as well as local bricks used in the manholes, and blue bricks in the sewer invert. Portland cement and stoneware pipes were supplied by Messrs. Doulton and Sons. Concrete was made in the proportions of 6 parts of gravel and sand to 1 part of cement. Sand and ballast of first-rate quality were found in abundance on the site of the works. The cement was mixed with an equal portion of good clean sand.

The construction of the main sewers and the pumping station, as well as of some of the private connections, was so far advanced by the autumn of 1877, as to admit of the sewage being pumped on to the land. From that date, with but little exception, the Thames has been practically free from pollution by Abingdon sewage; that is, the land first receives it, and after passing through the soil, the effluent water, free from polluting and contaminating matter, flows into the river.

The area of land purchased is more than double what Mr. Denton, in the first instance, recommended. As far as present experience goes, even less land than the quantity originally recommended, viz. 20 acres, would have been sufficient to effectually purify the sewage. Samples of the effluent water, when analysed by Dr. Woodforde, were stated to be less contaminated than the water from some of the wells in use in the town.

The farm with homestead has been let to a tenant from Michaelmas 1878 at £4 10*s*. per acre per annum, the Corporation pumping the sewage.

The pumping engines are managed by one man, with occasional assistance in cleaning, &c. At times one engine, and at others both engines are kept working, generally for seven or eight hours per day, till the reservoir is empty. The latter has proved, with few exceptions, of sufficient capacity to hold all the sewage that collects during the period of cessation from pumping. It is probable, however, that with a more extended use of water, an increase in population, and a possible extension of the main sewers beyond the borough, the hours of pumping will have to be increased.

The sewers in the town, which are 15 inches, 12 inches, and 9 inches in diameter, are kept in efficient working order by flushings once or twice a week. The absolute necessity of attending to this operation with regularity will be obvious from the following considerations. The velocity of the current in a 15-inch pipe, with a fall of 10 feet to a mile, is 145 feet per minute; a 12-inch pipe, with a fall of 12 feet to a mile, produces a velocity of

135 feet per minute, and a 9-inch pipe, with the same fall as the last, gives a velocity of 117 feet per minute; these velocities, however, are only attained when the pipes are at least half full. In a small town like Abingdon, especially one without a proper water-supply, the flow of sewage is seldom sufficient to fill the sewers one-half, or even one quarter full, and the velocity of the current is in consequence much reduced. And what is of equal, if not of greater, importance, the bulk, or sectional area of the sewage flow, is smaller, and floating substances become stranded in the sewer.

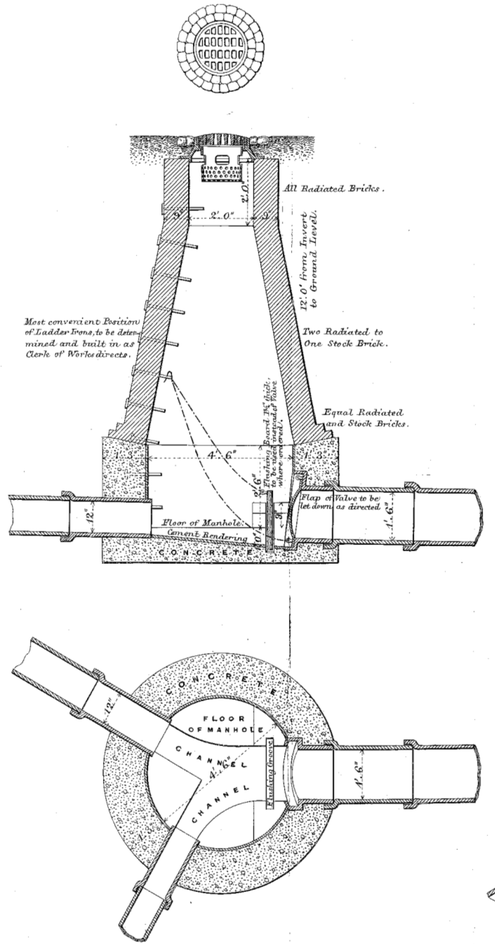
In Abingdon, flushing is the more easily effected owing to the fact that road detritus is not carried into the sewers—a feature worthy of consideration in the self-cleansing power of sewers. That the sewers should be made watertight is also essential for effective flushing, for with the escape of the sewage into the surrounding soil, the effect of the operation is much reduced. The injury done to property by undermining, consequent upon leaky sewers, is, in the opinion of the Author, great in proportion as it is hidden and unknown. Damp walls, rotten joists, and unwholesome emanations are, no doubt, frequently attributable to this cause.

The ventilation of the sewers has been effected by numerous shafts. These shafts maintain a constant interchange of foul air, generated within the sewer, for fresh air from without. Changes of weather, of wind, or of temperature, affect sewer ventilation; the most active agent, however, in driving out foul air, and replacing it with fresh, is perhaps the variation in the flow of the sewage itself. Whenever a sewer is flushed, foul air is discharged at the ventilators, and as the water subsides, fresh air is drawn into the sewer. This expulsion of sewer gas, though objectionable in narrow streets, is, however, safer for the public health than that it should find its way insidiously into dwellings. Ventilating pipes, carried up above chimneys and windows, should be adopted in narrow streets and thoroughfares in the place of ordinary manholes. The Author has had opportunities of visiting Abingdon since these works were completed, and has had the satisfaction of seeing that the flushing and other arrangements are attended to, and that the Borough Surveyor is still keeping records of the coal consumed by the engines, and of other details confirmatory of the foregoing statements.

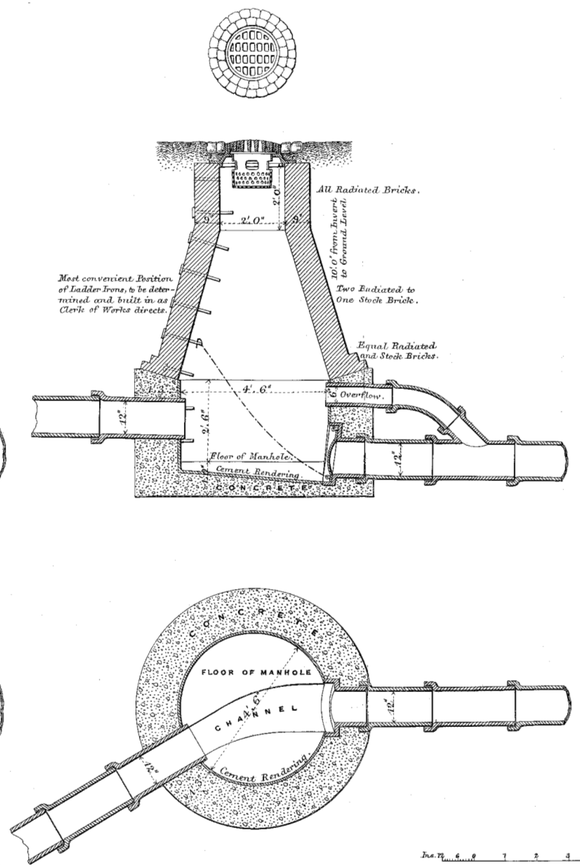
The Paper is illustrated by several drawings, from which Plate 3 has been prepared.

ABINGDON SEWERAGE.

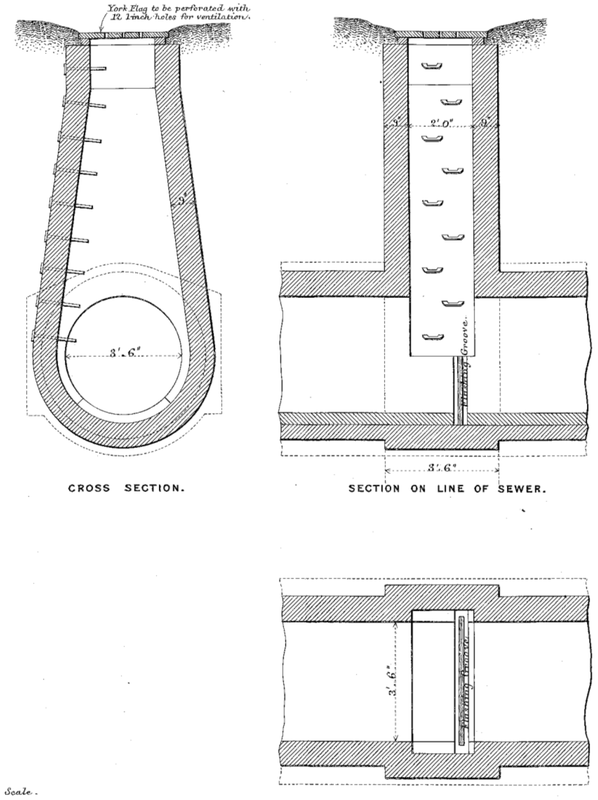
MANHOLE, WITH 18" FLUSHING APPARATUS.



MANHOLE, WITH 12" FLUSHING APPARATUS.



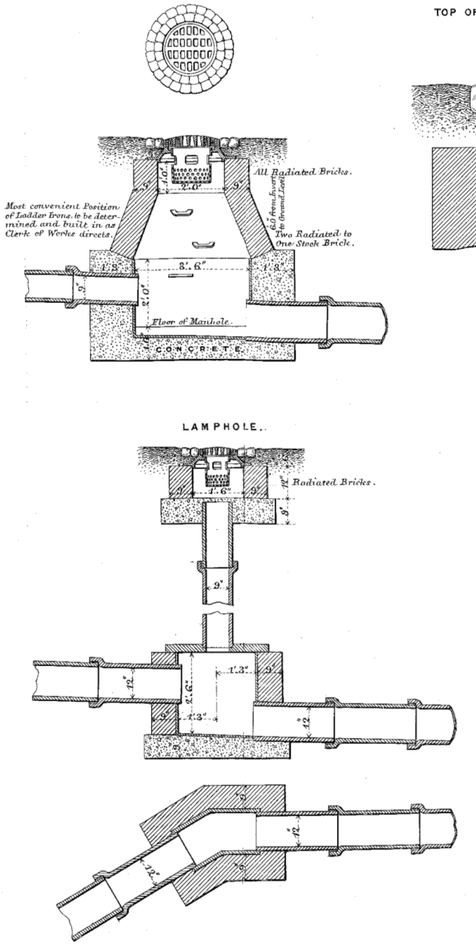
MANHOLE ON 3'.6" BARREL SEWER.



Scale.

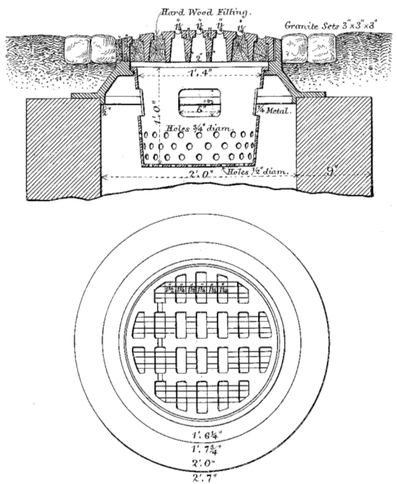
Ins. ft. 6 8 1 2 3 4 5 10 Feet

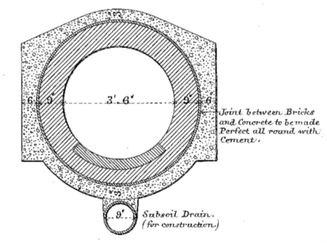
MANHOLE, WITH CHAMBER 3.6" DIAMETER.



TOP OF MANHOLE, FOR PUBLIC ROADS AND STREETS.

(Frame and Grate 302 lbs. Dirt Box 44 lbs.)





CROSS SECTION OF 3'.6" BARREL SEWER.

C. F. GOWER, DEL.

THOS KELL & SON, LITH. 40, KING ST. COVENT GARDEN.