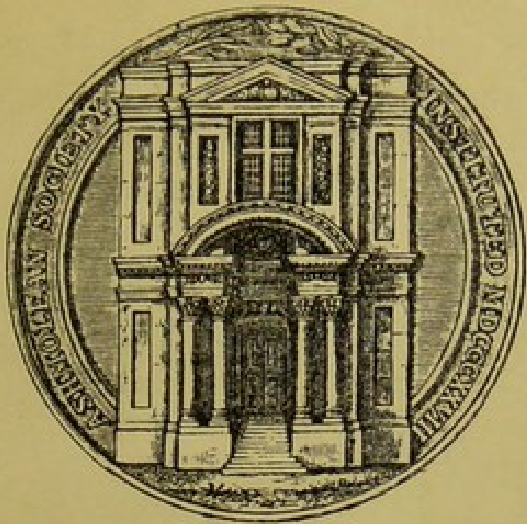

THE

MAIN DRAINAGE OF OXFORD

BY

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THE MAIN DRAINAGE OF OXFORD.

Introduction.

THE drainage question has much exercised the public mind of Oxford for the last quarter of a century. Several engineers have been consulted and employed upon its solution, and it has also engaged the attention of many distinguished members of the University, who, with others desirous of remedying the unsanitary conditions which prevailed, have written and worked to that end. Looking, however, to the fact that it must have been evident from the first that the requisite works would be very costly, entailing a heavy burden of taxation upon more than one generation, and also bearing in mind the conflicting opinions upon sewage disposal, it is not perhaps to be wondered at that the guardians of the public purse for some years held back from an expenditure of such magnitude, although convinced that 'something must be done,' and wishing to do it. But at length, under pressure from the Thames Conservancy Board, who had obtained parliamentary powers to impose large penalties upon towns continuing to foul the river with sewage, a move had to be made.

The Local Board decided to adopt what is known as the 'separate system' of drainage, and to utilize the sewage in irrigation, and the task of designing and executing the works ultimately fell upon me.

I would remark, in passing, that the delay here and in other places is not, in my opinion, an unmixed evil, for of late years the subject of town drainage has come to the front so prominently, that much study has naturally been given to it, and sanitary authorities have become more alive to its importance, and consequently more ready to vote the supplies. It may, therefore, safely be said that we are now profiting by the experience gained by past successes and failures, and should know better the true principles to be applied. At the same time it must be owned there is a reverse side to the picture, in the extraordinary increase in cost of materials and labour during the same period.

Explanation of separate system.

It is well that I should here offer a few words in explanation of the 'separate system.' An entire separation of rainfall and other clear water from the sewage proper would involve two drains for every house. At first sight this seems desirable, especially in a town where (as in Oxford) all the sewage and surface-water (if sent into the sewers) has to be raised by pumping at the outfall. Theoretically it is feasible enough, but there are several practical obstacles to the rigid application of the principle to those parts of a town where the houses are continuous and are already provided with single drainage.

The 'separate system' here therefore means the exclusion from the sewers of the rain-fall on the streets and roads and front part of the roofs of the continuous houses and buildings, and entire separation only in the cases of detached houses, churches, colleges, and other public buildings. Thus it is estimated that about 100 acres will contribute surface-water to the sewers, the total area of the city and suburbs, including college gardens and other open spaces adjoined or surrounded by buildings, being something like 2,000 acres, and the length of streets and roads in the Local Board district 33 miles, the surface-water of all which, except the

100 acres, will find its way into the rivers as heretofore.

Nature of subsoil.

The subsoil in which the sewers have been laid consists for the most part of the 'Oxford Clay' and gravel-beds resting upon the same.

Physical difficulties presented.

Oxford, from its complete intersection by rivers, streams, etc., and from so much of the town being built on the low ground bordering these streams, presents some amount of difficulty to a scheme which shall bring all the drainage to a common point, and at the same time ensure the exclusion of subsoil water from the sewers. In effecting these objects, many features of engineering interest arise.

Old sewers.

A few of the existing sewers were incorporated with the new works, and supplied with ventilators and flushing apparatus, but the majority of them were devoted to the surface drainage, and will continue to discharge into the streams at various points. The culverted streams, known as Trill Mill Stream and Shirelake Ditch, also remain for surface drainage. Some of the older drains were necessarily broken up, and new pipe surface drains substituted. Among the drains abolished was one situate for a great part of its length underneath living-rooms, domestic offices and other buildings. A kind of elongated cesspool, more or less filled with fermenting organic matter, and inhabited by innumerable rats, had thus been long in existence in uncomfortable proximity to dwellings, into which it doubtless ventilated. (See Plate 5, Fig. 15.)

Length of sewers.

The total length of new sewers and surface drains is $32\frac{3}{4}$ miles; of this length $7\frac{3}{4}$ miles are constructed of brick, and 25 miles of stoneware pipes.

Form of brick sewers.

The former are egg-shaped, of the usual proportions, viz.,—

Radius of invert arc being . .	1
Radius of semi-circular arch . .	= 2
Radius of side arcs . . .	= 6
Height of sewer	= 6
Greatest width	= 4

This form is generally considered the most advantageous, as it gives the greatest hydraulic depth with least frictional resistance to the flow.

Sizes.

The sizes range from 4 ft. 6 in. by 3 ft. down to 2 feet by 1 ft. 8 in.

Resting places.

Those 3 ft. high and upwards admit of a man walking through, and ventilated resting-places 6 ft. high are formed in them at suitable intervals between the points of entrance.

Pipe-sewers.

The pipe sewers are circular, their diameters varying from 18 inches to 9 inches.

Route, sizes, and gradients of main arterial sewers.

Besides the Outfall Sewer, there are five main arterial lines, which intercept and collect the discharges from the street sewers, viz.,—

The Western Sewer.—From Osney to the commencement of the Outfall Sewer near the eastern end of the Broad Walk, via Park End Street, County Gaol premises, Paradise Square, St. Ebbe's, St. Aldate's, and Christ Church Meadow.

At the upper end its size is 2 ft. by 1 ft. 4 in., increasing in its downward course successively to 2 ft. 3 in. by 1 ft. 6 in., 3 ft. 3 in. by 2 ft. 2 in., and 3 ft. 6 in. by 2 ft. 4 in.

Its gradients are at the rate of 6·41 ft. and 3 ft. per mile.

North-western Sewer.—From Cranham Street, Jericho, through Worcester College gardens and the Canal Wharf, to a junction with the Western Sewer at the New Road.

Size—3 ft. by 2 ft., and 4 ft. by 2 ft., and gradients 10·56 ft., 8·80 ft., and 5·28 ft. per mile.

North-eastern Sewer.—From Park Town, across Norham Manor and the Parks, past Holywell Church, through Long Wall Street, High Street, and Merton Field, to a junction with the Outfall and Western Sewers near the Broad Walk.

Size—2 ft. 6 in. by 1 ft. 8 in., 3 ft. by 2 ft., and 3 ft. 6 in. by 2 ft. 4 in., and gradients 13·20 ft., and 10·56 ft. per mile.

Eastern Sewer.—Through St. Clement's and Cowley Place to the Outfall Sewer, near the east branch of the Cherwell.

Size—2 ft. 3 in. by 1 ft. 6 in., and 3 ft. 3 in. by 1 ft. 8 in. Gradient 5·28 ft. per mile.

Hincksey Sewer.—From the village of New Hincksey across the valley to join the Outfall Sewer.

Size—2 ft. by 1 ft. 4 in., and gradient 5·73 ft. per mile.

(This was the most expensive part of the whole scheme in proportion to the population served by it, but it was made necessary by the recent annexation of New Hincksey to the district of the Local Board, to bring that suburb under sanitary control and guard the source of the Oxford water supply from contamination.)

Outfall sewer, route, size, etc.

The Outfall Sewer commences at the east end of the Broad Walk, crosses the Cherwell valley, and passes under the Christ Church cricket-ground and fields adjoining, beyond which it follows the line of the footpath to Iffley, passing below that village and close to the Mill, and terminates at the Pumping Station, against the Thame and Aylesbury Railway where that line crosses the river.

Its size is 4 ft. by 2 ft. 8 in. as far down as Iffley Mill, and beyond that point 4 ft. 6 in. by 3 ft.

The total fall from end to end is 4·84 ft. by an uniform gradient of 2·31 ft. per mile.

The smaller section has a discharging capacity of 5,000,000 gallons per twenty-four hours, when running full to springing of arch; that being the condition giving the greatest hydraulic mean depth, and, consequently, velocity of current.

(For the direction, depth, fall, and form of construction of the foregoing Main Sewers, see Plates 1, 2, 3, and 5.)

Branch sewers, gradients.

The falls in the branch sewers range from 6·60 ft. to 52·80 ft. per mile, but the great bulk are between 10 ft. and 25 ft. per mile. The principle of giving the greatest fall at the upper end, and gradually lessening it as the sewers increase in size and quantity of flow, has been followed on every line, as far as the conformation of the ground would allow.

Ventilation.

Upwards of 500 manholes and lampholes have been built, and ventilation is effected by gratings in their covers at the ground level. All constructions rising above the ordinary height of any sewer, so as to form receptacles for gas, are ventilated by special pipes leading to these gratings. It is found by experience that a good current of air is maintained in the sewers, sometimes in the direction of, and sometimes contrary to, the flow of sewage. The manholes appear to alternate in their action, being at one time upcast, at another downcast shafts. I presume this is governed by direction and force of wind, barometric pressure, temperature, position of shaft, quantity of flow in sewer, and other varying conditions.

Positions of manholes, etc.

The manholes and lampholes are placed at the summits and at all junctions of sewers, also at every intermediate change of horizontal or vertical direction. Light wrought iron ladders are built in the manholes for access to the sewer. (Plate 4, Figs. 5, 6, 7, and 8.)

The covers are circular, and are composed of cast iron open boxes with central grating (as above mentioned). The annular space between the grating and the circumference is divided radially, the panels thus formed being filled with wrought oak blocks, secured by screws to the bottom plate. These covers fit into fixed cast iron frames, from which are hung circular wrought iron boxes to catch road detritus, etc. falling through the gratings. The dirt boxes are taken out and emptied periodically.

Covers.

All pipe sewers and those of brick which are less than three feet high, are laid in straight lines between the manholes and lampholes, so that by entering any one of the former and placing a lighted lamp at the bottom of the next, or in the next lamphole (as the case may be), an examination can be made, and the presence of an obstruction (should such occur) detected.

Straight line principle.

Another advantage of the straight lines is that when openings are needed for the purpose of making house connections or otherwise, the exact line can readily be found by ranging from one cover to the next, and as the positions of the junction pipes are recorded in books kept for that purpose, they are also to be found by longitudinal measurement. Thus no experimental trenches should be needed.

The junctions of the large brick sewers are formed by bellmouths: that is to say, the side walls of the two approaching sewers are continued from their point of contact by a tongue or cutwater of brickwork diminishing in height and thickness, and dying out to a point on the bottom at the junction of the two centre lines, which are tangential to each other. Thus the two currents join without obstruction or disturbance. This space is covered by a semi-

Bellmouths.

circular arch spreading outwards and upwards in a bell-shape so as to embrace both sewers.

Junctions of pipe sewers.

The curves necessary to unite the straight lines of two or more pipe sewers, are made in the brick bottoms of the manholes, which are miniature bellmouths minus the arch, and a sudden fall of an inch or two is given in each case from the smaller sized pipes into the larger. (Plate 4, Fig. 6.)

Compound pipe junctions.

There are numerous instances of branch pipe sewers having to fall into mains many feet below them in level. In order to maintain the straight-line principle here, but at the same time to prevent the branch sewage from shooting out far up in the junction manhole, which would, if allowed, practically cut off the deep main from examination, I have devised a special arrangement. On the line of the lateral sewer, at a few feet from the junction, a downward branch has been put in, and pipes laid from it at a descending angle of about 45 degrees to the bottom of the manhole, while other pipes are continued straight forward at the proper gradient into the manhole at the higher level. Thus the sewage falls down through the descending pipes, while the line of sight through the branch sewer is provided for by the upper line of pipes. (Plate 4, Fig. 7.)

Steps at junctions.

Where however, under the like circumstances, the branch sewer carries the drainage of a considerable area, so that a damaging amount of scour might be caused by its sudden descent, as above described, the fall is broken by a flight of steps built of granite or of blue Staffordshire bricks, and the sewage ultimately enters the main with but little velocity. (Plate 4, Fig. 8.)

In those parts subject to the surface being flooded the manholes have been carried above the highest recorded flood-level, and an embankment formed round them, so that no flood-water may enter the sewers.

Manholes embanked.

Where the principal mains pass through streets, but had to be laid deeper than would have been necessary for local use, I have carried up from them at intervals of about 40 feet, a line of pipes to a brick chamber having four inlets at the level required, so that the drainage of several houses may converge and enter the sewer at one point. (Plate 5, Fig. 16.)

Junction chambers for house drainage.

St. Clement's is a notable example of the inconvenience and cost which would have been caused but for some such arrangement, for there, on account of branch sewers having to be laid against the great fall of the side streets which extend down to the river, the main is twenty-two feet deep.

Although until recently the Outfall and some other principal sewers were incomplete, I have been enabled by making temporary connections at certain points between the old and new sewers, where their respective levels allowed, to make use of the existing outlets into the Isis and Cherwell, and in this way accommodation has been provided for parts of the district hitherto undrained, and the use of cesspools has there been discontinued.

Temporary outlets.

Some hundreds of house-drains have also been transferred from the old to the new sewers, thus gaining the benefits of ventilation and flushing.

The use of these temporary outlets is now discontinued, as will hereinafter appear, but arrangements are made by which, in the event of any unforeseen contingency, a large proportion of the drainage could again be disposed of by their aid.

At the head of every line of sewer, the manhole also serves as a flushing shaft Water is laid on from the nearest main by a $1\frac{1}{2}$ in. pipe and screw-down tap. At the bottom of the shaft is a cast iron flap, which when lowered closes the sewer. The tap being then opened, a column of water accumulates in the shaft, and is suddenly released on raising the flap by a chain from the top. (Plate 4, Fig. 5.) In the intermediate manholes, grooves are left in the brickwork for the insertion of wooden stops, by which a head of sewage is obtained varying from 18 inches to 3 feet, according to circumstances. When the stop is removed a good scour is the result.

Flushing.

A greater flushing power than either of these is however provided in the Outfall, and other principal sewers having slight gradients, viz. wooden penstocks or doors for ponding up the sewage, 5 ft. 6 in. high, are placed so as to slide up and down in grooves. These penstocks have rack and pinion gearing with side pulleys to steady their motion, and spindle passing through girders to the top, whence they are raised and lowered with a key. The penstocks are fixed in such a position as to allow the sewage to flow over them, in the event of any neglect in opening them at the proper time. They are also useful for laying the sewers partially dry, section by section, for a few hours at a time to facilitate inspection.

These several appliances are found to keep the sewers quite clear, and they also conduce to ventilation, by rapidly expelling the air through the ventilators in front of the flush, and drawing in fresh from those behind

Method of setting out gradients.

An explanation of the method by which accuracy is insured in laying in the work to the proper gradients may be interesting. It is as follows :—

At convenient intervals posts are fixed in the ground on either side of the trench, and boards with their upper edges planed straight are secured to them horizontally across the trench at heights calculated and carefully levelled in from bench marks or stations of ascertained altitude from datum line. Half the length of these boards or sight rails is painted black, and half white, to assist the sight. Rods, with cross bars nailed on at the required height for ground work, brickwork, etc., are then held upright in the trench between these sight rails, and the lower end of the rod indicates the true level when the top of the cross bars coincides with a line of sight taken over any two sight rails. This process is repeated with every stage of the work until the pipes are got in, or if it be a brick sewer, until the centre bottom course of the inner ring of brickwork is laid and proved; after which the sewer is built to the proper form by wooden moulds and centres.

The fall of the Outfall Sewer being only about half an inch in 100 feet in length, this operation required some delicacy of management. The vertical posts were therefore set in concrete, and the sight rails were braced to them diagonally on both sides. Even then it was found necessary to check them with the level almost every day, and twice per day in some parts, as the exhaustion of the subsoil water caused the ground to contract and the sight rails to sink.

The brickwork of the sewers was set in cement mortar, composed of equal parts of Portland cement and sand.

Brickwork and concrete.

Concrete was used for filling in the spandrils between the vertical sides of the trenches and the egg-shaped brickwork. It was composed of one part of cement to six parts of gravel, which last-named material was fortunately excavated in abundance and of fitting quality.

As so much depended upon the cement, it was tested with a dynamometer to prove its resistance to tensile strain, and its weight and capability of setting hard both in air and water were also tried.

Cement testing.

The bricks were mostly of local manufacture, but the inner ring of the principal sewers was of gault bricks made near Cambridge.

The stoneware pipes were generally jointed in cement mortar, with sometimes a band of clay puddle in addition. In many parts, however, the trenches were so wet that these joints could not be made even approximately water-tight, and I therefore resorted to Stanford's patent joint. This invention consists of a ring of artificial asphalte convex in section, cast on round the spigot ends, and a similar concave lining within the sockets, so that when inserted one within the other by the aid of a little grease, a turned and bored joint is practically made, and the subsoil water is almost entirely excluded.

Jointing of stoneware pipes.

Stanford's joint.

The convex and concave form of the joint allows of a little settlement or other movement after the pipes are laid, without destroying the contact. Such a movement would open a cement or clay joint. Another advantage belonging to this joint is, that when the excavation is finished, the pipes can be quickly laid, and the filling in immediately done, as there is nothing that requires to set.

One of the most noticeable features of the works was the great amount of subsoil water to be contended with. This will be understood when it is stated that eight miles of sewers are laid from 1 to 11 feet below the average summer water-level, and in high floods nearly ten miles are under hydrostatic pressure due to a head varying between 1 and 14 feet.

Subsoil water.

In the high-lying parts of the district too, several miles of sewers are under the like pressure, as they cut through ridges of the clay, and beds of gravel within its undulations, which form natural reservoirs, and are full of water. These basins were at the time tapped, and I have reason to believe that some are still in communication with the water-bearing strata in the valley; but, generally speaking, the outlets temporarily made through the clay ridges have closed themselves, and the water regained its former height. To exhaust during construction these sources of unwished-for water-supply, portable engines were employed, of from seven to twelve nominal horse power, driving centrifugal and chain pumps, and occasionally large hand pumps worked by six or eight men were added. At the period of greatest activity, I calculated that five million gallons of subsoil water were daily pumped. The effect of this suction was to drain nearly all the wells in Oxford, and as a remedy for the temporary inconvenience, stand-pipes were erected here and there in the streets and courts, and water from the City Water Works laid on.

Pumping apparatus.

Wells drained.

The trenches were drained as follows:—In convenient situations for getting rid of the water, shafts or wells (technically called sumps) were sunk near to and connected with the line of trench, but 6 or 8 ft. deeper, and the pumps were placed therein. Stoneware pipes, generally of 12 in. diameter, were laid underneath the sewer to these pumps, always keeping a little ahead of the brickwork, etc., so that the subsoil water was thus caught, and carried away at a lower level than the bottom of the concrete and brickwork, which was then built in a dry trench, a condition indispensable to sound work. Generally the sewers

Draining trenches of subsoil water.

were constructed right and left from a sump, therefore one section was going down hill. The conditions then were that the sewer and pipe underneath must fall in opposite directions. This was managed by beginning the latter three or four feet below the former, and in boning the pipe in with the sight rails and rod previously described, a moveable slide was placed on the farther of any two rails between which the boning rod was being held up, and the sight taken from the top of the slide back to the nearer rail. Thus if the sewer fell one inch in the distance between the two sight rails, and the pipe was required to fall one inch in the opposite direction, the height of the slide would be two inches.

Cement rendering upon the brickwork of the deep main sewers was relied on for keeping out the subsoil water.

Mode of constructing sewers to keep out subsoil water.

To the Outfall Sewer it was applied as follows:—A continuous skin of cement half an inch thick was formed between the concrete backing and the outer ring of brickwork, and over the outside ring of arch; also a second cement skin of the same thickness between the two rings of brickwork. (Plate 5, Figs. 1 and 2.) Very great care and special precautions were necessary to insure a proper union between that part of the cement skin laid on the side walls and that round the arch, as it is difficult to exclude all grit and dirt when removing the lower moulds and fixing the arch centres. For this reason sewers built in any way are proverbially more liable to leakage about the springing of the arch than in any other part. The cement for rendering was guaged, two parts cement to one part sand, and was laid on in three coats, finishing with neat cement. There are two reasons for this strong mixture, the first being the rapidity with which it sets and allows the next stage of the work to go on, thereby saving in pumping and other ways; and the second is, that the nearer the mixture approaches to neat cement, the nearer it is to being water-tight, by the interstices between the grains of sand being more completely filled by the finer particles of cement. The other main sewers for which this plan was used, being smaller and not under quite so great a pressure, received but one cement skin instead of two. (Plate 5, Figs. 3, 4, 5, 6, 9, and 11.)

The result of the construction I have described has been satisfactory, the total leakage being very trifling.

Leakage.

What leakage there is, comes almost entirely from the branch pipe sewers, where it was so difficult to make water-tight joints, as before mentioned.

At the Pumping Station the Outfall Sewer discharges into a large well, the floor of which is 2 ft. 6 in. lower

Straining well.

in level. In this well are two gratings of $1\frac{1}{2}$ inch and 1 inch mesh respectively, through which the sewage has to pass before reaching the pumping well. Communication between the two wells can be cut off at pleasure by closing a cast iron penstock by means of gearing and counterbalance weight. The foundation of this well was one of the greatest difficulties on the works. The preliminary borings had indicated the Oxford Clay at seven feet from the surface at a spot thirty or forty feet distant, but a remarkable dip occurs here, for a depth of fourteen or fifteen feet was reached without finding any sign of it. The bottom was a quick-sand which would not bear the weight of a man, and piles ten feet long had to be driven, with sills and a continuous platform of two courses of 3 inch planking spiked down to them, upon which the superstructure was raised.

Having had occasion since to sink a smaller water-tight well near, I hit upon a plan of avoiding the trouble caused by the quicksand. When the excavation was finished, I caused a platform of double 3-in. planking, 8 ft. square, to be framed above ground, with strong ring bolts in each corner for lowering it. The joints were caulked and pitched, and side boards being nailed on, the platform then formed an open box 4 inches deep. This was filled with cement mortar, and when it was set hard, the whole contrivance, weighing about 1 ton 15 cwt., was lowered by shear legs and pulley blocks into the hole. A solid and water-tight floor was thus obtained upon which to build.

Foundation of small well.

Soil of a similar nature was found in cutting through the high ground below Iffley Rectory. The lateral pressure here was so great that the longitudinal timbers had to be doubled, and five horizontal and diagonal transverse struts were required in a 14 ft. length. Even then the ground slipped a little, pressing the ends of the struts 1½ in. into the horizontal timbers, which in the spaces between the struts bent inward so much as now and then to snap some of the fibres with a sound like a pistol-shot, causing an unpleasant impression among the men in the trench. No accident however happened, but it was considered unsafe to attempt the removal of any of the timber, which was accordingly buried. A crack showed in the hill-side at some distance from the work, and travelled along parallel with it, causing extensive damage to two houses.

Iffley cutting.

There are six crossings under the Isis and Cherwell, and one under the Canal, besides several under minor streams. The special constructions designed for this purpose are of cast iron, surrounded by concrete. Two of the river crossings are inverted syphons, viz. under the main navigable channel near Saunders' Bridge and at Osney. (Plate 4, Fig. 1.) These syphons consist of

River crossings.

a vertical brick shaft on either side of the river, the two being united by a straight line of pipes. A fall of a few inches is given from inlet to outlet, and the shaft at the outlet end goes down a foot below the pipes, to receive any sediment that may accumulate. Sluices are provided for flushing the syphon, and for detaining the sewage while it is pumped out for examination, special arrangements being made for this.

In order to comply with the requirements of the Thames Conservancy Board, the Saunders' Bridge syphon had to be laid so low that the sumps on the Oxfordshire bank were 20 ft. deep, and the volume of subsoil water was therefore so great as to necessitate the employment of three engines and pumps, lifting together about 3,000 gallons per minute, at this spot. This strong draught of water caused a quantity of gravel to blow out into the sump, making a cave under the completed part of the sewer, 20 ft. long, 3 ft. wide, and about 4 ft. high, leaving the work to stand by side friction against the earth and the cohesion of its own materials.

The cave was filled up with concrete.

For the two Cherwell crossings, (Plate 4, Fig. 3.) the headway being limited, tubes were put in 1 ft. 10 in. high by 3 ft. 9 in. wide, with segmental top and bottom. Their cross sectional area is 6·25 superficial feet, which is about one-fifth in excess of that of the Outfall Sewer exclusive of the arch. The form of tube laid under the two branches of the Isis between the Militia Barracks and the Railway Station is a modification of the egg-shape, the full headway for a semicircular top not being attainable. (Plate 4, Fig. 2.) The internal dimensions are 2 ft. high by 2 ft. wide. The sewers passing under the Canal and Trill Mill Stream are of brickwork and concrete, covered by cast iron segmental plates. (Plate 4, Fig. 4.)

For these river crossings timber dams were pitched, enclosing about one-half the width of the stream at once. It was found a troublesome matter to drive the piles so closely together as to exclude the water, on account of stones, etc. in the river bed, and the interstices were closed by putting down clay, cinders, and litter outside, and then pumping out the water inside as quickly as possible, so that the clay, etc. was forced in and detained between the piles. The frequent floods did much harm by causing a strong scouring action round the feet of the piles, through an increased quantity of water driving through a diminished channel. The dams were frequently blown up in this way, causing much delay, notably at Saunders' Bridge. The iron tubes and plates used in these crossings were cast with external flanges, bolted together, a ring or washer of vulcanized india-rubber three-eights of an inch thick being placed between the flanges to insure contact. An external fillet of cement was also run round each joint. The tubes were first lowered one by one on to transverse brick piers built in the centre of each length of tube and accurately adjusted for line and level. After the joints were finished, the open end of the tube was sealed by a brick wall, and the water admitted to the dam, so as to place them under external hydrostatic pressure. No leakage occurring, the water was again withdrawn and the tubes surrounded with concrete, after which the river bed was made good and the dam removed.

Tunnel under Castle tower.

In order to avoid another river crossing, a tunnel 202 feet long was driven under the old tower of Oxford Castle and other premises of the County Gaol adjoining, so as to carry the Western Sewer from the New Road into the St. Ebbe's district. This tunnel is considerably below the bed of the river and within six feet of it horizontally. At the same distance both horizontally and in level on the other side of the tunnel, is an underground tank, from which the prisoners lift the water by turning a capstan within the tower, communicating motion to a set of pumps. The cast iron pipe which feeds the tank from the river, passed through the tunnel, and as its level did not admit of a brick arch being turned under it, a curved piece of boiler plate was substituted. The tread of the prisoners at the capstan and the sound of the mill wheel could be distinctly heard, but although the tunnel cut through the old moat of the Castle and water was so close on both sides, very little found its way in, except some river water between the foundation stones of the tower. This water was dealt with by fixing sheets of zinc overhead, with pipes leading down at intervals in the sides of the tunnel into the pipes beneath the sewer. Very strong timbering was necessary, the whole of which was left in, and the space between it and the sewer was filled in solid with brick work and concrete. A slight subsidence was detected in one side of the tower foundation, which caused its summit to heel over to the extent of about two inches. The line for this tunnelling could not be set out in the ordinary way, being hemmed in by the river and high buildings and walls, therefore the direction had to be obtained by making an exact survey and ascertaining the position by diagram and calculation of angles.

G. W. Railway crossing.

A tunnel was also driven under the Great Western Railway near the Station, and the timbering and other work were similar to that described above. In this case, although the passing trains could be both heard and felt, no subsidence occurred. (For these tunnels, see Plate 5, Figs. 13 and 14.)

House drainage connected.

The house drainage of about three-fourths of Oxford has been connected with the new service of sewers, so that comparatively little remains to be done in the town.

Arrangements having been made with the Thames Conservancy Board to allow the sewage to be pumped for the present into the river at the site of the Pumping Station, the temporary outlets into the river at Oxford have during the last two months been gradually disused, and the Outfall Sewer brought into operation. The fouling of the rivers under the walls of Oxford has therefore to a great extent ceased.

Pumping into river.

The temporary pumping power supplied consists of a portable double-cylinder engine of fourteen nominal horse power, and a 12-inch centrifugal pump driven by a belt from the fly-wheel of the engine. At a fair working speed of about ninety revolutions of engine, 2,300 gallons of sewage are discharged per minute. Double this duty can be done if required, though at a waste of engine power. At present about 1½ million gallons are dealt with daily.

Temporary pumping power.

The water supply of Oxford is something over 2,000,000 gallons per day, that is 60 gallons per head of the entire population, and in very wet weather the 100 acres before mentioned as contributing surface-water to the sewers would yield about the same quantity. Therefore, if the present amount of water continues to be pumped into Oxford, the ultimate *wet weather flow* will be something like 4,000,000 gallons per day.

Water supply.

Ultimate wet weather flow.

It is however right to add that the high service reservoir now being constructed at Headington, and the measures being taken by the Waterworks management to stop the loss caused by defective fittings and wilful waste on the part of the users, should have the effect of reducing their supply one-half or thereabouts, to the great saving in

Measures for stopping waste.

outlay under the heads of both Water Supply and Main Drainage.

Overflow outlet.

An overflow outlet is provided at the Pumping Station, which in the event of failure of the machinery, would relieve the main sewers at such a level as not to flood any of the basements in Oxford, nor to interfere with the proper working of the street sewers.

Pumping station, irrigation works, etc.

To this time the works are only completed as far down as the Pumping Station. I will not therefore enter into details as to the permanent pumping machinery which will be erected, or the works of irrigation to be carried out, but will content myself with stating generally that about 370 acres of land have been purchased in the parishes of Littlemore and Sandford, to connect which with the Pumping Station, a rising main of cast iron pipes 1½ miles long is required (and has lately been commenced); the sewage will have to be lifted a height of 57 feet, and the engines will probably be from fifty to sixty horse power in duplicate.

If that part of the works should be considered of sufficient interest, I shall be very glad on a future occasion to contribute another paper descriptive of them.

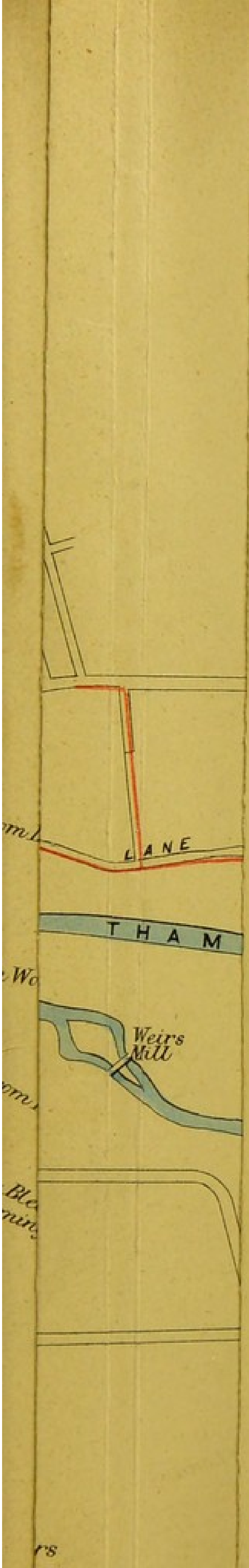

LANE
THAM
Weirs
Mill

PLATE I.


OXFORD MAIN DRAINAGE.
GENERAL PLAN.
SCALE
ST CLEMENTS
To Headington
To Cowley
COWLEY ROAD
IFFLEY ROAD
Cowley Church
LITTLEMORE
THE NORTH EASTERN SEWER
PARKS
PARK TOWN
Holywell
Mill
Ch. Ch. Cricket Ground
EASTERN SEWER
OUTFALL
LANE
THAMES
SEWER
IFFLEY
Mill
Ch. Ch. Meadow
RIVER
HINKSEY SEWER
ST GILES
Cathedral
ST ALDATES
Folly Bridge
Weirs Mill
PUMPING STATION
ISIS
KENFORD MILL LANE
NORTH WESTERN SEWER
WALTON STREET
JERICHO
CANAL
NEW HINKSEY
WATERWORKS
G. W. R.
ST THOMAS'S
Station
OSNEY
Mill
To Abingdon
Note. - Only the Principal Main Lines of Sewers Shown on this Plan.

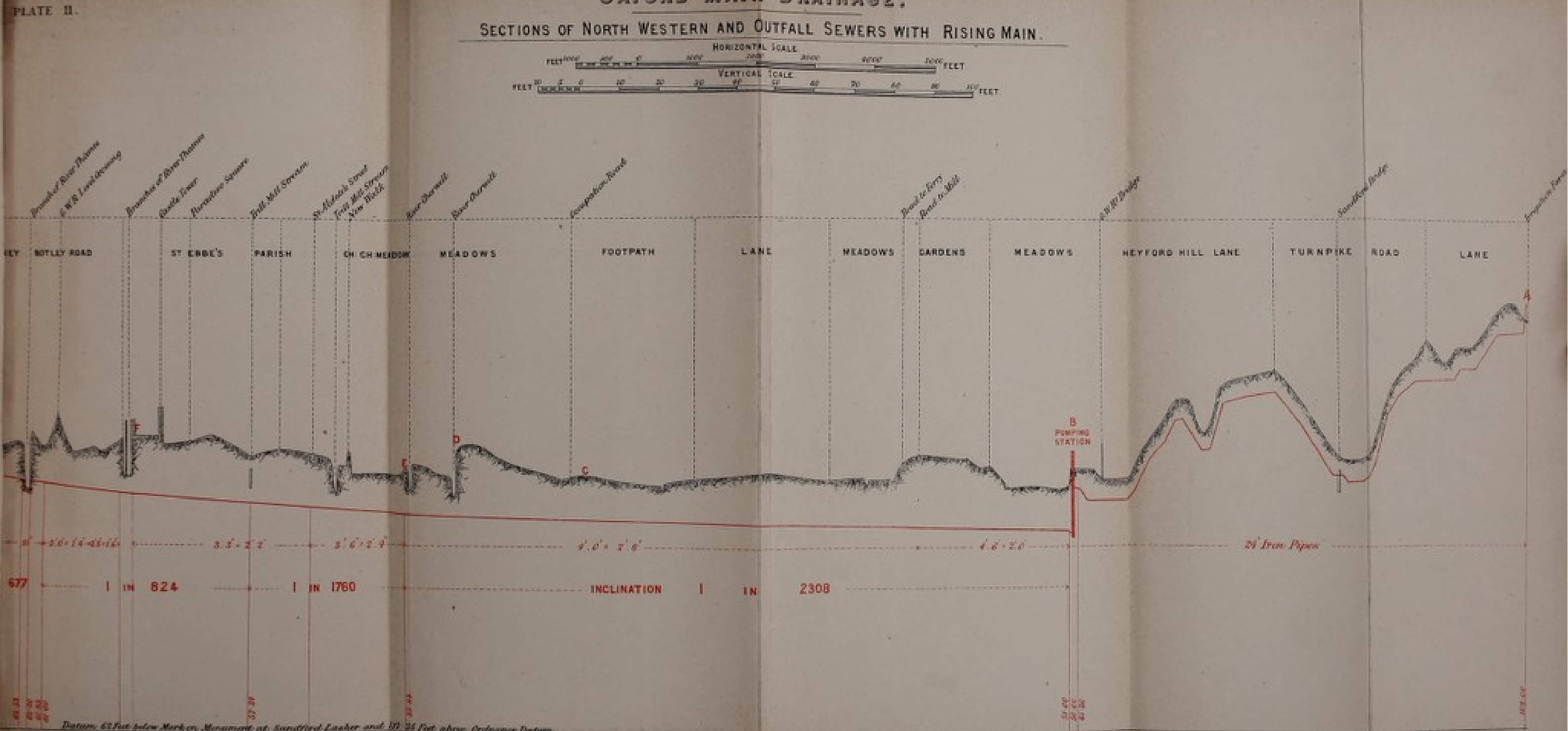
PLATE II.

Oxford Main Drainage.

Sections of North Western and Outfall Sewers with Rising Main.

Horizontal Scale.

Vertical Scale.



Datum 62 Feet below Mark on Monument at Sandford Lasher and 171·25 Feet above Ordnance Datum.

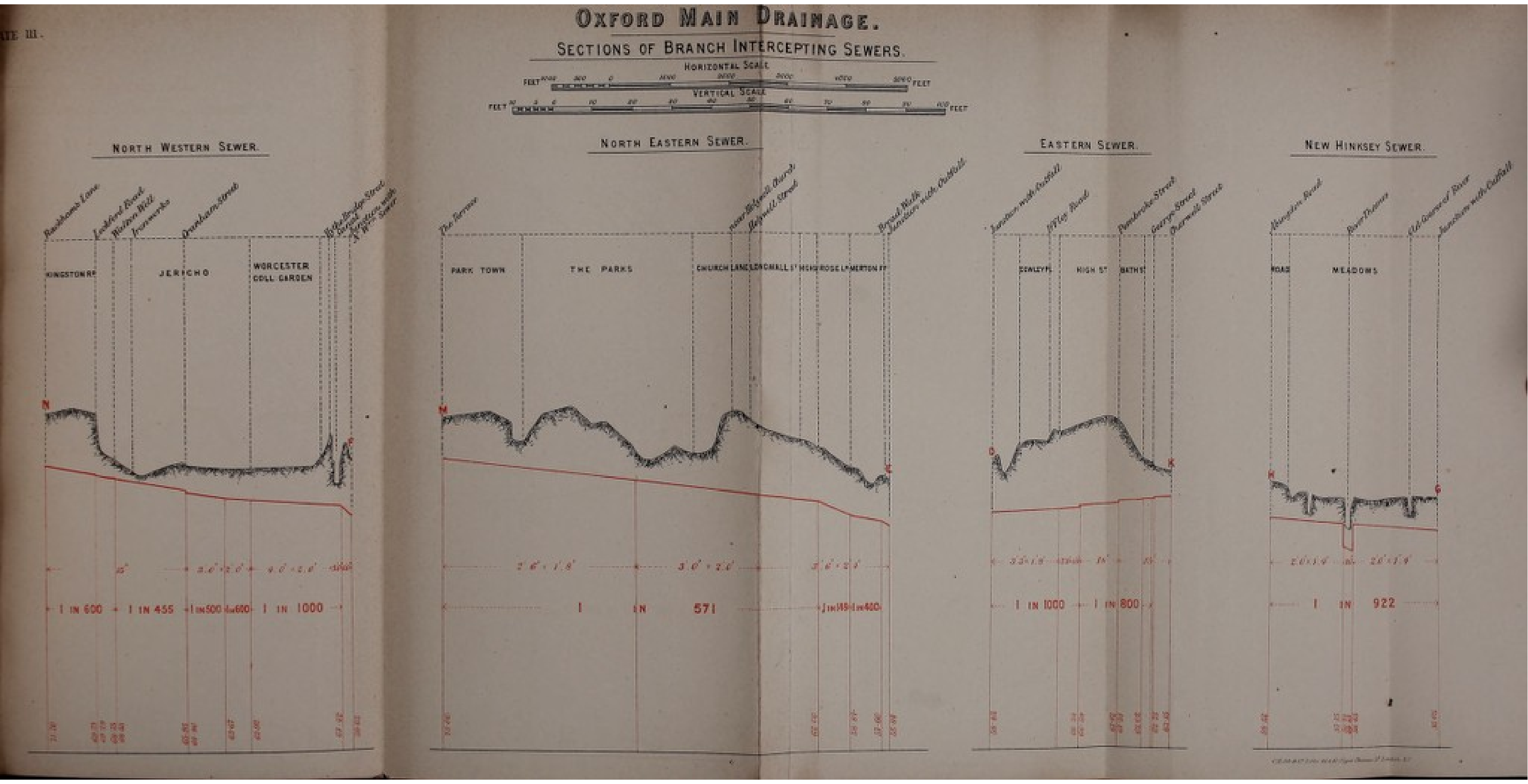


PLATE III.
OXFORD MAIN DRAINAGE.
SECTIONS OF BRANCH INTERCEPTING SEWERS.
HORIZONTAL SCALE
VERTICAL SCALE
NORTH WESTERN SEWER.
KINGSTON RD
JERICHO
WORCESTER COLL. GARDEN
1 IN 600
1 IN 455
1 IN 500
1 IN 1000
NORTH EASTERN SEWER.
PARK TOWN
THE PARKS
CHURCH LANE
LONGWALL ST
HIGH ST
ROSE LA
MERTON FD
1 IN 571
EASTERN SEWER.
COWLEY PL
HIGH ST
BATH ST
1 IN 1000
1 IN 800
NEW HINKSEY SEWER.
ROAD
MEADOWS
1 IN 922

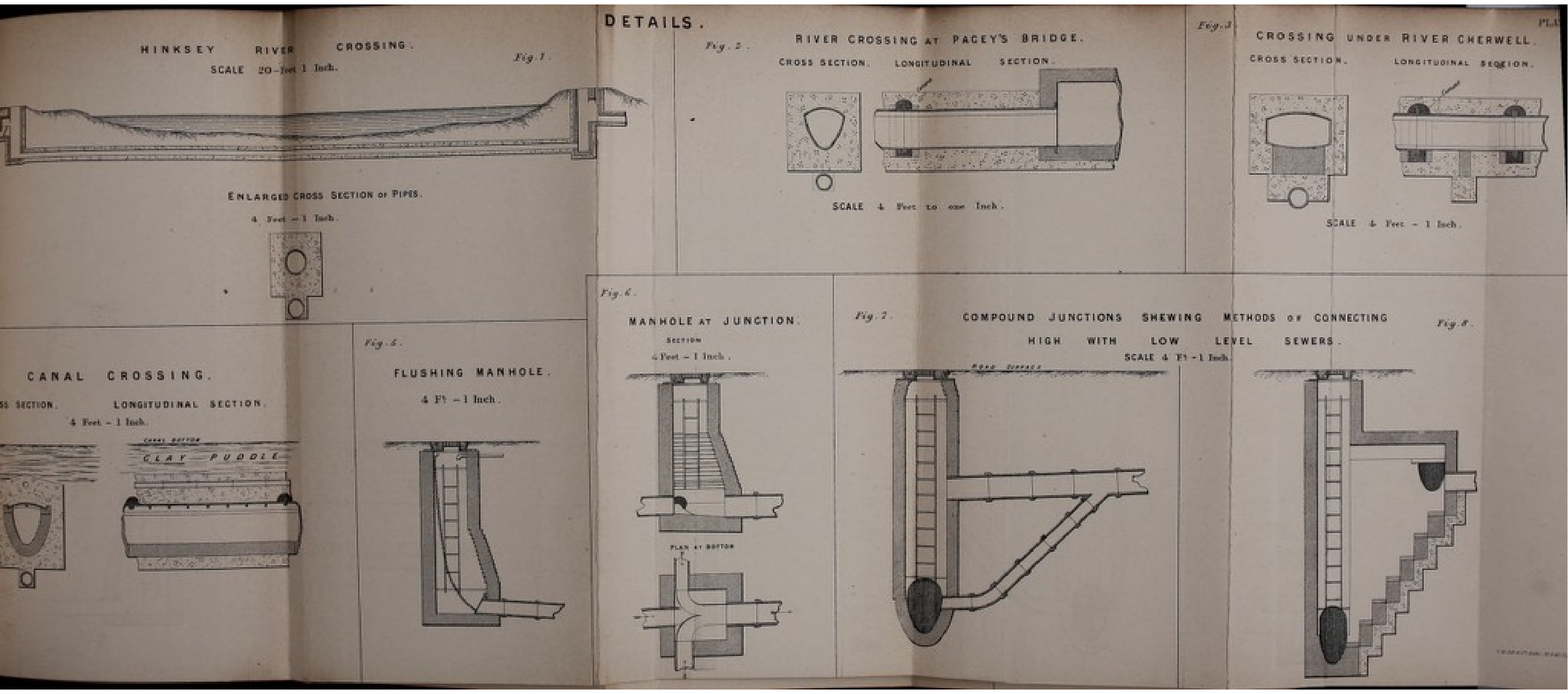
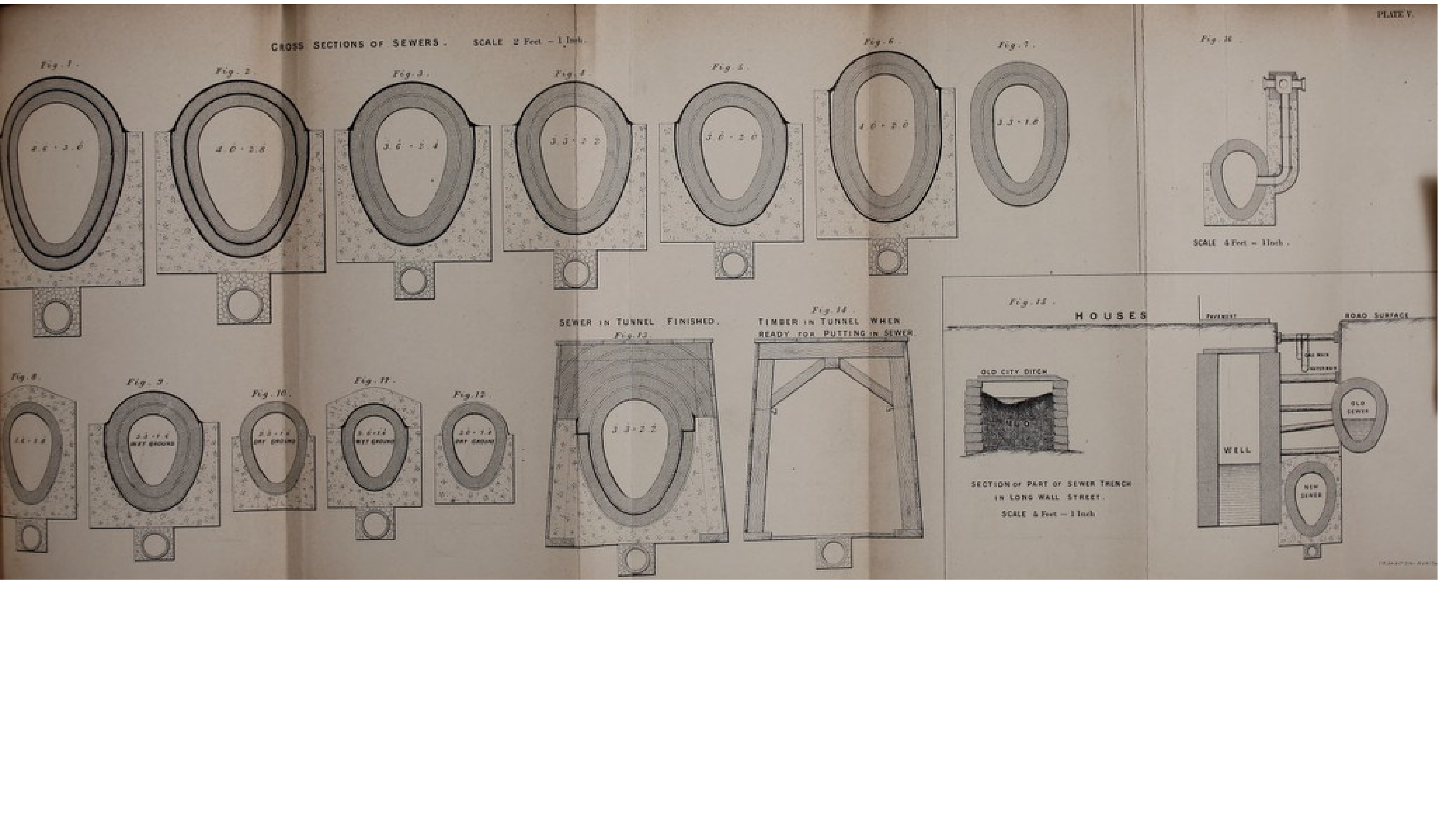

DETAILS.
PL.
HINKSEY RIVER CROSSING.
SCALE 20 Feet 1 Inch.
Fig. 1.
ENLARGED CROSS SECTION OF PIPES.
4 Feet – 1 Inch.
Fig. 2.
RIVER CROSSING AT PACEY'S BRIDGE.
CROSS SECTION. LONGITUDINAL SECTION.
SCALE 4 Feet to one Inch.
Fig. 3.
CROSSING UNDER RIVER CHERWELL.
CROSS SECTION. LONGITUDINAL SECTION.
SCALE 4 Feet – 1 Inch.
CANAL CROSSING.
LONGITUDINAL SECTION.
4 Feet – 1 Inch.
CLAY PUDDLE
Fig. 5.
FLUSHING MANHOLE.
4 Ft – 1 Inch.
Fig. 6.
MANHOLE AT JUNCTION.
SECTION
4 Feet – 1 Inch.
PLAN AT BOTTOM
Fig. 7.
COMPOUND JUNCTIONS SHEWING METHODS OF CONNECTING
HIGH WITH LOW LEVEL SEWERS.
SCALE 4 Ft – 1 Inch.
ROAD SURFACE
Fig. 8.

PLATE V.


CROSS SECTIONS OF SEWERS. SCALE 2 Feet = 1 Inch.
SEWER IN TUNNEL FINISHED.
TIMBER IN TUNNEL WHEN READY FOR PUTTING IN SEWER
HOUSES
OLD CITY DITCH
SECTION OF PART OF SEWER TRENCH IN LONG WALL STREET.
SCALE 4 Feet = 1 Inch
PAVEMENT
ROAD SURFACE
WELL
OLD SEWER
NEW SEWER
SCALE 4 Feet = 1 Inch.

1877