Preliminary report on the drainage of the metropolis / By Mr John Phillips, Chief Surveyor. July 23rd, 1849.

No. 57.]

Metropolitan Sewers.

PRELIMINARY REPORT

ON THE

DRAINAGE OF THE METROPOLIS,

By Mr JOHN PHILLIPS, Chief Surveyor.

In pursuance of the Order of Court of 5th July, 1849, I have the honour to present a preliminary Report, explanatory of the leading features of the Tunnel Sewer scheme, which I submitted on the 21st of June last, for the permanent and perfect Town Drainage of the Metropolis, including the City of London. Instructions for Report.

This area possesses some peculiar characteristics as regards drainage, essential to be noticed. The valley of the Thames was originally a broad arm of the sea, expanding itself every tide over the flat districts upon which are now built the City of Westminster, Battersea, Lambeth, Newington, Camberwell, Southwark, Bermondsey, Rotherhithe, Deptford, East Greenwich, Poplar, Bromley, as well as the other marshes from the Nore to a considerable distance above London, on both sides of the Thames. At a very early period this immense tract was reclaimed from the sea, and the estuary narrowed by embankments to the width of a deep river, leaving the marshes so secured at a level varying from two to ten feet below high water, those further removed from the River mouth being proportionably lower than those near the sea. The higher grounds comprised within this area present a variety of undulations intersected by several tributary streams. Description of the area.

Necessary to establish first principles.

The consideration of the entire drainage of the whole of this area is involved in the instructions for this Report, but primarily it is necessary to discuss and establish the first principles of Town Drainage, which have not yet been determined by the Court, but upon which depends the great question of outfall; and this I shall proceed to do, confident in the practical experience of many years, and in the results of long and anxious consideration of the subject.

Defects of present system, and their causes.

It is practically impossible to provide a perfectly innocuous system of Town Drainage while combining in one channel the house-washings and night-soil with the land and surface drainage. They must be separate.

It is only within the present half-century that night-soil, the drainage of houses, and other offensive matter, have been permitted to discharge into the sewers, which before that time were constructed for the reception of land-drainage and rain-water only. This combination of surface and foul water in the sewers, although an error in principle, has been extended to all parts of the metropolis and its suburbs, and the consequent evils consist of accumulations of foul matter in the house-drains and sewers, whereby noxious vapours are generated; which filling the large space of such drains and sewers not occupied by the sewage, thence escape into the houses and streets through innumerable inlets, and thus pervade and contaminate the atmosphere of the whole town. Nothing further is necessary to demonstrate this fact than the universal experience of the past few weeks—that the *whole of the atmosphere of London is perceptibly tainted by emanations from the sewers*, and that the population are complaining by whole parishes of such a fearful state of things, which imperfect and injudicious flushing rather aggravates than removes.

Contamination of the atmosphere.

The very necessity which now exists *as a rule* to resort to the expensive processes of flushing and trapping to prevent accumulation and to keep down the malaria where it most prevails, further proves this combined system of drainage eminently at fault in its first principles.

Under existing circumstances the evils are irremediable.

It is not the gullies that create the mischief, but this combination of house and surface drainage in one channel. Supposing the number of gullies to be *diminished*, the defects of the present system would not be remedied, inasmuch as the noxious gases would be not less freely generated, and the effluvia would be driven into the habitations through the house-drains instead of into the open thoroughfares. Neither would any actual benefit be derived by the general *trapping* of gullies, since experience proves the effect to be the same as described above; and therefore the defects of the present combined drainage, however they may be palliated or modified by such expedients, are irremediable.

Pollution of the Thames and its tributaries.

Moreover, the dangerous consequences arising from the house-drains discharging their contents into the sewers are not confined to the houses and streets; but as the sewers are constantly pouring floods of filth into the Thames and its tributaries, those waters also are disgustingly polluted; and in addition to these evils, the sewage, which, if saved, would be a source of great revenue to the rate-payers, and of the utmost value as a fertilising agent, is wasted and lost.

It cannot be too strongly urged that uniting house-washings and night-soil with land and surface drainage in one system of sewers is the primary cause of all the evils so much complained of by the public.

Urgent necessity of separate Drainage.

It follows that it is impossible to preserve the purity of the atmosphere we breathe, or of the River on the banks of which we live, if this description of filth, composed as it is of an enormous amount of human excreta and other foul matters, be allowed to pass through the sewers communicating with the streets into the open River: and therefore it is a *paramount and necessary condition of perfect drainage* that separate channels should be provided for that purpose, having no communication either with the River, the sewers in the streets, or the external atmosphere.

My object is to restore the atmosphere of the Metropolis as well as the natural watercourses and the River to their original purity; which is to be accomplished by diverting the sewage, which at present pollutes the earth, air, and water, into new channels, to be carried to a convenient and unobjectionable place for profitable disposal.

Principles of Town Drainage.

This alone is complete and perfect drainage, and to effect it the following principles must be conformed to:—

1st. That two outfalls independent of each other should be provided—one for the discharge of *natural* or land and surface waters, and the other for the discharge of *artificial* or house and soil drainage.

2nd. That in order to perfectly drain the subsoil of the town so as to free it from damp, and to carry off as quickly as possible the natural waters, a system of permeable land-drains and sewers should be provided to discharge into the natural watercourses and rivers.

3rd. That as outfalls are already provided by streams and rivers for the discharge of the natural waters, it is only necessary to provide separate and proper outfalls for the discharge of the artificial or house and soil drainage; which outfalls should convey the sewage, as fast as it is produced, to a depôt at a convenient and unobjectionable place, quite clear of and below the town (as intimated in my evidence before the Sanitary Commission, in October, 1847, 8vo. ed., p. 193).

4th. That in order to carry off the house and soil drainage without contaminating the atmosphere of the town by the escape of effluvia through the numerous inlets, as is at present the case, a system of impermeable drains should be provided distinct and separate from the permeable land-drains and sewers, to discharge without intermission into the said artificial outfall independently of the River.

5th. That at the main outlet a depôt should be formed and works established for raising the sewage, and for converting and distributing the same for agricultural and horticultural purposes.

Conformity of proposed plan with principles.

The plan of drainage hereafter laid down, and of which the Tunnel Sewer proposed to be constructed is the outfall for the house and soil drainage, conforms, as I believe, to the foregoing principles in every respect.

Two outfalls.

For, in the first place, the River being naturally the outfall for the land-drainage and rain-water, the Tunnel Sewer is proposed to be the outfall for the house and soil drainage.

Subsoil and Surface Drainage.

In the second place, for the complete drainage of the subsoil and surface, it is proposed to lay down throughout the several districts on both sides of the River, where no sewers now exist, a system of efficient permeable land and surface drains; to lower or otherwise improve those which are now inefficient; and to divert the upland waters, now descending upon and flooding the low districts (as stated in my evidence to the Sanitary Commission in October, 1847, 8vo. ed., p. 193), by catch-water drains, to be constructed for that purpose along the face of the hills above, in such a manner as that these waters would flow immediately and without interruption into the River or its tributaries at points above the influence of the tide, so as to be always discharging.

Catch-water drains for upland waters.

One of the many evils in the present combined system, and the difficulties of which have been represented to be insurmountable, is that the sewers in the districts below high water are, during every tide, filled with drainage, especially from the higher grounds.

By simply catching the upland waters, and conveying them round the base of the rising grounds into the River, this defect will be so far remedied as to afford an amount of storage for land and surface waters in the capacity of the low-level sewers, sufficient to accommodate that quantity of water falling only upon those low districts.

Present Sewers not to be destroyed, but improved.

In practically fulfilling these arrangements, which would be more specially particularised in future Reports, should the Court be so pleased to order, no material alteration of the present sewers is contemplated other than making them efficient, and constructing certain lines of catch-water drains in the manner above stated. It is not proposed to destroy, but to deepen and improve the present sewers, to serve as conduits for the land and surface waters only.

House and Soil Drainage.

Having thus provided outfalls and sewers for the complete discharge of the land and surface waters, it becomes a distinct consideration of far greater importance as to the most economical and perfect manner of relieving the town from the liquid refuse and filth accumulated in the houses.

The first consideration must be the provision for an efficient outfall as a substitute for the River in respect of this sewage.

In my evidence appended to the first Report of the Sanitary Commission, 1847 (8vo. ed., p. 193), it was suggested that such a main outfall sewer should be constructed, as will appear from the following extract:—

"The purification of the Thames is a subject of the first consideration; to

effect which, *an intercepting sewer* must be made near to and parallel with the River, to deliver itself at some distance below the town. It is quite practicable to carry out such a plan."

It is not only incumbent upon me to show the urgent necessity, practicability, and advantages of such a work, but also to prove it to be the most efficient for accomplishing the effectual house-drainage of the Metropolis and its suburbs.

The greatest difficulties in the drainage of the houses in the several districts below the level of high water, on both sides of the river, are, the want of fall, and the locking-in of the sewage while the tide is above the outlets of the sewers; whereby the subsoil is saturated with foul water, the basements and cellars are often flooded, deposit of filth in the sewers is promoted and constantly going on, and noxious gases are generated. Now, the advantages of this tunnel-sewer are, that any desirable amount of fall can be given to the entire system of house-drainage throughout these districts, and the flow, instead of coming to a stand for many hours of each tide, would be continuous and uninterrupted into shafts communicating with the tunnel. From these shafts main branch drains would be carried parallel with the River, and as near as posssible to the outlets of the present sewers, so as to intercept the sewage where it now runs into the River.

Outfall.

The nature and extent of this outfall sewer will depend upon the quantity and description of sewage it is intended to convey. It will almost entirely consist of the water which flows from the houses and premises, namely, that supplied for domestic use, and such of the rain as falls upon the premises which cannot be economically and conveniently carried into the sewers already provided for land-drainage and rain-water. In this case, and in this only, an exception must be made to the general principle of keeping the house and surface drainage separate.

Commencement of Tunnel.

The direction of this Tunnel Sewer is described on the accompanying plan, commencing in the Plumstead Marshes and terminating at Twickenham.

In its course it will be seen that it crosses the river at the most available points for intercepting the house and night-soil drainage now flowing into the River; and the line is so regulated that it would afford a deep outfall for effectually relieving the whole of the flat and densely-populated districts bordering on the Thames, which are now suffering so much from the want of drainage.

Plaistow Marshes, &c.

From the depôt (where would be brought in the house-drainage of Woolwich and Plumstead), the tunnel would pass under the River to the East Ham and Plaistow Marshes, where might be received the house-drainage of East Ham, Barking, Ilford, Plaistow, West Ham, Stratford, and the other towns in the neighbourhood between the Rive Lea and the River Roding, in the county of Essex, and which drainage now runs either into cesspools or filthy open sewers and ditches, considerably polluting those rivers.

Greenwich Marshes, &c.

From below Bow Creek the tunnel crosses the river to the Greenwich Marshes, where a shaft would be built and a branch drain laid across the marshes for the house-drainage of Charlton, East Greenwich, Greenwich, and other places near, all of which are at present without any provision for efficient drainage.

Poplar and Bromley Marshes, &c.

The tunnel then crosses the Thames near the east entrance of the West India Docks at Blackwall, where the present outfall of Poplar and Blackwall is situate. At this point a shaft would be formed, and main branch drains laid to take in the house-drainage of Poplar, Blackwall, and the Isle of Dogs, in addition to those parts of the Tower Hamlets and Bromley Districts of sewers which now discharge into the River Lea.

Limehouse.

The line of tunnel continues between the Export and Import West India Docks to the margin of the River south of the eastern entrance of those docks, where a shaft and a main branch drain would be made to receive the house-drainage of Limehouse, and to intercept the sewage discharging into the river between the City Canal and Shadwell Dock.

Deptford, Rotherhithe, &c.

Crossing the river to the Surrey side, the tunnel runs through the lower part of Rotherhithe. Here two shafts would be built with a main branch drain laid from the western shaft along Rotherhithe street and the Lower Deptford road, for the house-drainage of the upper part of Rotherhithe, Deptford, and Hatcham. This branch might be extended up to Lewisham, Lea, Eltham, Sydenham, &c., following the course of, and as a substitute for the River Ravensbourne and its minor branches. From the eastern shaft a branch drain would follow the bank of the Thames to the eastward, to intercept the sewage running into it along this part, as also for the house-drainage of Lower Rotherhithe.

Tower Hamlets, Holborn, Finsbury, and City of London.

The tunnel leaves Rotherhithe just below the entrance of the Grand Surrey Canal, and continues under the river to the Middlesex side, between the entrance to Shadwell Dock and the Rotherhithe Tunnel, and runs south of the London Docks through the lower part of Wapping to the margin of the river above the entrance of Hermitage Dock.

There would be two shafts along this part of the line. From the western shaft above Hermitage Dock a main branch drain would run round the north side of St Katherine's Docks and the Tower, and along Thames street to New Bridge street, Blackfriars, intercepting in its course (and that within a very short distance of the river) all the sewage running into the Thames, as far as Temple Gardens, a distance of two miles. From the east shaft near the bottom of New Gravel lane, branches would be carried east and west for the drainage of Wapping.

This part of the tunnel would receive the house-drainage of the greater part of the Tower Hamlets District, and that of the whole of the City of London, including the Holborn and Finsbury Districts, which drain through the Tower Hamlets and City sewers.

Bermondsey, Southwark, Lambeth, &c.

Leaving the entrance of Hermitage Dock, the tunnel crosses the river to the Surrey side near Shad Thames, and continues through the lower parts of Bermondsey, Southwark, and Lambeth, below Westminster Bridge.

Four shafts would be constructed on this length:—The first near the river at Shad Thames; the second, and principal one, in High street, Borough; the third in Blackfriars road; and the fourth in York road. Deep main branch drains *with any necessary amount of fall* would radiate from these shafts along the principal roads

and streets to *all* parts of this extensive low flat district, and would be applicable for the thorough and complete improvement or re-arrangement of the house-drainage of Bermondsey, Southwark, Lambeth, Newington, Kennington, Walworth, Peckham, Camberwell, Dulwich, Norwood, Streatham, Stockwell, Clapham, Brixton, and Battersea, as well as of Wandsworth, Tooting, Mitcham, Carshalton, Merton, and other places near the banks of the River Wandle.

City of Westminster, Pimlico, Chelsea, Hammersmith, &c.

From the Surrey side the tunnel would pass under the river below Westminster Bridge to the City of Westminster, and continue through that district to the King's Scholars' Pond Sewer at Pimlico.

In the enclosure between St Margaret's Church and Parliament street, there would be a shaft over the tunnel, into which all the sewage running into the river between Temple Gardens and Westminster Bridge, a distance of one mile, might be conveyed by a main drain laid along the Strand, Charing Cross, Whitehall, and Parliament street: the shaft at this spot would also serve for the outlet of the house-drainage of the City of Westminster. Proceeding on through Pimlico to Chelsea, and between Fulham and Hammersmith, the tunnel would intercept the large quantity of house and night-soil drainage at present collected by and flowing down the King's Scholars' Pond, the Ranelagh, the Counter's Creek, and other main sewers, which discharge into and seriously pollute the Thames between Vauxhall Bridge and Putney. There would be six shafts (exclusive of the one in Westminster) on this part of the line, from which deep main branch drains would be laid, affording the means of thoroughly draining the houses in Pimlico, Knightsbridge, Brompton, Chelsea, Kensington, Fulham, Walham Green, Hammersmith, the low grounds about Notting Hill, and other places contiguous.

Barnes, Putney, &c.

Crossing the river almost at right angles to Barnes, a short distance below Hammersmith Bridge, the tunnel would not only afford an outfall for that place, but also for the neighbouring town of Putney, and other places adjoining.

Chiswick, Brentford, &c.

The line is then carried under the river opposite Barnes, to receive the house-sewage of Chiswick, Brentford, Ealing, Acton, Hanwell, and other places to the north.

Mortlake, Richmond, Kingston, &c.

Crossing again, and taking up the drainage of Mortlake, with that of Kew, it would be continued upward for the drainage of Richmond, and that of Petersham and Kingston. It would then cross the river above Richmond Bridge, and take the house-sewage of Twickenham and the neighbourhood.

Direction taken by the Tunnel is a uniform curve.

The direction of the tunnel may appear circuitous from the above description; but that impression will be immediately removed by a glance at the plan, which shows the line there marked and explained above, to be a uniform curve which threads the windings of the river.

Fall of the Tunnel.

As the Tunnel is a substitute for the Thames with regard to the house and soil drainage, however high up the valley it may be carried, the fall of it should be like the river—towards the sea. Certain laws have been laid down by nature for regulating the fall of rivers, which our daily experience shows cannot be excelled by the utmost re-

finements of science and art. The line of the bed of rivers is a series of curves, flat and broad at the estuary, narrow and steep at the source. In arranging the inclination of this Tunnel, it is proposed to follow these obvious indications of nature. The accompanying section of the Tunnel shows the inclinations so arranged, and the following Table dispenses with the necessity of further description.

Locality of Tunnel.	Distance in miles.	Fall per mile.		Total fall.	
		Feet.	Inches.	Feet.	Inches.
From Plumstead Marshes to West Entrance of West India Docks .	4½	1	6	6	9
From West Entrance of West India Docks to Union St., Southwark .	4	2	0	8	0
From Union Street, Southwark, to Gloucester Road, Brompton .	3½	2	6	8	9
From Gloucester Road, Brompton, to Barnes	3	3	0	9	0
From Barnes to Richmond . .	2½	3	6	8	9
From Richmond to Twickenham .	2	4	0	8	0
	19½			49	3

Size of the Tunnel.

The Tunnel, by which I propose to carry out these objects, will be eight feet diameter at its outlet, and six feet at the upper end.

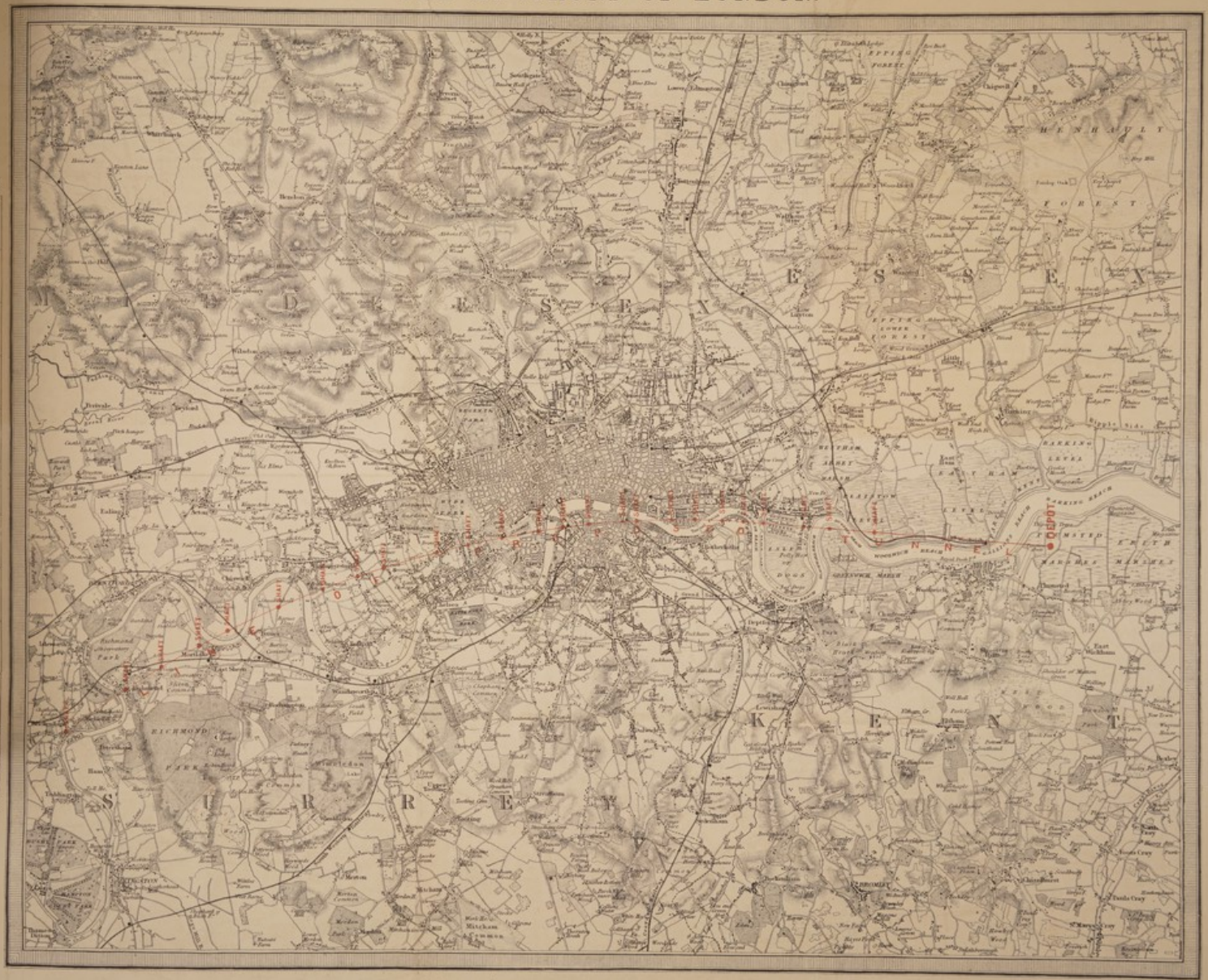
Depth of Tunnel.

It is proposed that the Tunnel should be driven at the most convenient depth, to avoid engineering difficulties. The time specified by the Court for the preparation of this Report not being sufficient, nor any outlay being authorised for making the requisite borings to ascertain the exact nature of the strata, a deviation from the depth described in the section may be necessary. Dr Buckland states (*Minutes of Proceedings Institution Civil Engineers,* vol. ii, p. 159,), that "the district called the London Basin is made up of a continuous seam of chalk from 300 to 500 feet in thickness, covered with beds of sand and gravel alternating with plastic clay, and over all these a thick covering of London clay."

It is proposed to drive the Tunnel in this bed of London clay, a thick seam of which extends about 200 feet in depth, between Bermondsey and Twickenham, and is found at an average depth of about 35 feet below the surface.

It has been ascertained that below Bermondsey the London clay runs into and mixes with beds of running sand, shingle, and loam, while the solid chalk

THE ENVIRONS OF LONDON.



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lies nearer the surface: difficulties will therefore proportionably increase along this part, but these contingencies have been considered, and from the size of the proposed tunnel there can be none in its execution which present experience in these matters could not easily overcome.

Material of Tunnel.

It is proposed to construct the tunnel in the most sound, substantial, and durable manner, of hard vitrified terro-metallic or fire-clay blocks, jointed and bedded in cement. There would be two rings of this material, each six inches in thickness.

But the further details of this work, that is to say, the machinery for excavating and lifting, and the general manner of doing the work, are of so mechanical a nature and free from difficulty, as to require no further mention here, but would properly form the subject of working drawings and specifications preparatory to a contract for the actual execution of these, as well as of other hereinafter proposed works.

Ventilation of Tunnel, during its construction.

Some means will be necessary for supplying fresh air to the workmen engaged in the tunnel. No expense need be incurred in this respect beyond the construction of tubes communicating with the furnace of the temporary engine placed at the top of each working shaft. The foul air would be exhausted, and would naturally be replaced with pure air, thus securing constant circulation. I now proceed to describe, in the *fourth* place, the manner of laying down "a system of impermeable house-drains distinct and separate from the permeable land drains and sewers, to discharge without intermission into the artificial outfall, independently of the River."

Shafts.

Along the line of tunnel, shafts will of course be required for the execution of the works in the first instance: the choice of spots for these shafts would be made at the most convenient positions on the line for the admission of the sewage to the tunnel.

Viewing the Thames as the present main common sewer of London, it is necessary that its tributaries, whether they be open or covered channels, should be provided with the same means of purification as itself, namely, separate channels for the reception of the foul drainage.

House Drainage.

The most economical and efficient manner of accomplishing this object, and that without any disturbance of the public thoroughfares or interruption to the traffic, would be by laying down pipes, of sufficient capacity for the purpose, upon or under the inverts of the present sewers, and effecting a proper junction with every house-drain. By this means all the filth would be diverted from the present sewers, which would then carry off only the land-drainage and rain-water, and at the same time become subways, by means of which the house-drains could at all times be made or repaired without opening the streets.

These works might be done at a very moderate expense. The enormous cost and incalculable public inconvenience of obstructed thoroughfares, arising from a rearrangement or extensive interference with the present sewers, would prove any scheme impracticable which involved them, but would be entirely avoided by this

plan. I contemplate in this system the entire abolition of all existing cesspools, and the provision of a constant supply of water.

In a few months from the commencement of the tunnel, all the villages and towns north and south of the Thames would have a perfect outfall, and the further progress of the work would be co-extensive with the improvement of the adjacent house-drainage.

Depôt at Plumstead Marshes for raising the sewage, &c.

The fifth principle of perfect drainage here laid down is, "that at the main outlet a depôt should be formed and works established for raising the sewage, and for converting and distributing the same for agricultural and horticultural purposes."

The depôt is proposed to be in the Plumstead Marshes. To this point would be brought all the house and soil drainage, the converting and distributing of which is an important question. It is not intended here to discuss the comparative merits of liquid and solid manure, the object of this Preliminary Report being to relieve from filth the Metropolis and its River, and to explain the means by which the sewage may be raised to the surface, to be dealt with as may be determined upon, should the principle of a tunnel be approved by the Court. It may be found more desirable to place the reservoirs and filtering beds on the Essex, rather than on the Kentish side. There are, however, a few points to notice, as bearing upon the works here proposed.

Occasional distribution of the sewage from higher levels over lower agricultural districts.

The sewage of the higher grounds might be distributed occasionally over distant agricultural districts on a lower level by gravitation, or to any level by mechanical power. This might be accomplished by intercepting the sewage at any suitable height, and conveying it through pipes to such districts. This local distribution might be undertaken either by the Commissioners themselves, or by companies willing to pay an annual rent for the same. But it is evident that there are seasons of the year during which it would be impossible to use all the sewage so intercepted, when the ground would be saturated with continual rains, covered with snow, during thaws, when bound up by frost, or during hay-time and harvest. The ground, therefore, would be for some months of the year in a state wholly unfit to receive manure in any shape.

Land not in a fit state to receive sewage some months of the year.

To suffer the sewage charged with all its impurities to overflow into the streams at such times, would be to pollute them, and thus would be violated the first principles of sanitary improvement now sought to be carried out. A main outfall should therefore be constructed, capable of receiving, with steam power at the depôt sufficient to raise, at such times and under such circumstances, the house and soil drainage of the whole of the Metropolis.

The outfall should be provided to receive the whole house-drainage of London, &c.

It may be here observed that the sewage could be pumped up by a moveable apparatus, for particular agricultural districts, such as the dry lands towards Hounslow, from any of the shafts along the line of tunnel, and at any season of the year, without injuriously interfering with the flow of the sewage to the depôt.

The maximum quantity of sewage to be raised per diem will be 10,080,000 cubic feet, requiring 1,326 horse-power.

Estimates.

I stated in my letter of the 21st June, that the cost of six miles of this tunnel would be 200,000*l.* After further and more mature consideration, and extensive inquiries as to the present available resources for the execution of such a work, I am confirmed in my opinion then expressed, and consider that estimate rather over than understated (*see Appendix A*). In the present calculation, the whole distance is estimated for, the upper end being of smaller capacity and at a less depth: the average expense per mile for the whole length would be about 25,878*l.* 10s.; and this estimate will include all the shafts except that at the commencement of the tunnel, which is estimated at about 4,099*l.* (*see Appendix B*).

The engine-house and works, which should be of the most substantial and permanent description, would cost 31,437*l.* 7s. 4d.: a large portion of this amount would be expended in the solid masonry foundation for machinery (*see Appendix C*).

Summary of estimates for 19½ miles.

The estimate for the whole length is as follows:—

	£	s.	d.
Constructing 19½ miles of tunnel sewer, at an average cost of 25,878*l.* 10s. per mile, including shafts . . .	504,630	18	2
Constructing the shaft at the terminus . . .	3,923	7	4
Steam-engines, pumps, and boilers complete . . .	95,000	0	0
Engine-house, &c. &c.	31,437	7	4
Total estimated cost of 19½ miles of tunnel sewer, with machinery, &c.	£634,991	12	10

The annual cost of maintenance, consumption of coals, and superintendence, is estimated at about 15,000*l.* (*see Appendix D*).

The rated value of the property draining into this Tunnel Sewer would be little short of ten millions, and an annual rate for 22 years of about 1d. in the pound would pay the principal and interest in that period.

But it is anticipated that the income arising from the disposal of the refuse would at least cover this annual charge and render such a rate unnecessary.

It has thus been my endeavour to show that the *urgent necessity* for immediately providing a permanent and efficient outfall, such as the Tunnel Sewer, for the house-drainage, lies, firstly, in the geographical character of the area to be drained, a very large part of it being several feet below high-water mark, and, in consequence, the sewers in such places are filled, in fine weather, almost wholly with the foulest drainage, which pollutes the atmosphere, and when discharged, contaminates the River, to the manifest prejudice of the public health: and secondly, that such an outfall is obviously necessary in order to the separation of house and soil drainage from the land and surface drainage, the connexion of which has been shown to be the principal cause of the evils sought to be remedied.

The *practicability* of constructing such an outfall has been attempted to be shown, and the details of the work laid down.

The *advantages* of such an arrangement have also been dwelt upon: amongst others may be enumerated the immediate and permanent relief of the Metropolis and the River from the liquid refuse and offensive matter, and conveying the same to a convenient depôt quite clear of the town, to be disposed of for agricultural purposes. By adopting these arrangements, the conditions and principles of perfect Town Drainage will be complied with.

I cannot conclude this Report without mentioning that I have received much assistance in its preparation from Mr Edward Gotto, Assistant Surveyor, who has greatly exerted himself, and has given the subject his best attention.

I have, &c.

(Signed) JOHN PHILLIPS,

Chief Surveyor.

July 23, 1849.

METROPOLITAN SEWERS,
July 23rd, 1849.

To the Right Honorable and Honorable the Metropolitan Commissioners of Sewers.

MY LORDS AND GENTLEMEN,

Having been engaged with Mr Phillips, the Chief Surveyor, in preparing the plan for the drainage of the Metropolis, propounded in his Report presented this day, I beg respectfully to state my concurrence in his recommendations, and in all the practical details and calculations, to which I have given very particular attention.

I have, &c.

(Signed) EDWARD GOTTO,
Assistant Surveyor.

APPENDIX A. PART 1.

ESTIMATE No. 1, for the Construction of 9½ Miles of Tunnel Sewer, 8 feet in diameter, including 14 Shafts on the Line:—

TUNNEL 9½ MILES IN LENGTH.

	£ s. d.	£ s. d.
ENGINE POWER, Pumping out Water, 1*l.* 10s. per foot run, for 4½ miles, and 1*l.* per foot run for 5 miles - - -		62,040 0 0
EXCAVATING 151,230 cubic yards of Earth, at 5s. - - -	37,807 10 0	
FILLING into Skips, Lifting to Surface, and Carting away 151,230 cubic yards of do., at 3s. 6d. - - - -	26,465 5 0	
TACKLE, Tramways, Trucks, Skips, Implements, &c., at 6s. per foot run of Tunnel - - - - - -	15,048 0 0	
PLANKING, Strutting, Shoring, &c., at 6s. 2d. do. - -	15,466 0 0	
CANDLES, 250,800lb. at 4½d. - - - - -	4,702 10 0	
		99,489 5 0
BRICKWORK, 2,834,040 feet super Hollow Brick Blocks, in two rings, 6 inches thick, at 6d. - - - -	70,851 0 0	
BEDDING, 2,834,040 feet super ditto, in Cement, at 3d. - -	35,425 10 0	
		106,276 10 0

FOURTEEN SHAFTS.

ENGINE POWER, per foot down, 1*l.* - - - -		1,400 0 0
EXCAVATING 7,980 cubic yards of Earth, including Lifting and Carting away, at 6s. - - - - -	2,394 0 0	
Cast-Iron Curbs and Iron Work, including Timber in Planking, Strutting, Shoring, &c. - - - - -	1,400 0 0	
		3,794 0 0
BRICKWORK, 140,000 feet super Hollow Brick Blocks, in Walls, Domes, Side Entrances, &c., at 9d. - - -	5,250 0 0	
BEDDING, 140,000 feet super ditto, in Cement, at 3d. - - -	1,750 0 0	
		7,000 0 0
		279,999 15 0
Add for Contingencies 10 per cent. - - - -		28,000 0 0
Total Estimate - - -		£307,999 15 0

APPENDIX A. PART 2.

ESTIMATE No. 2, for the Construction of 10 Miles of Tunnel Sewer, 6 feet in diameter, including 12 Shafts on the Line.

TUNNEL 10 MILES IN LENGTH.

	£	s.	d.	£	s.	d.
ENGINE POWER, Pumping out Water, at 10s. per foot run -				26,400	0	0
EXCAVATING 105,600 cubic yards of Earth, at 3s. 6d. - -	18,480	0	0			
FILLING into Skips, Lifting to Surface, and Carting away 105,600 cubic yards of Earth, at 3s. 6d. - - -	18,480	0	0			
TACKLE, Tramways, Trucks, Skips, Implements, &c., at 4s. per foot run of Tunnel - - - - -	10,560	0	0			
PLANKING, Strutting, Shoring, &c., at 3s. ditto - -	7,920	0	0			
CANDLES, 158,400lb, at 4½d. - - - -	2,970	0	0			
				58,410	0	0
BRICKWORK, 2,323,200 feet super Hollow Brick Blocks, in two rings, 6 inches thick, at 6d. - - - -	58,080	0	0			
BEDDING, 2,323,200 feet super ditto, in Cement, at 3d. - -	29,040	0	0			
				87,120	0	0

TWELVE SHAFTS.

ENGINE POWER, per foot down, 6s. - - - -				270	0	0
EXCAVATING 5,136 cubic yards of Earth, at 4s. 6d. - -	1,155	12	0			
CAST-IRON CURBS and IRON WORK, including Timber in Planking, Strutting, Shoring, &c. - - - - -	900	0	0			
BRICKWORK, 90,000 feet super Hollow Brick Blocks in Walls, Domes, Side Entrances, &c., at 9d. - - - -	3,375	0	0			
BEDDING, 90,000 feet super ditto, in Cement, at 3d. - -	1,125	0	0			
				6,555	12	0
				178,755	12	0
Add for Contingencies, 10 per Cent. - - -				17,875	11	2
Summary of Estimates -			-	£196,631	3	2
	At per mile.					
Total, Part 1, for 9½ miles -	32,421	0	6 =	307,999	15	0
Total, Part 2, for 10 miles -	19,663	2	4 =	196,631	3	2
Total, 19½ miles - - -				£504,630	18	2

(Signed) JOHN PHILLIPS.

APPENDIX **B.**

ESTIMATE for the Construction of a Main Shaft at the Outlet of the Tunnel:—

	£	s.	d.
ENGINE POWER - - - - - -	120	0	0
CAST-IRON CURB, Timber in Strutting, Planking, &c. - - -	372	0	0
DIGGING, &c., 2,354 cubic yards, at 6s. - - - -	706	4	0
BRICKWORK, 1,115 cubic yards, in Cement, at 1*l.* 10s. - - -	1,672	10	0
GRANITE, 1,420 cubic yards, including Labour, at 8s. - -	568	0	0
WROUGHT IRON, 8 tons, at 16*l.* - - - - -	128	0	0
	3,566	14	0
Add 10 per Cent. for Contingencies - - - - -	356	13	4
Total Estimate - -	£ 3,923	7	4

(Signed) JOHN PHILLIPS.

APPENDIX C.

Estimate for the Construction of an Engine-house, Boiler-rooms, Chimney Shafts, &c. &c., at the Depôt.

ENGINE-HOUSE AND BOILER-ROOMS.

	£	s.	d.	£	s.	d.
14,518 cubic yards Digging to Foundations, at 1s. 4d.	967	17	4			
3,579 cubic yards Concrete to ditto, at 6s.	1,073	14	0			
168 rods Reduced Brickwork in Foundations, Walls, &c., at 13*l.* 5s.	2,226	0	0			
52,000 feet cube of Stone in Engine Beds, &c., at 3s. 4d.	8,666	13	4			
4,872 feet cube of Stone in Cornices, at 6s.	1,461	12	0			
3,015 feet cube of ditto in Blockings, at 4s. 6d.	678	7	6			
188½ squares Iron Roofing, covered with Duchess Slating, at 12*l.* 5s.	2,309	2	6			
3,900 feet super 4-inch tooled York Paving in Boiler-rooms, at 2s. 6d.	487	10	0			
6,500 feet super 4-inch Rubbed Landings in Floor of Engine-room, at 3s.	975	0	0			
1,547 yards Stuccoing to Walls of Engine-room, at 1s. 6d.	116	0	6			
778 yards super Plastering to Ceiling of ditto, at 2s. 3d.	87	10	6			
778 yards super Wire Ceiling to ditto, at 3s. 3d.	126	8	6			
368 feet run Cornice to ditto, at 3s.	55	4	0			
1,900 yards super Limewhiting to Boiler-rooms, at 2d.	15	16	8			
To Door-cases, Doors, Windows, Handrails, &c. &c.	1,500	0	0			
Cutting round Engine-beds, &c. &c.	20	0	0			
1,541 yards cube Stourbridge Fire-brick work in Flues to Boilers, Chimneys, Shafts, &c., at 1*l.* 17s.	2,850	17	0			
				23,617	13	10

CHIMNEY SHAFTS.

2,000 cubic yards Digging in Foundations, at 1s. 4d.	133	6	8			
85 rods Reduced Brickwork in Shafts, at 14*l.*	1,190	0	0			
41 rods Reduced Brickwork in Cement, in Foundations, at 17*l.*	697	0	0			
500 yards cube Concrete in ditto, at 6s.	150	0	0			
1,800 feet cube Granite, in Bases, at 6s. 6d.	585	0	0			
1,101 feet cube Stone, in Cornices, &c. &c., at 5s. 6d.	302	15	6			
900 feet super 4½ inches Stourbridge Brick Lining to Flues, at 1s. 6d.	67	10	0			
2½ tons Iron, in ditto, at 16*l.*	40	0	0			
				3,165	12	2

TANK BUILDINGS, TANKS, &c.

73 rods Reduced Brickwork in Walls, &c., at 12*l.*	876	0	0			
1,696 feet cube Stone for Iron Girders, at 3s. 4d.	282	13	4			
3,498 feet cube in Cornices, &c., at 6s.	1,049	8	0			
246 tons Cast Iron, in Columns, Girders, and Tanks, at 9*l.*	2,214	0	0			
14½ tons Wrought Iron, in Stays to Tanks, at 16*l.*	232	0	0			
				4,654	1	4
Engine-house and Boiler-rooms				23,617	3	10
Chimney Shafts				3,166	2	2
Tank Buildings, Tanks, &c.				4,654	1	4
Total Estimate				£31,437	7	4

(Signed) JOHN PHILLIPS.

APPENDIX D.

FROM gaugings of the flow of sewage into the Thames in fine weather from all the outlets of the sewers, it appears that the discharge on the average of the day is 7,000 cubic feet per minute, and the total quantity per day 10,080,000 cubic feet.

To raise this quantity from a depth of 100 feet would require steam-power equal to 1,326 horses, as will appear from the following calculation :—

$$\frac{62{\cdot}5 \times 7000 \times 100}{33{,}000} = 1325{\cdot}75 \text{ H. P.}$$

This is the usual method of calculation; but the Cornish engine is capable of doing considerably more *work* than here stated.

The application of this power would be by eight engines of 165 horse-power each. The cylinders would be 84 inches, and the pumps 43 inches in diameter. There would be thirty-two boilers, each thirty-two feet in length by six in diameter.

The cost of the engines and pumps complete would be 95,000*l.*

WORKING EXPENSES.

It is calculated that the effect of the Cornish engine is equal to a duty of about eighty million pounds, raised one foot higher by a hundredweight of coals. There are about ten million cubic feet of water to be raised 100 feet per day; that is, 625,000,000lbs; to raise which one foot would require 7·8 cwts. of coal, which, multiplied by 100, gives 780 cwts., or thirty-nine tons of coal per day; that is, 14,235 tons per annum; which, at 15s. per ton, would cost 10,676*l.* per annum.

	£	s.	d.	£	s.	d.
Cost of Fuel, &c. per annum	10,676	0	0			
Six Engineers, at 100*l.* per annum	600	0	0			
Sixteen Stokers, at 52*l.* per annum	832	0	0			
Wear and Tear of Machinery, Oil, Tools, Implements, &c. &c.	1,500	0	0			
				13,608	0	0
Ten per Cent. for Contingencies, Repairs, &c.				1,360	16	0
Total Working Expenses				£ 14,968	16	0

(Signed) JOHN PHILLIPS.

PRELIMINARY REPORT

ON THE

DRAINAGE OF THE METROPOLIS.

By Mr JOHN PHILLIPS, Chief Surveyor.

JULY 23rd, 1849.

LONDON:
Printed by Reynell and Weight, 16 Little Pulteney street.