157

dupl

METROPOLITAN DRAINAGE.

RETURN to an Order of the Honourable The House of Commons, dated 31 July 1857;—*for*,

COPIES "of a LETTER dated the 31st day of December 1856, addressed by the First Commissioner of Her Majesty's Works, &c., to Captain *Douglas Galton*, R. E., *James Simpson*, Esquire, C. E., and *Thomas E. Blackwell*, Esquire, C. E., directing them to consider the PLANS for the MAIN DRAINAGE of the METROPOLIS, as submitted to the First Commissioner by the Metropolitan Board of Works:"

"And, of the REPORT, dated the 31st day of July 1857, presented to the First Commissioner, in accordance with the directions contained in that Letter."

(Sir Benjamin Hall.)

Ordered, by The House of Commons, *to be Printed,*
3 *August* 1857.

233—Sess. 2.

CONTENTS.

COPIES of a LETTER dated the 31st day of December 1856, addressed by the First Commissioner of Her Majesty's Works, &c., to Captain *Douglas Galton*, R.E., *James Simpson*, Esquire, C.E., and *Thomas E. Blackwell*, Esquire, C.E., directing them to consider the PLANS for the MAIN DRAINAGE of the METROPOLIS, as submitted to the First Commissioner by the Metropolitan Board of Works; and, of the REPORT, dated the 31st day of July 1857, presented to the First Commissioner, in accordance with the directions contained in that Letter.

Office of Works, &c. Whitehall,
31 December 1856.

Gentlemen,

I AM directed by the First Commissioner of Her Majesty's Works, &c. to forward for your consideration the plans for the main drainage of the Metropolis, which have been submitted to him for approval by the Metropolitan Board of Works, in accordance with the 18 & 19 Vict. c. 120, ss. 135 & 136. By the first of these sections it is provided, that the Metropolitan Board of Works "shall make such sewers and works as they may think necessary, for preventing "all or any part of the sewage within the Metropolis from flowing or passing "into the River Thames, in or near to the Metropolis, and shall cause such "sewers and works to be completed on or before the 31st day of December 1860, "and shall also make all such other sewers and works, and such diversions or "alterations of any existing sewers or works vested in them under this Act, as "they may from time to time think necessary for the effectual sewage and "drainage of the Metropolis; and shall discontinue, close up, or destroy such "sewers for the time being vested in them under this Act, as they may deem "unnecessary; and such Board shall from time to time repair and maintain "the sewers so vested in them, or such of them as may not be discontinued, "closed up, or destroyed as aforesaid.

"And for the purposes aforesaid such Board shall have full power and "authority to carry any such sewers or works through, across, or under any "turnpike-road, or any street or place laid out as or intended for a street, as "well beyond as within the limits of the Metropolis, or through or under any "cellar or vault under the carriage-way or pavement of any street, and into, "through, or under any lands whatsoever within or beyond the said limits, "making compensation for any damage done thereby, as hereinafter provided; "and all sewers and works from time to time made by the said Board shall vest "in them.

"And the said Board shall cause the sewers vested in them to be constructed, "covered, and kept so as not to be a nuisance or injurious to health, and to be "properly cleared, cleansed, and emptied, and for the purpose of clearing, "cleansing, and emptying the same, they may construct and place either above "or under ground such reservoirs, sluices, engines, and other works as may be "necessary, and may cause the sewage and refuse from such sewers to be sold "or disposed of as they may see fit, but so as not to create a nuisance, and the "money arising thereby shall be applied towards defraying the expenses of such "Board."

And by the second, it is also enacted, "That before the Metropolitan Board "of Works commence any sewers and works for preventing the sewage from "passing into the River Thames as aforesaid, the plan of the intended sewers "and works for the purpose aforesaid, together with an estimate of the cost "of carrying the same into execution, shall be submitted by such Board to the "Commissioners of Her Majesty's Works and Public Buildings; and no such "plan shall be carried into effect until the same has been approved by such "Commissioners."

I am further directed to forward to you copies of the several reports presented by the Engineer of the Metropolitan Board of Works, which reports contain drawings and sections, not merely of the plan B., but of other plans.

I am also directed to send you the enclosed copies of two letters from Captain Burstal, in reference to the flow of the tide in the river, which may be useful

useful in your investigation; the first of these letters is dated July 30th, and the second November 18th, the latter having been addressed to the First Commissioner, under the following circumstances:—

In the month of June last, the Metropolitan Board of Works submitted to the First Commissioner a plan having an outfall for the discharge of the sewage into the Thames, within the Metropolis. This plan was at variance with the provisions of the statute contained in the clause to which I have already directed your attention, and was accordingly rejected by him. On the 5th day of November, another plan was submitted by that Board, having an outfall so near to the Metropolitan boundary that the sewage would necessarily return to the Metropolis. This plan having been also rejected by the First Commissioner, he directed Captain Burstal to report to him what he considered to be the nearest points to the Metropolis at which the sewage could be discharged, so that the provisions of the Act might be complied with. Captain Burstal fixed these points about one mile above the town of Erith, on the south side of the river, and at Rainham Creek on the north side, being a distance of about 15 miles from London Bridge.

The Metropolitan Board of Works have adopted these points for the outfalls, and have so far complied with the Act. The First Commissioner, therefore, wishes you to consider all the details of the plan, in relation to such outfalls; and he desires me to direct your attention especially to the fact that, in the reports presented to the Metropolitan Board of Works, and the statements made to him by the Engineer, at an interview reported in the morning papers of 21st November last, there are great discrepancies as to the amount of sewage which is discharged.

It will, therefore, be necessary for you to obtain accurate information upon this important point, as the sizes of all the drains and reservoirs must necessarily be determined by the quantity of sewage.

The First Commissioner wishes also that you should not confine yourselves merely to the plan submitted by the Metropolitan Board of Works; he desires to have the fullest information you can afford him; and if you can devise any other scheme which may, in your opinion, be better calculated to carry out the object in view, he requests that you will in your report set forth that scheme, in order that he may lay it before the Metropolitan Board of Works for their consideration.

The plans now sent to you fix the outfalls at the points already indicated; but inasmuch as it is desired by the inhabitants of towns bordering upon the river below the 15 mile point that the main sewer should be extended, and that the outfall should be placed at a greater distance from the Metropolis, provided funds are obtained for the purpose of meeting the increased expenditure, the First Commissioner wishes you to report upon any such more distant points of discharge as may fairly meet the requirements alluded to; and when you submit to him the plans for effecting that object, you will set forth the increased cost consequent upon the extension of the works, the benefits, if any, to be derived by districts through which the extended main drain may pass, and how far those districts should contribute to the cost of such extended works. The First Commissioner feels sure that you will give to the various plans which doubtless will be laid before you such attention as they may deserve.

A commission is about to be appointed to inquire into the most effectual means of distributing the sewage of towns, and of applying it to beneficial and profitable uses, and it may therefore be desirable that you should put yourselves in communication with that commission, as a strong feeling seems to be entertained by members of the Metropolitan Board of Works and others, that the sewage of the Metropolis may be made a source of profit.

In conclusion, I am directed to request that you will report your views upon the question of the main drainage of the Metropolis and the points of outfall, at the earliest period consistent with the full consideration of so important a subject.

I am, &c.

Alfred Austin, Secretary

To Captain Douglas Galton, R.E,
J. Simpson, Esq., C.E.
Thomas E. Blackwell, Esq., C.E.

29, Great George-street, Westminster,
31 July 1857.

Sir,

We have the honour to report to you, that in accordance with the instructions conveyed to us through Mr. Austin in his letter of the 31st of December 1856, directing us to consider the plans for the main drainage of the metropolis, submitted by the Metropolitan Board of Works, and further directing us to devise from those or from any other plans the scheme which may, in our opinion, be calculated to secure the best system of drainage for the Metropolis, and the best point of outfall for the sewage, we have endeavoured to obtain the information necessary for the purpose, by making a minute personal inspection of every part of the metropolitan area, by carefully considering the numerous plans which have been submitted to us, and by communicating with many persons of practical experience on the subject.

We have now the honour to lay before you the results of the information thus obtained, and the opinions to which these results have led us.

The questions referred to us may be conveniently classified for consideration under the following heads, viz.:

1st. The principal features of the existing system of drainage in the metropolis; the system of drainage proposed by the Metropolitan Board of Works; and the amount of sewage for which provision should be made.

2d. A general consideration of the several schemes which have been submitted for draining the metropolis.

3d. The system of drainage which we recommend; and the modifications in the plan of the Metropolitan Board of Works, which this system will necessitate.

4th. The extent to which districts adjacent to London, which will be benefited by the proposed mode of disposing of the sewage, ought to contribute thereto.

I.—The Principal Features of the existing System of Drainage in the Metropolis; the System of Drainage proposed by the Metropolitan Board of Works; and the Amount of Sewage for which Provision should be made.

General Description of the Metropolitan Area.

The Districts which are comprised in the Metropolis are as follow, viz.:—

Districts on the North side of the Thames.

1st. The Western Districts, viz.:—Kensington; Chelsea; St. George, Hanover-square; Westminster; St. Martin-in-the-Fields; St. James's, Westminster.

2d. The Northern Districts, viz.:—Marylebone; Hampstead; Pancras; Islington; Hackney.

3d. The Central Districts, which include St. Giles'; Strand; Holborn; Clerkenwell; St. Luke; East London; West London; City of London.

4th. The Eastern Districts, composed of Shoreditch; Bethnal Green; White chapel; St. George-in-the-East; Stepney; and Poplar.

Districts on the South side of the Thames.

St. Saviour, Southwark; St. Olave, Southwark; Bermondsey; St. George, Southwark; Newington; Lambeth; Wandsworth; Camberwell; Rotherhithe; Greenwich; Lewisham; and Woolwich.

These districts cover an extent of nearly 118 square miles; and they are contained within that portion of the valley of the Thames which may be considered to commence where the high land approaches the river at Brentford on the north side, and at Richmond on the south side. The range of hills which bounds the valley on the north passes between Hanwell and Ealing, and then, turning eastward to Hampstead and Highgate, divides the valley of the Thames from that of the Brent. From Highgate the range continues in an easterly direction, separating the London Basin from the tributaries of the River Lea, and is terminated abruptly at Stamford Hill by the Valley of the Lea.

On the southern side the range of hills which bounds the main valley may be considered to pass from Richmond, by Wimbledon Park, to Tooting; then southward, by Streatham, Norwood, the Crystal Palace, Sydenham, and Forest Hill to Deptford; and to be terminated by the high land which passes south of Greenwich, and which abuts on the river at Woolwich. But this main range of hills is intersected by three subsidiary valleys.

First, on the east side of Richmond Park, it is intersected by the valley of the Baveley Brook; secondly, between Wimbledon Park and Tooting, by the valley of the River Wandle; and, thirdly, the valley of the River Ravensbourne, at Deptford, separates the main range from the high land which lies at the back of Greenwich and Woolwich.

The metropolitan district terminates in the marshes a little below Woolwich.

Present System of Drainage.

When considered with reference to drainage, the main valley of the Thames may be said to contain two distinct natural divisions; viz.:

1st. The Upland Districts.

2nd. The Lowland, or Marsh Districts.

The Upland Districts are divided into a series of valleys, generally at right angles to the main valley of the Thames, or nearly so; and in each of these valleys is the bed of a stream, which served to convey the natural drainage of the district towards the river.

The Lowland, or Marsh Districts, on the other hand, present generally uniform surfaces, seldom much above, and usually several feet below the level of high water. These districts appear to have been originally formed by inclosing the mud banks which skirted the river, the inclosed land being drained by ditches, with scarcely any inclination: the outfalls of these ditches are below the level of high water, and therefore the water they contain can only be discharged when the tide is low.*

Through large portions of the metropolitan area these marsh districts lie between the upland districts and the river, and consequently, the streams which convey the drainage of the upland districts, discharge into the drains of the marsh districts, in which the water naturally remains stagnant for a portion of every tide.†

When houses were first built over the metropolitan area, the streams and ditches retained their original functions as channels, to convey away the rain-fall from the fields, roads, and roofs of the houses; water for domestic purposes was not so largely used as it is at present, and the house drainage was collected into cesspools.

But even the best devised cesspools caused occasionally great inconvenience, and those which were badly constructed were a great source of annoyance, discomfort, and disease; hence, when improved means of disposing of the sewage were appreciated by the public,‡ the legislature required that the use of cesspools should be discontinued in populous districts. The house drains have consequently been connected with the sewers; and the flow of the contents of these sewers is assisted by means of a largely increased water supply.

This important change in the habits of the people, and in the system of drainage, necessarily rendered the streams and ditches extremely offensive, and created the necessity of covering them over.

Springs

* Although no records of the construction of these embankments are accessible, they are unquestionably of very ancient date, and viewed as engineering works, are of a magnitude and extent which entitles them to be considered as belonging to the most remarkable, as they certainly are the most ancient, of any of the same character in the kingdom. And there is every reason to believe that they were constructed at a period contemporaneous with the Roman occupation of Britain.—(*See* Dugdale's History of Embankment and Draining, 1772.)

† The condition in which many of these districts remained down to 1843, may be gathered from the Reports of Mr. J. Gwilt and Mr. I'Anson. (*See* Appendix VIII.)

‡ We believe that the introduction of water-closets in the metropolis, to any extent, may be dated from about the year 1810, from which time until 1830 their increase was only gradual; but since 1830, the increase has been very rapid and remarkable. The number of cesspools which have been discontinued in London, is stated to be not far short of 200,000.

Springs, arising from the rain-fall of the districts stored up in the ground, formed the original supply of these streams. But as the agricultural drainage of a district is improved, or as a district becomes occupied by houses and streets, the water passes off with greater rapidity into the drains, and a smaller proportion is retained in the ground; hence the quantity of fresh water flowing in the streams was diminished, whilst the quantity of sewage, and the consequent impurity, was increased. Thus, the Walbrook, the Fleet, and the Bayswater, or Ranelagh streams, which pass through inhabited districts, contain in dry weather scarcely any water beyond the sewage derived from the houses, and even in those streams which pass through what may be still considered agricultural districts, such as the Stamford Brook, or the Counters Creek* on the north, and the Effra and the Falcon Brook on the south, the proportion of pure water is comparatively small; it is, in fact, much less than the amount of sewage which will be derived from the houses which, it may fairly be calculated, will be built over the districts within a very few years; and when these houses shall have been built, the natural flow of the streams will very nearly cease.

In order to understand thoroughly the question of the impurity of these streams, we have examined every line of main sewer from its commencement to its outfall; and we have been forcibly struck with the great extent to which every spring, brook, and open watercourse is polluted. This amount of pollution has been very much aggravated during the last four or five years, principally in consequence of the water supplied by the companies having been conveyed higher up the hills; owing to which, large quantities of foul sewage are continuously forced into the heads and upper branches of the streams. This sewage passes into the lower districts, and thence into the Thames.†

We have carefully considered the possibility of separating the pure water of these streams, and conveying it to the river‡ free from sewage; but we are of opinion that it is utterly hopeless to attempt this, on account of the extent of the pollution, and of the complete saturation of the ground with sewage.

It is, therefore, obvious that no useful result would be gained by preserving this water for the Thames. It may be here observed, that if a district, provided with proper sewers, be covered with buildings, the sub-soil of that district will be rendered much drier, and therefore more healthy in that respect, than it was before.§

The three streams on the south side of the Thames, which have been mentioned as occupying valleys subsidiary to the main valley of the Thames, form exceptions to this view; viz., the Baveley Brook, the Wandle, and the Ravensbourne. These streams receive the sewage of the detached houses, and of the villages and towns in their course; they also drain extensive agricultural districts, and convey large volumes of water, derived partially from the chalk formation. Great expense would, on the one hand, be entailed on the metropolis by treating these streams as sewers; and, on the other hand, it is very desirable that the pure water they contain should continue to flow into the Thames.

This,

* At present the proportion of water from land springs in the Counters Creek is larger than in the other streams mentioned; but this sewer is of comparatively recent construction, and there is reason to believe that this excess of spring-water is rapidly diminishing.

† Many of the larger watercourses, which have latterly become common sewers, are still uncovered, and are such intolerable nuisances, that we feel they must seriously affect the health of the inhabitants in many of the districts they traverse.

‡ Mr. Leach, engineer to the Navigation Committee of the Corporation of London, estimated the smallest discharge of the Thames at under 500,000,000 gallons in 1852-3; and considered that the present discharge (July 1857) is not much above 600,000,000 gallons per 24 hours.

§ The construction of sewers in the Metropolis has also been the means of abstracting and diverting large quantities of spring-water flowing in the various strata through which the sewers passed. The absorption of water in all the sandy districts, and the loss of the celebrated springs at Bayswater, from which, in ancient times, water was conveyed to the City of London by leaden conduit pipes in the direction of Oxford-street, and Holborn, and some of which springs, in the early part of the present century, formed the source of supply of the Stone-pipe or Spring Waterworks, a company whose interest was purchased by the proprietors of the Grand Junction Waterworks, at the beginning of their career, are remarkable instances of the diminution of underground streams as the sewers have been extended through the metropolis.

This, however, involves the necessity of intercepting the sewage which no flows into them, and leads to the consideration of a question which has an important bearing on the drainage of the metropolis.

These streams rise in districts beyond the limits of the metropolitan boundary, and receive in those districts large and increasing portions of the sewage which pollutes them.

The Wandle, for instance, receives the sewage of Croydon,* Beddington, Carshalton, Mitcham, and Merton, all which places are beyond the limits of the district, and out of the control, of the Metropolitan Board of Works. But the Wandle discharges its contents into the Thames at Wandsworth, a point within the limits of the metropolitan district.

The Ravensbourne receives and conveys into the Thames great quantities of sewage from Penge, Beckenham, and Bromley, where large and populous districts are springing up.

The River Lea† and the Brent, on the north side, also contribute large amounts of foul drainage to pollute the Thames, although much of that from places to the north-west of the metropolis, which flows into the valley of the Brent, is arrested in the canal reservoirs.

The 145th section of the Public Health Act, 11 & 12 Vict. cap. 63, possibly provides a remedy for cases of this description; but it will certainly be an anomaly if, whilst the inhabitants of the metropolis are called upon to purify the Thames from sewage, at a large cost, the inhabitants of adjacent districts should be allowed to continue to pollute it, by passing large quantities of sewage through these streams into the river.

This question is connected with that of the pollution of the Thames, and of all its tributary streams, to which we shall have occasion to allude in a future part of the Report. But we must here express our decided opinion, that if the River Thames is to be effectually relieved from the sewage which flows into it within the limits of the metropolitan districts, it is essential that the scheme of drainage to be adopted should embrace not only the metropolitan districts, but all those out-lying districts the drainage from which is included in the same area by the natural features of the ground.

The system of drainage which we have shown to be in operation throughout the metropolis has, in the first place, occasionally subjected the low-lying districts, from the earliest period, to very great inconvenience and damage to property from floods; and, secondly, since the time when the house sewage has been discharged through the drains, a serious injury has been inflicted on the health of the inhabitants of those districts.

1st. Floods have frequently been caused‡ by the occurrence of rain at the time of high water, from the fact of the basements of many of the houses in the

* The case of Croydon appears to be one which demands serious attention. A partial deodorization of the sewage, which was eventually diverted into the Wandle, caused serious complaints, and some very embarrassing legal difficulties, which induced the local Board to take steps to carry the sewage to a point in the stream below the mill of the plaintiff in the action; but we cannot withhold our opinion that this process will be insufficient as respects all other parties on the banks of the Wandle below the new point of outfall; and having regard to levels and other circumstances, we consider that the proper and obvious direction for the outfall of the sewers of this town is the valley of the Ravensbourne. If the sewage of Croydon is conveyed through the valley of the Wandle, it will have to be passed into the sewer from Wandsworth to Greenwich, a most circuitous and objectionable course, inasmuch as this sewer crosses populous districts, and the distance from Croydon to Deptford, *viâ* Tooting, Wandsworth, Brixton, Camberwell, &c., is 15 ½ miles; while the distance *viâ* Penge, Sydenham, and the valley of the Ravensbourne, to Deptford Bridge, is only nine miles.

† In the valley of the Lea a cut or sewer has been made by the East London Waterworks Company, to divert the sewage from Ponder's End downwards; this sewer is upwards of four miles long, principally open, and *falls into the River Lea below Tottenham Mill, conveying a considerable quantity of sewage and foul water.*

‡ Floods have occasionally, though rarely, taken place in consequence of the neglect of the persons charged with the superintendence of the outfalls to close the flaps, and thus prevent the ingress of the tide.

the low-lying districts being below the level of the storm-flow in the sewers; and consequently, when these sewers have been full of water, the sewage has flowed back into the houses through the house drains.

It appears from the records of the Commissioners of Sewers, that injury from floods to the low-lying districts was experienced long before the ground was so much occupied by houses as it now is, and that in the case of the King's Scholars' Pond Sewer, the outfall of which is near Vauxhall Bridge, the late Mr. Rennie, the eminent engineer, proposed, in 1806,* to prevent these floods, by intercepting the drainage of the upland districts, and by conveying the water into the river near Charing Cross, through a channel capable of discharging it at all times of the tide. Similarly on the south side of the Thames the Commissioners of the Kent and Surrey Sewers had decided, before the Commissioners of Sewers for the several districts were consolidated, to intercept the upland waters, by a sewer following very much the course of Mr. Bazalgette's high level intercepting sewer, and capable of discharging into the Thames, near Deptford, at all times of the tide.

2d. The serious injury which the existing system of drainage has caused to the general health of the inhabitants, has been due to the fact of the sewage being ponded back during a portion of every tide.

During this period the main sewers are stagnant, and become no better than cesspools; and when leakages occur through the walls, the district becomes charged with sewage. The stagnation of the sewage also permits large amounts of suspended matter to be deposited in the sewers; and this can only be removed from time to time, and at a considerable expense.

Another serious evil arises from the continued flow of sewage into the sewers during the time when they are tide-locked, which causes the deleterious gases from the sewers to be expelled into the streets and houses of the water-logged districts; and the occasional flooding of the basements of houses with sewage, which has been already alluded to, is at least as injurious to health as to property.

With the view of exhibiting the effect which the stagnation of the sewage appears to have upon the health of the inhabitants, we have prepared a map of the metropolis, from information supplied to us by the Registrar-general, showing the mortality during the cholera in each sub-district. From this map it appears that those districts in which the sewage has been thus held back, have been much less healthy than the districts from which the flow of sewage has been continuous. (*See* Appendix III.)

Pollution of the River Thames.

In addition to the flow from the sewers into the Thames, there are other serious sources of pollution which were brought to our notice in our visits to the outfalls of the sewers, and to which it is necessary to direct attention At almost all the wharves and manufacturing premises on the banks of the Thames, great nuisances arise from the privies, urinals, foul drains, &c., which communicate directly with the river. At the dung wharfs and other places, large quantities of objectionable matter are frequently left on the foreshores to be washed away by the tide.

A similar extent of pollution prevails in the docks, canals, and inlets which communicate with the Thames. We have also witnessed on several occasions most objectionable foul matter being thrown into the river from barges in various parts; and, from observations of the state of the water, our decided conviction is that large quantities of foul and polluted water and other liquids are occasionally let off from chemical works, gas works, and many other manufactories, not only directly into the river, but into many of the sewers and watercourses which drain into it. These practices are of common occurrence, notwithstanding the efforts of the conservators of the Thames to prevent them.

In

* In a Report to the Commissioners of Sewers for Westminster. *See* Appendix VIII.

In order to obtain an exact knowledge of the effect which the continued flow of polluted matter has had in diminishing the purity of the Thames, we requested Dr. Hofmann, LL.D., F.R.S., Chemist to the Museum of Practical Geology, and Mr. Witt, F.C.S., Assistant Chemist to the Museum of Practical Geology, to undertake the analysis of specimens of Thames water selected from various points between Teddington Lock and Rainham Creek, as well as the analysis of samples taken at the same time from the mouths of sewers.

The results of these analyses, which were performed with great care, are shown in the very able communication of these gentlemen, which is attached to this Report. Appendix I.

The general conclusions, however, to which these samples lead, appear in the following Table, which contains the analysis of the more polluted specimens of river water, compared with the water from the mouths of the sewers:

Total Amount of Solid Constituents in Grains per Gallon.	RIVER WATER.							SEWERS.			
	* Kew Bridge.	Crab Tree Slip, near Fulham.	Opposite Lock at Wandsworth.	Westminster Bridge.	London Bridge.	Victoria Dock.	Mean of these Specimens.	Earl.	Falcon Brook.	King's Scholars' Pond.	Fleet.
Organic - - - - -	1·844	1·992	2·359	1·937	2·194	2·032	2·059	2·738	3·987	17·75	16·117
Mineral - - - - -	23·067	20·124	23·672	23·496	23·676	25·649	23·281	46·11	40·146	47·23	51·304
TOTAL - - -	24·911	22·116	26·031	25·433	25·870	27·681	25·340	48·848	44·133	64·98	67·421

It appears from this Table, that the mean amount of organic matter contained in the specimens of river water was equal to about three-fourths of the amount of organic matter contained in the Earl Sewer, and that the mineral matter in the river water was half that in the sewer; and that, as compared with the Fleet Sewer, the quantity of organic matter in the river was as 1 to 8 in the sewer, the total impurity of the river to the total impurity in the sewer being as 1 to 2·6.

We collect from the report of Dr. Hofmann and Mr. Witt,† to which we particularly beg to call attention, that the proportion of organic matter compared with

* The small difference in the degree of impurity at Kew Bridge and at London Bridge is at first sight remarkable, and must be accounted for by the fact that the whole of the sewage which flows into the river at low water, and during the first hours of the flood, is carried up by the tide into the higher parts of the river.

† Since the *quantity* of dissolved organic matter is so small, the unwholesome character which it imparts to the water must arise chiefly from the peculiar *condition* in which it exists in the water. The opinions of chemists are divided as to the manner in which it exerts a deleterious effect upon the animal economy; but it is now generally admitted that the substances which constitute the organic matter of water act injuriously by no means in consequence of being poisonous themselves, but by undergoing those still imperfectly understood processes of transformation called *decay* and *putrefaction*, to which all animal and vegetable matter is subject when no longer under the control of vitality, in animals or in plants. These putrefactive processes either give rise to the formation of poisonous bodies, or—and this is far more probable—they act simply as ferments, exciting similar processes of decomposition in the substances composing the living animal organism. Decay and putrefaction areremarkably accelerated and facilitated by heat, and it is, in fact, during the comparatively short season of hot weather that the inconvenience arising from the presence of dissolved organic matter in the river water is particularly felt. The small amount of this matter, which is scarcely perceived in winter, and which during spring and in the early part of summer is perfectly harmless, becomes decidedly mischievous soon after the hot weather has set in.

The share which the dissolved organic matter has in the generation of those deleterious emanations which rise from the river during the hot season cannot be doubted. A portion of Thames water which has been allowed to deposit all the suspended matter, which has been filtered through sand or paper, or even animal charcoal, or which has been treated with lime, and thus been rendered transparent, colourless, and inodorous, when exposed to the air for a day or two during the hot weather, rapidly undergoes putrefaction, which in the first place manifests itself in the exhalation of an offensive odour, and gradually exhibits all the well-known appearances presented by putrefying substances, not unfrequently with the development of some of the lower forms of organised beings which generally attends these processes. The water gradually becomes slightly turbid, and after a time a quantity of insoluble matter collects at the surface in the shape of a thin froth. The water has now become clear again; every trace of colour and taste, or odour, has disappeared: the process of putrefaction is accomplished.

The

with the water in which it is contained is small, but that it is very pernicious, in consequence of its peculiar liability to putrefy; for when water contaminated with sewage has been completely filtered through sand, paper, or even through animal charcoal, and by that means been rendered perfectly colourless, clear, transparent, and inodorous, or after it has been treated with lime, it speedily begins, especially in hot weather, to ferment and putrefy, and becomes decidedly mischievous.

It would also appear that the black mud from the sewage contains a considerable quantity of organic matter, which is most deleterious; an immense mass of this fetid mud has accumulated in the bed and on the banks of the river, and it is continually supplying to the water large amounts of soluble matter in a state of putrescence, and contaminating the atmosphere with most offensive emanations. It is probable that the unhealthy condition of many towns on the sea coast is caused by deposits from the sewers, of mud of this character.

We have also obtained from Mr. Etheridge, Naturalist to the Museum of Practical Geology, the results of a microscopical examination of specimens of mud taken from the banks of the Thames. This mud appears to contain about 15 per cent. of organic matter, 20 per cent. of debris of metropolitan roads, while the remainder is partly alluvial and partly crushed flint and gravel from the basin of the Thames. (*See* Appendix II.)

From these several considerations, we are of opinion that if the sewage were removed from the Thames, the river would be very materially altered in character; but we do not anticipate that it would present the appearance of a clear stream until the projecting headlands at the termination of every reach shall have been protected from the disintegration caused by the agitation of the water which is principally caused by the steamboats.

Our attention, during the last few weeks, has been particularly called to the state of the River Thames, the noxious smell from which has assumed a great degree of intensity; but this arises not so much from any unusual accession of foul

The phenomena to which we allude here are well known to those engaged in storing Thames water on board ship, where this putrefactive fermentation and subsequent purification of the water is frequently observed.

Processes of a perfectly analogous character, and following each other in similar succession, are accomplished throughout the entire river and during the whole year, but more particularly so during the hot summer months. We have already pointed out the fact that numerous analyses by very different observers, and extending over a considerable period, have undoubtedly proved that the amount of this dissolved matter is *extremely small*. It has been shown, moreover, that its amount is not very perceptibly greater at London or Westminster Bridge, where the water of the river looks so dirty, than at Kingston, Kew, and Richmond, where it presents so beautifully clear and inviting an appearance. Why then is it, we may ask, that the effects of these putrefactive decompositions become so intolerable on the banks of the Thames in the immediate neighbourhood of London, when compared with those perceptible in the higher portions of the river?

It is obvious that the greater surface of the river as it traverses the metropolis, together with the agitation to which it is constantly subjected by the navigation, but especially by the steamboat traffic, as well as its tidal movements, must considerably facilitate and accelerate the progress of putrefaction; it is also evident that the quantity of soluble matter which, in consequence of the increased rapidity of putrefaction, is constantly being removed from the water is as quickly and constantly replaced by the discharges of the sewers. These conditions alone would be sufficient enormously to increase the intensity of the process of putrefaction in this part of its course, and consequently to multiply the quantity of offensive emanations to an intolerable and dangerous degree.

But the river in the neighbourhood of London contains an additional and even more formidable element of mischief in the black mud which subsides from the sewage, and which, in spite of the tidal movements of the river, has accumulated to a considerable degree, and is daily more and more accumulating in the bed of the river, so much so, indeed, that the continuation of the process would lead to the formation of deposits which, in future geological ages, might prove a source of manure scarcely less valuable than our beds of coprolites, phosphorite, and even of guano itself This black mud contains a very considerable quantity of organic matter of a most putrescible kind. Alternately immersed in water, and exposed to the action of air, which, in consequence of its porous condition, it absorbs in large proportions, this mud unites all the conditions favourable for the most active putrefactive fermentation, evolving not only most offensive gaseous emanations, but diffusing also a large amount of putrescible soluble matter through the river, which supplies additional material to the process of decomposition which is going on in the water itself.

We cannot but emphatically insist upon it, that the formation of this mud deposit in the river appears to us by far the most serious evil which results from the discharge of the London sewage into the river. We cannot too strongly urge this point upon public attention.—Extract from Dr. *Hofmann*'s and Mr. *Witt*'s Report.

foul sewage, as from the diminished volume of the stream at the present season, and from the more rapid decomposition of the organic matter, which has been favoured by the very high temperature of the water of the Thames.*

The pollution of the river is an evil which has increased, and must continue to increase with the growth of the metropolis. It will therefore be useful at this part of our Report to show what the increase of population has been, and to consider what may in all probability be the future rate of increase.

Population.

The rapidity in the increase of the population of the metropolis during the present century (especially within the last 30 years), and the localities in which the greatest additions are taking place, are very important features in the consideration of this question; on the one hand, considerable provision must be made for future increase; but on the other, it would be hardly consistent with true economy for the present generation to provide for the possible wants of a very distant period.

To illustrate the localities in which the greatest increase has taken place, by affording a comparison of the areas successively built over, we have appended a map, showing what the size of London was in 1745 as compared with its size in 1818, in 1834, and in 1857. We have obtained this information, 1st, from Roque's valuable map of London, 1745, made before the date of periodical census returns. 2. From Carey's map of 1818, issued a few years after the commencement of the long peace. 3. From the Ordnance map of 1834, at which date the Greenwich railway was the only one established in or near London. 4. From Wyld's map of 1857, showing the rapid additions which have taken place in the suburban districts since the termini of the principal lines of railway have been established. (*See* Appendix III.)

We have appended a Table showing the rates of increase and decrease in population of the districts and sub-districts of the Metropolis during the ten years from 1841 to 1851; and also a diagram showing at one view the progressive increase of population at each of the Census returns from 1801 to 1851 inclusive. It appears that in the City districts the increase has been very small, and even in some cases an actual decrease has occurred.

TABLE showing the Population and the Increase per Cent., and the actual Increase in Numbers, in the whole of the Metropolis, in each Period of 10 Years.

——	1801.	1811.	1821.	1831.	1841.	1851.
Actual Population - - -	958,863	1,138,815	1,378,947	1,654,994	1,948,417	2,362,236
——		1801–11.	1811–21.	1821–31.	1831–41.	1841–51.
Actual Increase - - - - - - -		179,952	240,132	276,047	293,423	413,819
Increase per Cent. - - - - - -		18·76	21·08	20·06	17·73	21·23

An examination of this table shows that the actual numbers, as well as the rate of increase, in the decennial period between 1841 and 1851 were greater than in any equal period since the establishment of the census.

Our own observation of the enormous increase in the number of houses lately built, or now in progress, and the information which we have derived from various official and other sources, lead us to believe that the present rate of increase is quite as high as that which we have quoted from the census returns; although the state of the money market during the last three years has to some extent restricted building operations.

The actual increase of 413,819 in 10 years, is about equivalent to the addition of the

* As bearing on this subject, we append a series of observations showing the daily temperature of the River Thames, and the fall of rain, at Kingston-on-Thames, from January 1855 to the present time. (Appendix III.)

the entire population of Birmingham, of Leeds, of Cheltenham, and of Ramsgate, as well as of the cathedral cities of Canterbury, of Salisbury, Wells, and Hereford; or, it may be compared to the accession in 10 years of the whole population of the county of Hants, which occupies an area of upwards of a million of acres.

This addition has hitherto principally occurred in the northern and western districts of the Metropolis; but in consequence of the construction of railways round the Metropolis, new districts for building have been opened out in every direction, especially towards the south; the various sites being selected with reference to health, facility of communication, and other causes.

The System of Drainage proposed by the Metropolitan Board of Works.

The plan upon which the Metropolitan Board of Works propose to drain the London district, is briefly as follows:—

I.—On the North Side of the Thames it is proposed to divide the district into three distinct drainage areas; viz.:

1st. The high level area, which might more properly be termed the upper part of the valley of the Hackney Brook, which is a tributary of the River Lea. This area is 9·68 square miles in extent.

2d. The middle level area, which is 17·64 square miles in extent; and is composed of the upper portions of the principal valleys on the north side, the streams from which flow into the Thames.

3d. The low level and western districts, which include the remainder of the northern Metropolitan area, as well as the portion of the upper valley of the Thames, which is not now included in the Metropolitan area, but which is described by Mr. J. W. Bazalgette, Engineer to the Metropolitan Board of Works, as "Prospective Area." The low level district is 10·87 square miles in extent, and the western district is 21·45 square miles in extent.

The sewage of the high level and middle level areas is to be intercepted in its course down to the river by drains of sufficient size to convey at the same time a proportion of rainfall; all the rainfall in excess would flow into the river. It is intended that the sewage from these districts should flow by gravitation to its final outfall, and the boundaries of the districts are consequently regulated at every point of interception by the level from which the sewage will so gravitate.

The sewage from the third area, the levels of which do not admit of this gravitation, is to be intercepted from the river by a low level sewer, and to be lifted to the necessary height to allow of its flowing to the selected point of outfall.

The general course of the sewers for draining these areas is as follows:—

1st. The sewer for the high level area intercepts the Fleet near Hampstead and Highgate, and is then carried across the fields to the Hackney Brook, the present course of which it may be said to follow, to a point near Sir George Duckett's Canal and the River Lea.

2d. The middle level intercepting sewer commences at Kensal-green and runs down to the Uxbridge-road, near its junction with the Queen's-road; it is then carried along Oxford-street and Holborn, and, generally in an easterly direction, under Sir George Duckett's Canal, to near the River Lea, where it is joined to the high level intercepting sewer. The combined sewer is then carried by an aqueduct across the main stream, and across numerous branches of the River Lea in the Hackney Marsh, to Abbey Mills.

The middle level intercepting sewer receives in its course two branches, viz., the Piccadilly branch and the Aldgate branch, by means of which the drainage of two projecting tongues of high land is intended to be intercepted for gravitation.

3d. The drainage of the western districts is divided into two portions, of which one, consisting of about one-third, is collected in the Counter's Creek Sewer, and flows into the low level sewer. This was at one time proposed to be conducted to a point on the banks of the Kensington Canal, and to be there deodorised; but objections having been made to this course, it is proposed, in the later

plans, to bring the drainage of the western districts by a low level sewer, near to the river, to the King's Scholars' Pond Sewer, and then to lift it to a height of 19·7 feet into the main low level sewer, which passes along Millbank and Old Palace Yard, between Henry VII.'s Chapel and the Victoria Tower, along Whitehall and Charing Cross into the Strand and Fleet-street, and thence, nearly due east, to the Commercial-road, near the Stepney Station, where it is turned towards the north-east in a direct line to Abbey Mills. At Abbey Mills the sewage will be raised into the high level sewer, to a height of 37 feet.

It receives on its way a branch from the Isle of Dogs, and one from the Hackney Marsh.

It will thus be seen, that, with the exception of about 28 square miles, which are to be carried off by gravitation, the remainder, amounting to 32·32 square miles, will have to be raised by artificial means. In the first place, the drainage of about two-thirds of the area, or about 14 square miles, will have to be raised near the King's Scholars' Pond Sewer to a height of 19·7 feet, and the whole will have to be lifted at Abbey Mills to the height of 37 feet.

The united sewage of the three areas is conveyed from Abbey Mills in one channel to the confluence of the Rainham Creek and the River Thames, at a point which has been designated as B*, where it is to be stored up in a large reservoir for discharging into the river near the period of high water.

The highest line of water level, which of course regulates the area of interception, in the two gravitating sewers at the junction near the River Lea, is 32 feet above Ordnance datum, or 19 ft. 6 in. above Trinity High-water mark, the bottom of the sewer being 21 ft. 6 in. above Ordnance datum, or 9 feet above Trinity High-water mark.

An objection having been made to the discharge of the sewage at the point B.*, Mr. Bazalgette has submitted to the Metropolitan Board of Works an alternative plan for removing the sewage by gravitation to a point at Mucking Flats, in that reach of the River Thames called the Lower Hope.

II.—On the South Side of the Thames.

On the southern side of the river it is proposed to divide the district into two areas of drainage, viz., a high level area, occupying 19¾ square miles, and a low level area, occupying 22 square miles.

The object of the high level sewer is to intercept the upland sewage in its descent towards the lower district; it commences at Clapham, and passes by Camberwell and Peckham to Deptford; at this point the sewage is carried in a double conduit, each of which is 10 feet 6 inches in diameter, and is passed under the Ravensbourne by a pipe of four feet diameter, which is intended to act under pressure.

The low level sewer commences at Putney, and passes under the Wandle at Wandsworth, and thence through Battersea Fields to the Brixton Road, from which it will be carried through the low level district to Deptford, where the proposed sewer is to be nine feet six inches in diameter; and at this point the sewage is to be raised to a height of 20·5 feet, into the high level sewer.

From Deptford the united sewage is conveyed in a conduit of 10 feet diameter by Greenwich to Woolwich, where the diameter is increased to 10 feet 6 inches, and thence through the Plumstead Marshes, to a point on the river opposite Rainham Creek, where the whole sewage is to be lifted a height of 21 feet into a reservoir, whence it would be discharged into the river.

In the plan before mentioned, which proposes to convey the sewage to the Mucking Flats, in the Lower Hope, it is proposed to carry the southern sewage under the river by a tunnel, and then lift it into the northern sewer.

Amount of Sewage for which Provision should be made.

1. Amount provided by the Plan of the Metropolitan Board of Works.

The quantity of sewage to be removed for which the plan of the Metropolitan Board of Works provides has been computed by Mr. Bazalgette as follows:

The upper portions of that part of the main valley of the Thames in which the metropolis is situated, have been added to the metropolitan district as prospective areas, and the whole have been divided into sections, of which some have been considered to be urban and some to be suburban. It has then been estimated that the population of the urban districts will rise to 30,000 per square mile,

mile, if they have not already attained that amount; and that the suburban districts will attain to a population of 20,000 per square mile. The districts which have a population in excess of these figures have been taken at the present population. It has been assumed that the sewage to be removed for each person will amount to five cubic feet per day, half of which it has been assumed will flow off in six hours.

To this has been added a proportion of rain-fall equivalent to one-quarter of an inch flowing through the sewers in 24 hours in the urban districts, and one-eighth of an inch in the suburban districts.*

2. Amount obtained by Experiment.

The question of the quantity of sewage to be removed having been one of the principal points referred to us in Mr. Austin's letter, we have given very careful consideration to this subject.

We have already described the large increase which is taking place in the population of the metropolis and its suburbs. With the view of estimating the population for which provision must be made, we have examined very carefully the population of each sub-district, and, after considering the local circumstances, have added to each the amount which we are of opinion that the population will reach in 30 or 40 years. Thus, in the case of districts in which building is now being carried on rapidly, we have assumed a population equal to that of adjoining districts already filled with houses of a similar class; whilst in districts which do not show any decided progress, we have taken a smaller rate of increase. The results are shown in Appendix III, Table, No. 6.

We have also examined the population returns of that part of the main valley of the Thames, between the boundary of the metropolitan districts and Brentford and Richmond, which is termed "prospective area" by Mr. Bazalgette, and we have assumed an increase upon that population. This is also shown in the Tables.

And inasmuch as we consider it essential to a complete scheme of drainage for the metropolis, that such scheme should include the drainage of those places which are situated in the same natural drainage area as the metropolis, we have added to the Tables the population of the valleys subsidiary to the main valley of the Thames before alluded to, viz., the valleys of the Baveley Brook, of the River Wandle, and of the River Ravensbourne on the south, and we have also added East Ham, Stratford, and Barking, and a portion of the valley of the Lea, as a probable prospective area on the north side of the Thames.

The

*TABLE, showing Amount of SEWAGE and RAINFALL provided for within the Metropolitan District by the Plan of the Metropolitan Board of Works.

(Extracted from Mr. Bazalgette's Report on the Southern Main Drainage, dated 3d April 1856, and from the Report on the Northern Main Drainage, dated 22d May 1856.

	Prospective Population.	Area.	SEWAGE. Prospective Amount provided for at 5 cubic feet per head per diem. Cubic feet per minute.	Prospective Amount provided for at 5 cubic feet per head per diem. Gallons per diem.	Maximum Flow. Cubic feet per minute during 6 hours.	Maximum Flow. Gallons per diem, if extended over 24 hours.	RAINFALL. Proportions of Area provided for	RAINFALL. Cubic feet per minute.	RAINFALL. Gallons per diem.	TOTAL of Maximum Sewage and Rainfall which the Sewers are capable of removing. Cubic feet per minute during 6 hours.	TOTAL of Maximum Sewage and Rainfall which the Sewers are capable of removing. Gallons per diem if maximum flow be extended over 24 hours.
		Acres.					*Acres.*				
North side - -	2,318,800	31,030	8,047	72,423,000	16,094	144,846,000	31,030	15,676	142,902,000	31,972	287,748,000
South side - -	1,094,600	25,038	3,800	34,209,000	7,600	68,400,080	17,676	8,341	75,069,000	15,941	143,469,000
	3,413,400	56,968	11,847	106,623,000	23,694	213,246,000	49,606	24,219	217,971,000	47,913	431,217,000
Deduct Total Sewage per diem, See Column 4 - - -											106,623,000
											324,594,000

	Gallons.	*inches.*	
Rainfall on North side - -	215,325,000 of rain =	·29 per diem over 31,030 acres.	
Rainfall on South side - -	109,269,000 ,, =	·19 ,, ,, 25,038 ,,	·27 ,, ,, 17,676 ,,
Total Rainfall - - -	324,594,000 ,, =	·25 ,, ,, 56,968 ,,	·28 ,, ,, 49,606 ,,

The population which we have thus assumed for the metropolitan districts amounts to 3,578,089, as compared with a population in 1851 of 2,362,236; and the assumed population for the additional area, the drainage of which we are of opinion should be included, amounts to 401,000 inhabitants, as compared with a population in 1851 of 154,076; the total assumed population being 3,977,532.

The population of the total area in 1851 was 2,516,304, and therefore the assumed number gives an increase of about 54 per cent.

We have in the next place examined the question of the amount of sewage which these districts thus inhabited will afford. We have gauged 13 sewers on the north side, whose united flow appears to represent about three-fourths of the whole flow of sewage on that side of the river. We have also gauged four sewers on the south side, whose united flow represents more than 60 per cent. of the whole flow on that side.

We have carefully compared these with the flow of the sewers as ascertained by Mr. Bazalgette in 1853, as well as with a series of gaugings* made in 1853 by Mr. Haywood, engineer to the Commissioners of sewers for the City of London, and recently published.

The amount of sewage as shown by our gaugings is 54 per cent. on the north side, 23 per cent. on the south, and 42 per cent. in total amount above that shown by Mr. Bazalgette's gaugings of the same sewers, whilst the flow of the sewers which we gauged, and which were also gauged by Mr. Haywood, does not differ greatly from Mr. Haywood's results.

The differences are to some extent accounted for by the fact that the sewers which Mr. Haywood gauged flowed from the City, in which the water supply has probably not increased materially; whilst a very great increase has taken place in the water supply of the districts which the sewers gauged by Mr. Bazalgette traverse.

The sewers may be divided into two classes, viz., first, those sewers which flow through districts closely built over, and, second, the sewers which flow through districts partly agricultural.

1st. It will have been seen, from what we have already stated respecting the effect of covering a district with houses, that in all the sewers which occupy areas closely built over, the flow depends almost entirely upon, and is in proportion to, the population.

2d. In the sewers which flow through large agricultural districts, as, for instance, the Effra, the Falcon Brook, or the Counter's Creek, there is a proportion of water due to the stream; but it appears that even with so small a population as five persons per acre this flow in the London district, if we except the Baveley Brook and the rivers Wandle and Ravensbourne, does not equal the flow of sewage; and a very small increase in the population augments the quantity of sewage to such an extent as to render the stream water proper comparatively insignificant.

We estimate from our investigations that the total volume of sewage discharged in twenty-four hours in dry weather on the north side is 11,513,227 cubic feet, and that the total volume on the south side is 3,736,550 cubic feet, making a total from the present metropolitan area of 15,249,777 cubic feet, which is equivalent to 95,311,106 gallons.

In order that we might compare the flow of the sewers with the supply of water, we applied to the several Metropolitan Water Companies for returns of the quantity of water supplied by them in the present year, and they have furnished the information in detail as requested; from these returns it appears that the water pumped into London daily by the Water Companies averages about twelve million and a quarter cubic feet, or about 80 per cent of the estimated quantity of sewage, the difference being due to springs and to water from public and private sources of supply, streams, wells, &c., independent of the Water Companies. (*See* Appendix III.)

It also appears, that the supply of water in the Metropolis is on the increase, and that it has a material influence on the sewers. There is considerable difficulty in comparing the water supply with the drainage hour by hour, but the results of the comparison, as far as they can be traced, afford much interesting and useful information, which bears immediately on the habits of the population. The

* The flow from the City sewers represents about 18 per cent, of the whole sewage on the north side.

The amount of sewage when unaffected by rain depends upon the number of people in a district, upon the habits and occupations of those people, and upon the cost of obtaining water. As these conditions are all subject to variation, it is very difficult to estabish any fixed standard which would furnish a comparatively correct approximation to the future quantities of sewage.

It is not sufficient to add a per-centage to the gross amount of sewage, because the sizes of the sewers in the metropolitan district require to be apportioned to the wants of the population in different parts of that district.

And if a per-centage upon the actual flow of each sewer be apportioned over the area occupied by that sewer, it would only give true results in exceptional cases, because the upper parts of most of the sewers flow through unoccupied districts, whilst the lower parts pass through a dense population; and, therefore, any addition for prospective population should be made to the upper part alone.

It will be seen from Table 3, App. III, that the amount of sewage per acre, on areas occupied by different sewers varies from above 1,200 cubic feet to under 60 cubic feet in 24 hours; but when a carefully estimated population is apportioned to that area, the amounts, per head of the population, derived from each sewer are much more regular.

After an attentive consideration of this question, in which much must necessarily be assumed, we are of opinion that the safest guide to be followed in estimating the future amount of sewage in a district, is to adopt an average flow per head of the population.

It will be seen that the amounts vary from 4·8 cubic feet per head in the more thickly inhabited parts of the town, occupied by a larger proportion of the poorer classes, to eight cubic feet per head in the western districts, where the value of water for domestic purposes is more appreciated, and where the cost is less a matter of consideration; and that the average of the whole metropolitan district appears to be 5·8 cubic feet per head.

It is not to be supposed that all this water is used in houses. A large quantity flows from manufactories, breweries, distilleries, &c. But it must also be borne in mind that a large portion of the water thus used, at places both on and contiguous to the banks of the Thames, now flows into the river, without passing through the sewers, and that under the Metropolis Local Management Act the owners of all these premises will be obliged to turn this water into the sewers.

When we consider the large increase which is taking place in the use of water for domestic and other purposes in the metropolis, and the advantages which result in a sanitary point of view from the abundant use of water, we are of opinion that the flow of sewage, per head of the whole population, should be calculated at not less than seven cubic feet per diem. This amount is much larger than has hitherto been estimated, but we are convinced that the quantity of water now supplied is daily increasing; and an increase is desirable in order to maintain the sewers in a healthy condition and in proper working order in times of continued drought, such as we have witnessed during the past spring.

The actual rate at which the sewage passes off at different hours of the day was, we believe, first clearly exhibited in the results of the gaugings of the City of London sewers, before alluded to; and the gaugings which we made entirely corroborate Mr. Haywood's results.

It appears that if the day be divided into periods of eight hours each, the amount which passes off from the metropolitan sewers during the eight hours of maximum flow, viz., between 9 A.M. and 5 P.M., is 49 per cent. of the whole; whilst about 18 per cent. only flows off during the eight hours of minimum flow, which occur between 11 P.M. and 7 A.M.; we have therefore assumed that half the estimated quantity of sewage will pass off in eight hours.

We have in the next place to consider the question of rain-fall.

The average amount of rain which falls in the London district during the year is about 25 inches; it has varied from 33 inches in 1841 to 17·7 inches in 1847.

In order to exhibit generally some of the features of this rainfall, we have appended Tables of various recorded observations in London and its vicinity.

Taking one-third of an inch falling in 24 hours as a large ordinary rainfall, it will be found recorded in Howard's "Climate of London," that during 10 years, from 1820 to 1829 inclusive, there were 183 days in which the rain exceeded this depth, but taking the winter months, there were only 60 days during that period on which it exceeded one-third of an inch.

It is important, however, to observe that more extraordinary rainfalls than

the above frequently occur in the Metropolis, and the table below* contains instances of the fall of rain, amounting to or exceeding 0·5 inch per 24 hours, recorded in Mr. Glaisher's observations at the Royal Observatory, Greenwich.

The effects of the storm experienced in the Metropolis on the afternoon of the 1st of August 1846, will be in the recollection of many persons; most of the sewers were gorged to overflowing, large quantities of water ran down the surface channels, and the basements of the houses were in many instances flooded to a considerable extent. Mr. John Roe, the surveyor, in his annual report on the Holborn and Finsbury sewers, in alluding to this storm, states that "four inches of water fell in one hour over the district." This was no doubt a most extraordinary occurrence,† and is an illustration of what may occur; but these heavy falls of rain generally extend over limited areas.

The effect of a fall of rain is so entirely dependent upon the previous state of the atmosphere, on the condition, nature,‡ and mode of occupation of the ground, and on the rate of the fall of rain, that in calculating the exact quantity to be removed it is necessary to take into account not only the amount of rain, but also all the foregoing circumstances. Thus the rate at which water from rain falling upon districts occupied by houses and gardens will reach the sewers, depends upon the proportion which the houses, paved streets, &c., bear to the whole area, and must therefore depend upon the population of the district; but when districts are covered by houses and streets, the rain will pass off into the sewers at nearly an uniform rate, whatever be the population of the district. It

*DATE.	Amount Fallen in 24 Hours.	Duration of Fall.	Rate per Hour.	REMARKS.
1851:				
March - 15	1.45			
April - 20	0.70			
– - 22	0.55			
July - 23	1.44	- - -	- -	At times 0.25 inch fell in 10 minutes.
– - 24	0.54			
August - 17	1.71	- - -	- -	At times it fell at the rate of 0.5 per hour.
1852:				
January - 13	0.91			
May - 26	0.56			
June - 9	1.36	17 hours -	- -	At times it fell at the rate of 0.15 per hour.
– - 10	0.99	18 hours.		
– - 19	0.52			
July - 25	1.99	8 hours -	- -	½ inch fell within a quarter of an hour.
August - 12	0.55			
– - 15	0.84			
– - 19	0.50			
September 8	0.97			
– - 18	0.70	- - -	- -	¼ inch fell within a quarter of an hour.
– - 28	0 94	24 hours -	0.04	
October - 4	0.75			
– - 25	0.92			
November 12	0.80			
– - 26	0.85			
1853:				
March - 14	0.50			
April - 25	0.80			
May - 3	0.50	13 hours -	0.04	
June - 13	1.15	17 hours -	0.07	
July - 8	0 63			
– - 14	2.63	18 hours -	0.15	At times it fell at the rate of 0.3 per hour.
– - 28	1.11			
August - 23	0.89	11 hours -	0.08	
October - 12	0.58			
– - 19	0.59			
– - 27	1.05			

† The fall of rain during this extraordinary storm has been variously stated—

At Highgate - - - - - - - - - - - 3.5 Inches.
Ditto - - - - - - - - - - - 3.3 „
At Greenwich - - - - - - - - - - 0.95 „

It is asserted the shower was comparatively partial, and much heavier in the western than in the eastern districts of the metropolis.

‡ *See* Mr. Bailey Denton's Experiments, Appendix III.

It is evident, from the registered results of the occasional storms to which we have alluded, that it would be very inexpedient to provide for conveying to distant points large amounts of storm-water, in addition to the sewage, because it would involve not only mechanical difficulties, but very large and expensive engineering works, which, even in wet years, would only be employed on a comparatively small number of days; and sewers of sufficient magnitude to accomplish the object, would, in our opinion, be found extremely inconvenient and objectionable as conduits for the ordinary flow of sewage.

Mr. Bazalgette has taken much the same view. He has allowed a small amount of rainfall in the suburban districts, and provided for removing a larger amount from urban districts. After a careful consideration of the subject, we are disposed to adopt generally the principle thus laid down by Mr. Bazalgette; but, bearing in mind the very variable character of the suburban metropolitan districts, we think that it is desirable to estimate the amount of rainfall which is to be removed from these districts upon the basis of the proportion in which the districts are covered; and as this proportion may be considered to vary with the population, to provide that the sewage shall not flow into the river until it shall have been diluted to a specified extent.

In the urban districts, *i. e.* the districts covered with houses and streets, the rate at which the rainfall reaches the sewers will no longer be affected to the same extent by the increase of population; and over these districts, therefore, we propose to provide for the removal of a fixed quantity of rain during the period of the maximum flow of the sewage.

To determine the quantity of water from rain with which the sewage should be diluted in the suburban districts, it was necessary to obtain a knowledge of the effect of rainfall in diluting the sewage; and we consequently caused samples of sewage to be taken during rain, when the volume of the sewage exceeded a certain amount.

The peculiarly dry spring which we have experienced, although favourable to the general results of our gaugings, has been unfavourable to the determination of the question of dilution. It appears from the samples obtained, that during periods of drought, a very large amount of deposit takes place in the smaller sewers and branches, and that this deposit is washed out by degrees during periods of rain. Samples of sewage taken during rain when the stream was four and five times what the flow of the sewage would have been in dry weather at the time when the samples were taken, contained as much matter in suspension as the ordinary sewage, and were nearly as offensive. And the heavy rain which occurred on the morning of the 20th of June* caused a flow in the Savoy-street sewer, which was equivalent to 20 times the ordinary flow of the period at which it was taken, viz., the period of the minimum flow. This would have been about six times the maximum flow. In this case, although the sewer had been scoured to a considerable extent by a heavy fall of rain on the previous night, the sample contained more than double the amount of total impurity contained in specimens of ordinary sewage.

These and other observations, made from time to time during the progress of the investigation, have convinced us that it is only the question of the mechanical difficulty involved, and the great expense of the necessary works, that put a limit to the quantity of rainfall to be removed with the sewage; and we are of opinion that an amount of dilution, equal to six times the maximum flow of the sewage, is the lowest point at which it is advisable to admit storm-waters into the river.

After a careful consideration of the various returns of rainfall, we are of opinion that a sufficient provision will have been made for rainfall in the urban districts, if the sewers of those districts are made capable of removing two-fifths of an inch of rain during the eight hours of maximum flow; and we assume, that a population of about 80 persons per acre, or somewhat above 50,000 per square mile, constitutes an urban area.

The volume of sewage and rainfall thus arrived at, and which we propose that the sewers should be capable of removing, is shown in the following Table.

* It appeared from our rain gauges that in some places one inch of rain fell in little more than an hour. *See* Appendix III.

	Population in 1851.	Area in Acres.	Assumed Population per Acre.	Assumed Population.	Assumed Amount of Sewage in 24 Hours.	Assumed Amount of Rainfall to be removed for Dilution of Sewage in 24 Hours.	TOTAL.	Amount of Rainfall during 24 Hours, over District to which Amount of Dilution is equivalent.
METROPOLITAN DISTRICTS:	*Number.*	*Number.*	*Number.*	*Number.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	Inches.
North side of Thames - -	1,745,601	31,556	74·6	2,355,225	16,486,575	99,055,041	115,541,616	·867
South side of ditto - - -	616,635	43,695	28·0	1,222,864	8,560,048	61,548,332	70,108,377	·387
AREA TERMED PROSPECTIVE BY MR. BAZALGETTE:								
North Side: Chiswick, Brentford, Hanwell, &c. - - -	22,344	8,973	6·7	60,000	420,000	3,360,000	3,780,000	·103
South Side: Richmond, &c. - -	15,253	3,564	14·0	50,000	350,000	2,800,000	3,150,000	·216
ADDITIONAL AREA TO BE PROVIDED FOR:								
Valley of the Baveley Brook and Wandle - - - -	13,477	16,605	2·4	40,000	280,000	2,240,000	2,520,000	·037
Valley of the Ravensbourne -	31,458	31,448	3·2	100,000	700,000	5,600,000	6,300,000	·049
Wimbledon, &c. - - -	2,693	3,700	4·1	15,000	105,000	840,000	945,000	·079
Valley of the Lea - - -	59,432	74,598	1·3	100,000	700,000	5,600,000	6,300,000	·021
East Ham and Barking - -	6,480	8,455	3·5	30,000	210,000	1,680,000	1,890,000	·055
Willesden, &c. - - -	2,939	4,190	1·4	6,000	42,000	336,000	378,000	·022
	2,516,312	226,784	17·5	3,979,089	27,853,623	183,059,370	210,912,993	·222

From this Table it will be seen, that whilst we have provided for a large volume of rainfall to be removed from the thickly inhabited parts of the metropolis, a much smaller amount will be provided for in the thinly peopled outlying and agricultural districts.

II.—General Consideration of the Schemes submitted for Draining the Metropolis.

It will have been seen from the description of the area to be drained, that any scheme of drainage, to be effectual, must fulfil the following conditions, viz.:

1st. The scheme must relieve the low-lying districts from floods, and from the evils attendant upon a tide-locked drainage.

2d. The scheme must cleanse the river to the greatest practicable extent; and,

3d. While removing the nuisance from the Metropolis, the proposed system of drainage should be attended with as little practical injury to, or interference with, other towns as possible.

The plan of the Metropolitan Board of Works, which we have already described, adopts as a basis the first of these necessary features; but that plan was objected to both in principle and in detail by a large number of persons; and we had, moreover, received instructions from you to consider all plans that might be brought before us, with a view to adopting those parts of each which should appear to offer most advantages.

We therefore gave notice, by advertisement,* under your sanction, that we were prepared to receive plans and suggestions from persons who had given attention to the subject of the Metropolitan Drainage.

We have received in consequence several plans and suggestions; we have also received several schemes which had been forwarded to the Office of Works; all these we have considered and classified for more easy reference in a tabular form (*see* Appendix X.)

We have also considered the concise statements of the schemes of drainage submitted to the Commissioners of Sewers in 1848 and 1850; and have examined the detailed plans therein described, many of which, however, are the same as those presented to us.

The plans which we have thus had under consideration include almost every variety of expedient for disposing of the sewage which ingenuity could devise. Some

* *See* Appendix X.

Some of the communications contain suggestions respecting special points, and others relate principally to the improvement of the Metropolis. These latter plans have generally been designed without that knowledge of the peculiarities of the metropolitan district, or of the subject referred to us, which are essential to the design of a complete scheme of drainage, nor do they, as a whole, fall within the scope of our inquiry; hence we do not propose to allude to them further.

The remainder may all be included under one or other of the following heads, viz.:—Plans proposing,

1st. That the sewage of each house should be collected in cesspools or moveable receptacles of various constructions, reserving the ordinary drains for rainfall.

2d. That the Metropolis should be divided into districts of greater or less extent, and that to each district a reservoir should be supplied, into which the sewage should flow, to be there deodorised or prepared for utilisation.

3d. That the sewage should flow down to the present points of outfall in the river, and be there either run into barges, or converted into manure at these points, the liquid being allowed to flow into the river.

4th. That the sewage should, after being collected in central positions, be pumped along lines of pipes into the country, and there be applied to the irrigation of land.

5th. That the mouths of existing sewers should be connected either with a main drain on each side of the river, or with one central drain in the bed of the river, by which the sewage would be conveyed to some point down the river, where it would be deodorised or be discharged into the river without deodorisation.

6th. That a portion of the sewage should be intercepted at a high level, and the rest be intercepted and raised by artificial means from a low level, so as to enable it to gravitate to deodorising works, or to an outfall at some distance down the river, or at some point on the sea coast.

A large number of the plans are based upon the advantages that are assumed to accrue from turning the sewage to account for purposes of agriculture; and several propose that, with the view of overcoming the difficulties which have been supposed to be in the way of utilizing sewage arising from the large amount of dilution which it undergoes at present, and the presence of road grit, and other matter, the house drainage, or the more valuable part of the house drainage, should be separated from the water which flows during rain from the streets and roofs. Other plans provide for this separate system, with the view of retaining as large a flow as possible for the sake of the navigation.

The questions involved in these modes of remodelling the drainage of the Metropolis are most important, and it is therefore necessary that we should state our opinion upon them.

Separation of House Sewage from Rain-fall.

The arrangements suggested for effecting this separation may be classed under two heads:

1st. To place in each house tanks, cesspools, or moveable receptacles, for receiving the sewage, or the more valuable parts of the sewage, and to allow the rainfall and water used for domestic purposes to flow down existing drains.

2d. To construct a second system of drainage through the streets, in addition to the system now existing, so arranged that the house drainage proper should flow down one system, and the rain falling on streets, roofs, yards, &c. should flow down the other system.

1. Remarks upon the proposed return to Cesspool Drainage.

With regard to the proposal to return to the old system of cesspool drainage, or rather to provide another, which is alleged to be an improvement upon it, we would in the first place observe, that within the last few years, a very large proportion of the householders of the Metropolis have been compelled by legislative enactment to incur great inconvenience and expenses (ranging between 5 *l.* and 20 *l.* per house, and upwards), for doing away with cesspools, and for connecting the house drains with the sewers in the streets; and that every householder would be required to expend a further sum, not much less in amount, and to

incur further inconvenience, if this system were to be re-established. In the next place, the ordinary cesspools were found most objectionable, in a sanitary point of view, from the retention of accumulated sewage matter in the houses, and also from the pollution of the district, caused by the cesspools being seldom watertight, and by the occupiers of houses being either negligent, or frequently not averse to the contents being removed by soakage into the ground, rather than by the more costly process of cleansing and removing by carts or otherwise. With the view of preventing these evils, some of the plans suggest that the cesspools should be constructed of materials impervious to water, such as cast iron.

It would, however, be difficult to provide places where such cesspools could be conveniently placed in many of the smaller houses which have neither front areas nor back yards. Nor do we think that occupiers of houses who have enjoyed for some time the immunity from trouble and annoyance, resulting from the house drains being connected with sewers, would consent to return to the cesspool system. On the contrary, after having witnessed the sacrifice of money freely made to secure this immunity, we feel confident that the public would rather add to, and perfect the present system, than return to the cesspool system, which is not suited to the present ideas of health, of cleanliness, or of public decency. And since that system would in no way relieve the Metropolis from the necessity of constructing sewers to intercept the rainfall of the upper districts, and large volumes of foul drainage from the streets and back yards, we are not prepared to recommend it.*

2. Remarks on proposed Construction of a System of Drains for House Sewage, and another System for Rain-fall.

The advantages of this system have been strongly advocated, and the following are the remarks which we have to offer on the subject.

1. We have carefully observed the condition of the London streets; the water which usually flows from them, more especially during rainy weather, contains foul organic matter to a serious extent†, and there is, in point of fact, no such difference between Metropolitan surface drainage and house sewage as to justify the one being removed from the river, whilst the other is still permitted to flow into it. Again, the rain falling on the roofs and yards of buildings in the Metropolis is subject to a vast amount of contamination, and there is much objectionable matter washed out of the yards of manufactories, and from the various stables, mews cow-houses and other places, during rain; in numerous instances the house gutters are immediately outside the attic windows, and into them quantities of slops, &c. are constantly discharged; the pipes from the waterclosets and sinks of many houses are also connected with the rain-water pipes which are made use of as the regular soil pipes for these houses.

Professor Way has analysed samples of street waters intercepted in their passage to the sewers, and states that it would be as valuable "in a manuring point of view as the ordinary contents of the sewers."‡ (Journal of Royal Agricultural Society, 1855.)

2. The existing system of sewers under the streets of the Metropolis, and the large number of gas and water-pipes, as well as the numerous cellars, vaults, ovens and other works of similar construction, render it expedient to reduce the interference

* If cesspools constructed as suggested by Dr. Hawkesley were found in practice not to be attended with deleterious effects to the community, there could be no objection to occupiers of houses providing themselves with air-tight cast iron receptacles in which they could preserve their sewage, and sell it to those who might desire to purchase it. From our experience of cesspools, however, we do not think that any system of the kind can be conducted in the metropolis without considerable annoyance and expense to the inhabitants; and as a saleable article for agricultural purposes, we have reason to doubt its commercial value, from the fact that it will always be in competition with stable litter as well as artificial and other manures. At Aldershot the privies have been so constructed that the valuable portion of the sewage, *i.e.* the *excreta*, are alone preserved in iron tanks; these are removed by a contractor for manufacture into manure; for this service the contractor receives 1,200 *l.* per annum.

† Indeed the gutters in many of the inferior streets receive every night large quantities of *urine*, *excreta* and other matter, to which horses and cattle add materially throughout the day by the deposit of their ordure.

‡ Mr. Bazalgette informed us that when Regent-street was paved with wood, the wood pavement became saturated with ammonia and sulphuretted hydrogen from the road refuse, the exhalations from which tarnished the plate in the silversmiths' shops.

interference with the streets to the smallest possible extent, and would create very great practical difficulties in the way of introducing a fresh system of drains or sewers, as the new sewers must be constructed at nearly the same level as the existing sewers. This difficulty is more particularly apparent at the points of crossing of two or more streets. In many instances it would be found impracticable to construct a double system of the kind proposed; and such system, if carried into effect, would be as difficult to maintain in working order as to construct.

3. The expense * to which each householder would be put, in constructing separate drains for the house sewage and the rain-water from the roof would be very great; and this separate system, even if established, could not, we feel confident, be maintained in its integrity. We have already mentioned that it is customary now in many houses for the waste pipes from the sinks to be connected with the rain-water pipes. And it is difficult to imagine any system of inspection which, in the event of the separate system being established, would prevent a householder or the builder, or workmen employed by either of them, from joining the house drains to the sewers for rainfall, and *vice versâ*, if by so doing expense could be saved, or inconvenience avoided; nor could such mistakes be prevented from occurring through negligence or ignorance.

It is also to be borne in mind in considering these proposals, that in addition to the expense which they would entail for constructing new systems of drainage for the removal of the house sewage, provision would in any case have to be made for preventing the flooding of the low-lying districts. And we have already shown that heavy rains have, under the existing system, a very beneficial effect in washing out the small drains.

For these several reasons we are of opinion that it would be inexpedient, and indeed most injudicious, to provide a plan for the drainage of the Metropolis which should separate the house sewage from the rainfall.

We shall now proceed to consider the value of London sewage as an agricultural manure.

Application of Sewage to Agricultural Purposes.

The mode by which the several schemes submitted to us propose to apply the sewage to agricultural purposes may be classed under the two following heads:

1st. As solid manure, by means of deodorisation, filtration, or subsidence; the liquid being turned into the river.

2dly. As liquid manure, by irrigation.

Under these circumstances it was essential at the outset of our inquiry that we should investigate the possibility of turning the London sewage to profitable account.

The commission which was appointed for the purpose of inquiring into the best mode of applying sewage manure to beneficial purposes, had not proceeded in its inquiries sufficiently far to be able to afford us assistance; we were, therefore, obliged to seek for ourselves as much information upon the subject as the limited time allotted to our inquiry would permit.

We consequently made inquiries respecting, and visited several towns where works have been established for the utilisation and the deodorisation of the sewage. But we were not satisfied with the success of these undertakings; and we also soon came to the conclusion that the example afforded by deodorizing works in a town of ordinary size such as Leicester, even if perfectly successful, was not a safe guide to be followed in the case of the sewage of London; because the magnitude of the Metropolis, the variable volume of the sewage, and the alteration in its character, from dilution, are such as to render the circumstances under which the sewage would be received at the works, entirely different from those of any other town.

We therefore requested Dr. Hofmann and Mr. Witt to report to us upon the value of sewage, and upon the practicability of utilizing it. These gentlemen have entered most fully into the subject, and have furnished us with very complete and valuable information, which will be found in their very able report in Appendix I.

We

* Allowing that there are 300,000 houses in the metropolis, the cost of forming a separate system in the houses alone, without taking into account the cost of the street sewers, would probably exceed 2,000,000 *l.*; and Mr. Bazalgette has informed us that he had at one time estimated the cost of draining London in this way at 10,000,000 *l.*

We have carefully considered this report; we have also received much evidence upon the subject,* and the following are the conclusions at which we have arrived.

It will be seen from the report, that the total annual value of the fertilising agents in London sewage is above 1,000,000*l.*, and therefore there is every inducement to adopt some means of saving this valuable matter, if any exist.

But the first consideration in draining a large town is to remove the sewage speedily and effectually from the habitations, and to dispose of it in such a manner as not to affect prejudicially neighbouring towns. No amount of profit would compensate the inhabitants of a town for the annoyance, inconvenience, risk of health, and diminished length of life, consequent upon delay or want of efficiency in the scheme for removal, nor would justify them in injuring their neighbours; and, therefore, no plan of deodorisation or utilisation can be adopted which is incompatible with this first principle.

Bearing this in mind, we will proceed to the consideration, first, of the deodorisation of sewage, and secondly, of its utilisation.

I.—Deodorisation of Sewage.

The question of deodorisation may be considered from two points of view.

The first being the extent to which sewage can be deodorised by known cheap processes, and the nature of the liquid which remains after the solid matter has been separated.

The second being the value which the solid deposit possesses as a manure.

1.—*The Extent to which Sewage can be Deodorised by known cheap Processes, and the Nature of the Liquid which remains after the Matter has been separated.*

It will be seen from the report of Dr. Hofmann and Mr. Witt, that of the valuable matter in sewage, one-seventh is in the insoluble or suspended form, whilst six-sevenths is held in solution; and that in all the experiments upon deodorisation, viz., mixing the sewage with lime or charcoal, or with lime, charcoal, and sulphate of alumina (as proposed by Messrs. Gotto and Stothert), or by simple filtration through charcoal, the chief constituents of the residue were the suspended matters; the fluid which passed off still holding a very large portion of the dissolved matter.

These experiments were performed on a small scale with great care, and we cannot but believe that, in deodorising works on a large scale, the results would be much less favourable.

The most favourable result was obtained by the filtration of sewage through charcoal. The liquid which first passed off was quite clear and free from smell, but by analysis it was shown to retain a large amount of highly putrescible organic matter in solution, and after a short time it lost its colour, and the smell returned. But on continuing the process of filtration, the charcoal soon loses its power, and consequently the expense of deodorisation by this agent, even to the limited extent shown, becomes enormous.

We visited in cool weather several deodorising works in operation on a small scale; and even at the works at Leicester, to which a large amount of time, money, and intelligence have been given, and where the arrangements are tolerably effective, the deodorisation was by no means complete.

The opinion, therefore, at which we have arrived, and in which Dr. Hofmann and Mr. Witt† coincide is, that so called deodorising works cannot in practice be carried

* A letter from Dr. Gilbert, containing much valuable information on the subject, will be found in Appendix XII.

† Extract from Dr. Hofmann's and Mr. Witt's Report.—The several processes submitted to us for *deodorising and consolidating sewage into a manure* (viz., 1. By means of lime; 2. By the use of Stothert and Gotto's mixture; 3. By filtration through charcoal; and, 4. By shaking with charcoal), *all fulfil, to a certain extent, the office for which they were proposed.* If we were asked to select one of the processes as particularly calculated to furnish satisfactory results, we should certainly give the preference to the lime process; at the same time, it is found that this process, as well as all the others, *leaves a large quantity of putrescible organic matter still in solution, which,* especially in hot weather, is *apt to undergo decomposition, and to give rise to the generation of effluvia of the most offensive and dangerous character.* The experience obtained in establishments in which the lime process is carried out on a small scale, and under the most favourable circumstances, leaves no doubt on our minds that the *erection of works in the immediate neighbourhood of the metropolis,* for the deodorisation of the London sewage, *might prove very prejudicial* to he *health and comfort* of the inhabitants of London.

carried on in inhabited districts without risking the health of the inhabitants; and that if conducted on a large scale, they would probably create a considerable nuisance in the neighbourhood where they are established.

We have already stated that it appears from the experiments that the liquid which passes off after deodorisation retains a very large amount of matter in solution, and it also appears * that the organic matter in solution possesses those highly putrescible properties which render the presence of the sewage in the river at the present time so deleterious and offensive.

Hence, bearing in mind the enormous volume of the London sewage, which volume is daily increasing, and also bearing in mind that the flow during heavy rain could scarcely be operated upon, we are decidedly of opinion that, if deodorising works were established, the liquid which would pass off† ought not to be discharged into the river at any point nearer to the metropolis, or to other towns, than that at which it should be permitted to be discharged without the *so-called* deodorisation.

2.—*The Value which the solid Deposit possesses as a Manure.*

It appears, from the analysis of mean specimens of London sewage, that 100 tons of liquid sewage possess a value of 17*s.* 7*d.* The suspended matter amounts to 82·72 lbs. in weight, and is worth 2*s.* 2½*d*; whilst the dissolved matter is 245·95 lbs. in weight, and is worth 15*s.* 4½*d.*

And the following extract from the Report of Dr. Hofmann and Mr. Witt shows the results arrived at:—

"With respect to process 2 (Messrs. Stothert and Gotto's), we find that the "cost of the materials employed, irrespectively of working expenses, nearly "equals the money-value of the manure produced; whilst in process 3 (filtration "through charcoal) the cost of materials very considerably exceeds the money-"value of the manure obtained (as compared with guano at 11*l.* per ton).

"With reference, however, to the two remaining processes, viz. treatment "with lime (1) and agitation with charcoal (4), we find, from our experiments "made on a small scale, that the value of the manure produced considerably "exceeds the cost of the materials employed. However, on going minutely "into all the conditions involved in the manufacture of a manure from the "London sewage by the two processes above mentioned, we come to the con-"clusion that they offer no chance of success as commercial speculations."

The lime process appears,from the experiments which were made, to afford the best prospect of commercial success; but in considering the value obtained by Dr. Hofmann and Mr. Witt, it must be borne in mind that the sewer from which the sewage operated upon was taken contained sewage in a considerably less diluted state than the average of London sewers‡.

The Leicester sewage, as shown by Mr. Versmann's experiments, appears to contain about the same quantity of fertilizing matter as the sewage experimented upon; but the value of the manure manufactured therefrom on a large scale, as shown by analysis,§ is only 17*s.* per ton, compared with 1*l.* 18*s.* 9*d.* per ton obtained by Dr. Hofmann, by experiments on a small scale. We do not think, therefore, that the value of the manure abstracted from London sewage in Dr. Hofmann's experiments on a small scale, could be realised in deodorising sewage on a large scale.

Assuming, however, a mean between the two, it would require eight tons of sewage manure to produce a similar result upon the land to that produced by one ton of guano; the other constituents are at best inert matter; and it may be said, that for every ton of fertilizing matter which a farmer * who applies the sewage manure would draw on to his land, he would draw at the same time seven tons of useless matter, and therefore the cost of carriage must absorb all profit beyond a certain distance.

The

* *See* that part of Dr. Hofmann and Mr. Witt's Report on the influence of sewage on the Thames.

† Extract from Dr. Hofmann's and Mr. Witt's Report.—In the event of the establishment of such works, *the liquid run off from the sewage deposit, if discharged into the Thames in the vicinity of London, might very seriously affect the river,* on account of the large quantity of putrescible matter still retained in such fluids.

‡ The Savoy-street sewer, from which the specimen was obtained, is probably richer than most other London sewers; the average quantity of water per head of population is very low; the district is thickly inhabited; and the distance traversed by the sewage is comparatively small.

§ *See* Dr. Hofmann's and Mr. Witt's Report.

The general conclusions at which we have arrived on this subject are, therefore, as follows:

1. The fertilising agents which pass off from the population of the metropolis, if they were separated from the water in which they are suspended, would be worth annually above 1,000,000*l.*, and, therefore, it is not surprising that much science and money should have been expended upon the question of utilising them.

2. The fertilising agents are however diluted with from 36 to 40 gallons of water per head of the population, and six-sevenths are in a dissolved state. The extent of dilution renders it impracticable in the present state of chemical science to recover the dissolved matter in an economical manner; but water is one of the most valuable and cheap deodorisers; the dilution could only be checked by a diminished water supply; and any diminution of the water supply would be antagonistic to the rapid and economical removal of the sewage from the houses, and to the preservation of health.

3. The deodorisation of sewage scarcely separates any of the matter which is dissolved, and the dissolved matters which remain in the liquid which passes off after deodorisation, retain some of the most highly putrescible, and noxious constituents of sewage. Consequently, even if the manufacture of sewage manure were adopted as a basis of any scheme of drainage it would be necessary to provide for removing the liquid which would pass off, to the same point to which the sewage alone would have to be removed. And during rain, either a large portion of the sewage would require to be passed off without being operated upon, or a large amount of surplus machinery must be always in readiness to meet the requirements of the increased volume; and this would be inconsistent with the economical manufacture of sewage manure.

4. Works for the manufacture of sewage manure could not be safely placed in or near populous districts, consistently with the health of the inhabitants.

5. After a careful consideration of the results obtained by Dr. Hofmann and Mr. Witt, and of all the other facts bearing upon the subject, we do not think that the manufacture of manure from sewage by any known process would prove remunerative; because whilst guano contains comparatively little besides the fertilising properties, the sewage manure contains various quantities of inert matter, proportioned to the nature and quantity of the agents employed in deodorising; and because therefore the extra weight of this inert matter would so add to the cost of carriage as to absorb in a comparatively short distance any profit on manufacture; and hence the cost of producing sewage manure, and of conveying it to the place at which it is to be applied, would be greater than the cost of supplying other known fertilisers; and also, the sewage when deodorised, would be a compound manure, in which the fertilising elements would have a fixed ratio, which might not all be suitable to the requirements of the locality, and it would not therefore possess the advantages which is possessed by artificial manure composed by fertilising agents specially adapted to the requirements of the soil.

The next point for consideration is, to what extent the sewage can be utilised by means of irrigation.

II.—Utilisation of Sewage by Irrigation.

From all that we can learn on the subject, we have no doubt that the application of liquid sewage to land by irrigation, especially on sandy soils, produces very beneficial results. We believe that the results are partly due to the fertilizing properties contained in the sewage, and partly to the fact that the water renders soluble the fertilizing properties existing in the soil.

The utilisation of sewage by irrigation has been in practical use at Edinburgh for many years, and has been found to be successful commercially.

But there the sewage is distributed over the land to a great extent by gravitation; and the water which has passed through the land, as well as any surplus sewage, flows into the Firth. The quantity of sewage is comparatively small, viz. 1,600,000 gallons daily, which flows over about one and a half square miles, and it is diluted with 20 gallons of water per head of the population; whereas London

* Agriculturists are the first to appreciate the importance of economy in carting manures to the land, and there are at this moment, doubtless, very few who do not estimate the various fertilisers by their relative portability and convenience of application; this, it is well known, is the distinctive characteristic of guano, and most of the other fertilisers of modern introduction.

London sewage, which amounts to 96,000,000 gallons in dry weather, is diluted with 37 gallons of water. (*See* Appendix XII.)

From the calculation before mentioned, it would appear that, in order to apply fertilizing matter of the value of 17*s.* 7*d.* to an acre of land, it would be necessary to cause 100 tons of liquid sewage to flow over it; that is to say, to cover it all over with sewage to a depth of nearly one inch. The daily flow of London sewage in dry weather, at the present time, would cover about 4,500 acres to this depth; and if the quantity of land required for irrigation be in proportion to that required at Edinburgh, a total area of about 90 square miles would be necessary for the application of the sewage.

In order to irrigate land to this extent, it would be necessary to provide for pumping the sewage on to the ground, and this narrows very much the limits within which the use of the sewage would be commercially profitable.*

The land must also be laid out with channels or pipes for the distribution of the sewage, and with drains for the removal of the water after irrigation.

These will be found to entail a very considerable preliminary outlay per acre for the reception of the sewage, as well as an extensive and elaborate organisation for its daily distribution; and even assuming that the sewage would be applied to the land without intermission, it would be necessary, in addition to this outlay, to provide means for disposing of the surplus sewage during times of rain.

But we doubt whether any district within a reasonable distance of London could be found over which the sewage could be allowed to flow without intermission; and we consider it probable that if so large a quantity of sewage were to be continuously discharged over any district, it would not only affect the purity of the atmosphere during certain times of the year, but that it might eventually pollute the springs and streams, and thus affect the water supply of the inhabitants.

For these various reasons we are of opinion that, even under a system of irrigation, it would be occasionally necessary to remove the daily flow of London sewage, as well as of the increased water due to rain; and that, consequently, means would have to be provided for removing it in as effectual a manner as if irrigation were not contemplated.

The conclusion, therefore, at which we have arrived on the subject of disposing of the sewage by means of deodorisation and irrigation is, that even if the utilisation of sewage could be shown to be commercially successful, it would be necessary to provide for removing to some unobjectionable place as large an amount of sewage as must be provided for without deodorisation or utilisation.

We, however, doubt the commercial success of manufacturing a manure from sewage; and we fear that the very large outlay which must be incurred, to prepare the land, before the sewage can be used for irrigation, in addition to the continual expenses attendant upon pumping the sewage to a place of distribution, would absorb the anticipated profit.

The whole question of the utilisation of sewage is at present in a theoretical, or at least in an experimental state; and even assuming that it may one day become practically successful, it is most improbable that such a result could be attained without numerous preliminary trials and failures. If these preliminary experiments be made at the expense of a public body by persons not directly and pecuniarily interested in the result, we fear they will entail an expenditure of money, which would far exceed the cost of the best system of drainage.

We are therefore of opinion that it would be very inexpedient for the Metropolitan Board of Works to undertake operations of this nature; and that their only course is to provide for the efficient removal of the sewage to some place where it cannot be offensive; the mode of removal being so arranged that private enterprise may, if such can be found, adopt means for its application to agriculture: and if private enterprise can render the application profitable, the Metropolis will eventually participate in the profits, without having incurred the risks.

Plans submitted for Consideration.

1st Class.—The conclusions at which we have arrived upon the subject of the separation of house sewage from rainfall, and upon the deodorisation and utilisation of

* *See* Mr. Lane's Evidence, in Appendix XII., on the Stanley Bridge Sewage Manure Works. We understand that these sewage manure works have been given up, after an expenditure of upwards of 40,000*l.*

of sewage, render it unnecessary for us to enter into any more detailed consideration of the numerous plans which advocate these systems, or to allude further to the first class of plans before mentioned; viz., those which propose a return to the cesspool system.

2d Class.—The second class of plans, viz. those in which it is intended to separate London into districts, and to establish in each a centre for deodorisation, may be set aside on the ground that the existence of numerous deodorising works in the heart of London would create nuisances and be injurious to health, unless very expensive chemical processes were resorted to, and unless they were worked with the most constant and scrupulous care.

As an instance of this class, we may mention the plan of Messrs. Gotto and Stothert, which proposes to divide the Metropolis into four separate areas, each having a depôt or point of outfall; these depôts to be placed one at the mouth of the Kensington Canal, another on the banks of the River Lea, the third at Deptford Creek, and the fourth at Battersea; and intercepting sewers to be constructed to convey the sewage to these depôts, where it is to be deodorised, the solid portion to be retained for manure, and the supernatant water to be used for purposes of irrigation, and for flushing the sewers. The sewage from the low level would be raised by artificial means.

Great care has been given by these gentlemen to the preparation of the plan, which is based upon the principle of utilizing the sewage.

3d Class.—As regards the third class, viz. plans which propose to deodorise the sewage at, or remove it by mechanical means from the outfalls of existing sewers, we have only to observe that the local deodorisation would be inadmissible, and that this system would in no way relieve the low-lying districts from the floods and other evils to which we have shown that they are subjected by the present system.

4th Class.—The fourth class, viz. plans which propose to run the sewage by conduits into the country, is inadmissible, because it requires that arraugements should be previously made with persons who cultivate the soil, over very large areas, by which they must bind themselves to receive large supplies of liquid sewage, and to apply it to their land permanently, and with but little possibility of intermission. The Metropolitan Board of Works could not with any prudence be recommended to purchase and farm out land to the required extent; and it is probable, that if negotiations were opened with proprietors in districts round London, they would rather urge claims for compensation than offer to pay for the assumed benefit.

5th Class.—The fifth class, viz., plans which propose to remove the sewage by intercepting it at the outfalls of existing sewers, and by passing it through low-level conduits* to some point low down the river, would still leave the low-lying districts subjected to floods, as they are at present, and would involve the necessity of lifting the whole of the sewage at an enormous permanent expense.

When it is considered that the ordinary daily flow of the sewage in the Metropolitan District, will, according to the prospective quantity which we have assumed, amount to above 150,000,000 gallons, of which, whilst about 50 per cent. passes off in one division of eight hours, only 18 per cent. passes off in another eight hours; and that by the occurrence of rain the whole amount may sometimes suddenly rise to above 1,000,000,000 gallons daily, the difficulties and risks attendant upon an artificial system for removing the sewage will be very evident. The liability to sudden fluctuations in the quantities to be raised, renders it imperative that a large amount of surplus power should be always ready even during the periods of small flow; and the contingencies to which machinery is at all times liable, render it necessary to provide a large amount of duplicate power.

We, further, do not consider that the plans which contemplate the construction of main sewers following the course of the river are practicable. It will not be possible to pass the entrances to the docks and other places except at very low levels, which would place the sewers in very objectionable positions; and the cost of constructing and maintaining main sewer works within the tidal action of a river like the Thames would far exceed all reasonable limits.

We may take this opportunity of observing, that the necessity for constructing a low-level sewer in the bed of the Thames has been a favourite argument with those

* The most complete scheme of this class which has been submitted was designed by Mr. G. Thornton and Mr. T. Jackson. The estimated cost of the low-level sewers was nearly 5,200,000*l.*, and the annual expenses for working and maintenance, 147,000*l.*; but the works did not apply to the whole of the metropolitan area.

those persons who advocate the embankment of the Thames. Without expressing any opinion upon the several schemes for embanking the Thames, we would observe, that we do not consider it desirable to add the difficulties and delays attendant upon the construction of a large work of that nature to those attendant upon the construction of a low-level sewer.

6th Class.—The only plans which fulfil the conditions which are essential to the complete drainage of the Metropolis, besides those of the Metropolitan Board of Works, are those plans included in the 6th class, viz., the plans which provide a means for intercepting the storm waters from the upland districts, and discharging them at some point above high-water in the river.

We have already shown that this system of interception was proposed for a portion of the district of the Westminster Sewers in 1806, by Mr. Rennie, and also more recently by the Kent and Surrey Commissioners before the amalgamation of the several districts; it was further advocated in the plans sent in to the Sewer Commissioners, in 1848, by Mr. M'Clean, Mr. Bailey Denton, and others; and it was adopted by the late Mr. Frank Forster, the engineer to the Commissioners of Sewers, in 1850, as well as by Mr. Bazalgette, the engineer to the Metropolitan Board of Works.

The principal feature of the intercepting system is, that it provides a means by which the sewage of a portion of the Metropolis shall flow by gravitation to the point of its ultimate discharge; and that it also enables that portion of the rainfall in those upper districts, for which no provision can be made in the sewers, to be conveyed directly to the river by conduits capable of discharging at all times of the tide.

In opposition to the intercepting system, it has been insisted on, by many persons, that the water from the sewers in the upper districts should not be diverted, but should be allowed to flow down and contribute to cleansing the sewers in the lower districts. We are of opinion that this view is a mistaken one; because the water from the upper districts flows only through the main sewers, whereas the principal obstructions take place in the lateral drains, which are affected in very few instances by the upland water. Obstructions rarely occur in the main sewers, except when they are tide-locked.

We have already stated the objections which exist to a large amount of pumping. The difficulties and expenses are great, and the liability to derangement frequent, even though a large amount of duplicate power be provided; hence we are of opinion that the first principle to be followed in a system of interception is, that the system should be, as far as possible, self-acting, and free from the contingency of accidents to machinery; in fact, that the amount to be removed by gravitation should be as large as possible.

The area from which the sewage can be intercepted by gravitation depends upon the rate of the inclination of the channel in which it is to flow, and upon the distance to which the sewage is to be conducted. And the rate of inclination which must be give to the channel to obtain a given velocity depends upon the form of the channel, and upon the volume of sewage flowing through it.

The main point for consideration in these several systems is, therefore—

1st. To select the point of discharge for the sewage, or the outfall.
2d. To devise the best mode of reaching that outfall.
3d. To choose the plan upon which the system of intercepting sewers in the Metropolis can be designed, so as to lead the sewage in the most advantageous manner into the main outfall sewer.

Before stating our own conclusions upon this subject, we propose briefly to comment upon the principal plans under the 6th class which have been submitted to us, viz.:

1st. The plan of the Metropolitan Board of Works.
2d. The plan proposed by Mr. M'Clean.
3d. The plan proposed jointly by Mr. Murray and Mr. R. Mylne.

1.—Observations on the Plan of the Metropolitan Board of Works.

We must in the first place express our decided opinion, that this plan does not provide for the removal of a sufficient quantity of sewage from the population of the metropolitan districts, including the prospective increase; and that the provision for the removal of storm water during rain, is not carried to the extent necessary to prevent the frequent pollution of the river. Also that this plan does not make sufficient provision for the removal of sewage from the outlying districts,

districts, which, from the natural formation of the country, must of necessity be discharged, into the Thames, through sewers or other channels within the metropolitan district.

The instructions under which we have the honour to report, direct our attention especially to the question of the outfall. We propose therefore to state our objections to the outfall which has been selected, before alluding to certain details of the plan which in our opinion might be advantageously modified.

1.—*Remarks on the Point of Outfall.*

The outfall for the sewage of the north side is situated at the confluence of the Rainham Creek with the River Thames, at a point which is designated as B* on the maps of the Metropolitan Board of Works; the outfall for the sewage of the southern side being placed at a spot opposite on the south side of the river.

We have received from a committee of gentlemen who reside in the neighbourhood of Erith and Gravesend, a statement of their objections to this outfall. *See* Appendix, IX.

With respect to this locality, we have to observe that if a stream loaded with sediment be poured into a river, the sediment will have a tendency to deposit and to form shoals,* unless the place at which the stream is turned into the river be subject to the action of a strong current. Erith Reach, at the head of which the outfall has been placed, is stated by Mr. Stephen W. Leach, the engineer of the Conservancy of the Thames, to be at the present time peculiarly liable to shoal, and we therefore consider that upon this ground alone it would be very injudicious to select this as the point of outfall.

We have also carefully studied the very valuable series of float experiments made by the late Mr. Frank Forster, engineer to the Metropolitan Commissioners of Sewers, and those made by Captain Burstal, R.N., in the course of last autumn, as well as some float experiments made recently by Mr. Homfray, the engineer of the Erith and Gravesend Committee; and we have also made some experiments ourselves at this place.† The conclusion at which we have arrived upon the subject is as follows; viz.:—

That a float put into the centre of the stream at high water will move down the river with the ebbing tide, and ascend again with the flowing tide, and that at the end of a fortnight it will be found to have reached a point in the river about five miles below that at which it was put in. But the part of the river selected for the outfall B*, is full of shoals, which cause eddies and slack water in these places, as is shown by the frequent tendency of the floats to set in shore; and consequently the sewage would be liable to form deposits of mud upon the banks, of the same putrescible character as is found in the Thames in London at the present time.

It must also be recollected that, whilst the floats when once put in, were followed up and down the river in the strength of the stream, the sewage would be turned in continually twice every day; and that much of that portion of it which would flow into the river during the ebb tide would hang about in slack water, and be liable to be carried up with the flood to a point much above that which is assigned as the probable limit, by float experiments made in the fairway of the channel. It is worthy of remark, that the water is sometimes salt in the river as high as Barking Creek and Woolwich.

Also, it cannot be denied that sewage turned into the river in two concentrated streams above Erith, would be much more objectionable to the inhabitants of that locality than the same sewage flowing into the river by a number of separate channels at a point several miles higher up.

With the view of avoiding the objections which have been urged by the inhabitants of Erith against the outfall at B*, Mr. Bazalgette has proposed to bring the southern sewage across the river, and to convey the united stream to Mucking Flats. Although we concur with Mr. Bazalgette in thinking it expedient to seek for an outfall in that locality, we are of opinion that the particular point which he has selected is objectionable, because it is situated in a part of the river subject to slack water during a great portion of the ebbing tide.

* For evidence of this *see* Captain Burstal's section of the River Thames, near the principal sewers.

† *See* Appendices V. and IX.

2.—*Observations on Details of Plan.*

1st. The proposed northern aqueduct, to be formed to convey the whole of the sewage, and such part of the rainfall as is not considered fit to flow into the river, to Rainham Creek, would, by means of the storm-overflow provided at the River Roding, cause a considerable quantity of storm-water to flow into the river at that place.

2d. We do not approve of the mode by which it is proposed to convey the sewage across the marshes by means of iron aqueducts of great length, and above-ground. We are apprehensive that they might be subject to derangement from a variety of causes; and that, in fact, they would not be found to possess those elements of permanency which are essential to works of this nature.

3d. We are of opinion that the proportion of sewage to be raised by mechanical means is larger than is necessary. Mr. Bazalgette proposes that the whole of the southern sewage, and that more than one half of the northern sewage shall be raised by artificial means. In fact, it appears that there will be conveyed—

	Square Miles.
1st. By complete gravitation, the drainage of - -	27·32
2d. By pumping once - - - ditto - - -	30·62
3d. By pumping twice - - - ditto - - -	43·45

And he has provided a short statement, which we annex,* embodying at one view the amount of estimated engine-power for lifting the sewage.

We

* TABLE showing the Amount of Pumping, Height of Lifts, &c. proposed by Mr. *Bazalgette*.

	Quantity to be Lifted per Minute.		Height of Lift.	Time required for Pumping.		Maximum working Horse-power.	Duplication or Total Horse-power.	Total Estimated Cost per Horse-power.	Annual Estimated Cost per Horse-power.
NORTH SIDE.	*Gallons.*	*Cub. feet.*	*Feet.*	*Hours.*	*Min.*	*Single.*		£.	£.
ABBEY MILLS - - - - - -	- -	- -	37	-	-	- -	- -	One uniform rate of 70 *l.* per horse-power, including pumps, engine-houses, wells, &c.	One uniform rate of 20 *l.* per horse power.
(*a*) At state of normal flow - - -	51,288	8,206	- -	-	-	- -	- -		
(*b*) At expanded maximum flow - -	106,144	16,983	- -	-	-	1,184	2,368		
2. KING'S SCHOLARS' POND - - -	- -	- -	19·7	-	-	- -	- -		
(*a*) At state of normal flow - - -	22,962	3,674	- -	-	-	- -	- -		
(*b*) At expanded maximum flow - -	57,162	9,146	- -	-	-	340	680		
3. PROPOSED EXTENSION TO BRENTFORD -	The sewer could be extended to Brentford, which is beyond the metropolitan area, without additional pumping.								
(*a*) At state of normal flow - - -									
(*b*) At expanded maximum flow - -									
SOUTH SIDE.									
4. MAIN OUTLET B* - - - - -	- -	- -	21	-	-	- -	- -		
(*a*) At state of normal flow - - -	49,875	7,980	- -	-	-	- -	- -		
(*b*) At expanded maximum flow - -	103,744	16,599	- -	-	-	657	1,314		
5. DEPTFORD - - - - - - -	- -	- -	20·6	-	-	- -	- -		
(*a*) At state of normal flow - - -	31,938	5,110	- -	-	-	- -	- -		
(*b*) At expanded maximum flow - -	69,106	11,057	- -	-	-	428	856		
6. PUTNEY:									
(*a*) At state of normal flow - - -	No lift is proposed here		-	-	-	- -	- -		
(*b*) At expanded maximum flow - -									

Note.—The information asked for in Mr. Saunders' letters of the 4th and 7th July (1857) is given above as nearly as possible in the tabular form required; but in order fairly to exhibit the facts of the case, the following explanation is necessary. The sewage provided for is as stated in the report at the rate of five cubic feet per head per diem, computed for a prospective population; one-half of which is assumed to pass off during six hours of the day, and the remaining half in varying proportions during the remaining 18 hours. It is presumed that this maximum flow is what the referees term the "normal flow," and it is treated here as such. To this has been added the rainfall provided for, and this addition, it is presumed, gives what is termed by the referees the "expanded maximum flow." For this quantity engine-power is provided, and that power has been doubled to provide for repairs, &c. &c. The maximum sewage or "normal flow," it will be observed, forms about one-half of the total quantity intercepted, but the rainfalls occur only on 139 days out of the year, and then generally in much smaller quantities than those for which provision is made, and these quantities are so uncertain that the pumping power required to raise them cannot be given prospectively in detail. In order therefore to arrive at the annual cost, a large margin has been left to meet the expenditure of getting pumps at work, &c. &c. for these occasions, by providing for the raising of the discharge of the sewers, supposing them to be always running half full, which would be nearly the same as the prospective maximum flow of the sewage or "normal flow" during the 24 hours, instead of 6 hours per diem all the year round, and this is estimated for at 20 *l.* per horse-power per annum. The present outlay and working cost of pumping would be considerably less than the above prospective figures.

J. W. Bazalgette.

10 July 1857.

We have already explained the difficulties and the anxiety caused by a system of drainage dependent upon artificial means, and we take this opportunity of recording our opinion, that although it is impossible entirely to dispense with lifting a portion of the sewage, it is worth making a very great sacrifice to secure to as large a district as possible the advantages of being relieved from its sewage by a constant natural flow, independent of mechanical contrivance.

4th. The levels of the Aldgate Branch and of the Isle of Dogs Branch would cause the discharge of these sewers to take place under pressure in times of storm.

5th. The line of the main low level sewer on the north side of the River would pass between the Houses of Parliament and Henry 7th's Chapel. Sir Charles Barry has stated to us that he entertains some apprehensions that the construction of this sewer might endanger the safety of the Houses of Parliament, the foundations of which rest upon a bed of sand and gravel fully charged with water. (*See* Appendix IX.)

This sewer is also proposed to be carried, at a distance of about 60 yards to the south of St. Paul's, at a considerable depth from the surface.

Mr. Penrose, architect to the Dean and Chapter of St. Paul's, has furnished us with copies of a correspondence which took place respecting the construction of a sewer in St. Paul's church-yard, in the year 1831, from which it appears * that in consequence of apprehended injury to the building, the Commissioners of Sewers of the City of London were induced to divert the course of a sewer then in progress.

6th. The storm-overflows provided do not appear to fulfil, in all cases, the objects for which they were designed; viz., to discharge storm-water, at all times of the tide, without interfering with the low-level districts; but in the execution of the works Mr. Bazalgette would no doubt obviate this objection.

7th. In respect to the estimates of the work, we are of opinion that, in order to carry into effect a plan which involves many difficult engineering works, and which interferes with many public and private interests, a much larger amount of expenditure will be required than that which has been provided for in Mr. Bazalgette's estimates.

2.—Observations upon Mr. M'Clean's Plan.

Mr. M'Clean's plan may be briefly described as follows:—

With the view of overcoming the objections which have been urged against discharging the sewage into the Thames, Mr. M'Clean proposes to convey it to a point on the Essex coast, between the Crouch and the Blackwater, which he assumes will place it in the German Ocean.

For this purpose, it is proposed to collect the sewage of the district south of the Thames into a well at the foot of Southwark bridge, whence it is to be pumped through conduit pipes, laid under the roadway of the bridge, into the Aldgate branch of the northern middle level intercepting sewer, and to Abbey Mills, at which point the proposed main conduit begins.

By uniting the sewage in one stream, Mr. M'Clean obtains so large a volume as to be enabled to maintain the same velocity of flow as is proposed by Mr. Bazalgette, with a very much reduced fall per mile.

The advisability of adopting this plan turns entirely upon two points; and unless these points be conceded, it is unnecessary to consider the details.

These

* With respect to the question of constructing the large sewer near St. Paul's, it appears that the Commissioners of Sewers for the City of London commenced the construction of a sewer through St. Paul's Churchyard in 1831, and that Mr. G. Rennie, Mr. Smirke, Mr. Cockerell, Mr. I. Brunel, Mr. Sibley, and Mr. Acton, were appointed to consider the question; after making borings, these gentlemen reported that, as part, if not all, of the footings of St. Paul's Cathedral Church rest upon a thin bed of pot-earth, beneath which is a thick stratum of sand with gravel intermixed, containing a considerable body of water; and that, as the south transept of the cathedral has heretofore settled, and been fractured, it would not be advisable to prosecute the construction of the sewer in the churchyard, inasmuch as there is a possibility that, however carefully the work might be executed, some degree of motion might, either then, or at some remote period, take place in the said stratum of sand and gravel; they therefore recommended the commissioners to abandon this line for their sewage, however eligible it might in other respects be; and looking to the nature of the strata, to construct their sewer at such a distance from the fabric as in their judgment would leave no chance of injury. The sewer was consequently carried through Little Carter-lane in lieu of St. Paul's Churchyard. *See* Appendix, IX.

These points are:—

1st. That the outfall proposed is a desirable one.

2d. That the mode of dealing with the southern sewage is satisfactory.

1st. The proposed outfall is situated in a small creek, termed the Hoo Outfall, which runs up into the Dengie Flats. These flats are banks of mud skirting the marsh land which lies between the rivers Crouch and Blackwater, in Essex. We have appended the Admiralty chart of the district, and we beg to call particular attention to it, as showing the local peculiarities, and the position of the proposed outfall. (*See* Appendix X.)

It will be observed that the proposed outfall is situated in a deeply indented bay within what may be called the combined estuary of the Thames, the Blackwater, and the Crouch, and at a part where it is very much intersected with sandbanks.

The river Crouch is approached by two narrow channels, which are separated by a sand-bank called the Buxey; one of these channels is called the Ray Sand Channel, and the other the Whitaker Channel, and the creek termed the Hoo Outfall empties into the Ray Sand Channel. The rivers Crouch and Blackwater afford a very small amount of land water to assist the outflowing tide; and a slow, progressive increase of the coast is taking place by a natural process of warping.

A consideration of these facts leads to the conclusion that the movement of the tides on this coast must be comparatively small, and that there must be a considerable period of slack water. These conclusions were entirely borne out by tidal experiments. (*See* Appendix V.)

The experiments were made with the assistance of Captain Burstal, and took place within two days of the highest spring tides. The results are shown on the map, and may be briefly described as follows:—

A float put in, at high water, at the proposed outfall, was carried by the receding tide to the Bachelor Spit, a distance of about seven or eight miles; slack water prevailed in the Ray Sand Channel for about two hours before low water, so that floats put in near the mouth of the Hoo Outfall at that time scarcely moved till the flood began to make, and then some were carried up the Crouch nearly as far as Burnham, and others set in shore on the Dengie Flats. We ought to add, that the weather was the fairest possible for the experiment.

The opinion which we have arrived at with respect to this outfall is, that if the sewage were discharged there, neither the depth of water nor the strength of tide would be sufficient to carry it away, as assumed; and, consequently, that it would hang about the coast and the creeks.

We are unable to state what would be the probable result of an accumulation of sewage deposit on a coast where ague is already a constant disease; but it has been urged upon our consideration that whilst this plan would probably cause increased ague and malaria fever along the coast, and even at Burnham, compensation would have to be made for the damage done to the oyster fisheries in the Crouch. We have not, however, inquired into this last question; and we do not consider that the proposed point of outfall fulfils those conditions of carrying the sewage to the German Ocean, upon which its claims for adoption are principally based.

2d. The next point in Mr. M'Clean's scheme to which it is necessary to allude, is the question of uniting the sewage from the districts south of the Thames to the sewage of the northern districts.

The main feature of this portion of the plan is, to dispense with any high level intercepting sewer on the south side, and to allow the sewage and a portion of the rainfall from the upland districts to flow down as at present into the low district; upon the assumption that, if the sewage be continually pumped, the sewers will be generally free from water, and will have sufficient storage capacity for a large amount of rain.

Mr. M'Clean also considers that a large portion of the water from the upland districts might be permitted to flow through its natural channels into the river as pure water.

We have already described the condition in which we found all the main streams of the southern upland districts; and we now repeat that we do not consider that, with the exception of the Baveley Brook, the River Wandle, and the

Ravensbourne, any of the surface streams are in a condition to flow into the river.

Without entering at length into a discussion of this plan, it appears to us sufficient here to state that we do not consider that any scheme of drainage for the south side of the Thames is satisfactory which does not provide a means for intercepting and removing the water from the upland districts by gravitation, and thus preventing it from flowing into the lower district, because a large portion of the lower district is below the level of high water, and is now occasionally waterlogged for weeks together. We further consider that the proposal to make use of the sewers for storage reservoirs, when the water cannot be removed with sufficient rapidity by pumping, is, even if they had been of adequate capacity, opposed to sound sanitary principles.

And our opinion also is that the proposal to pump the whole of the sewage on the south side is undesirable, because it entails great risk of floods, and an expense which would be considerable at the present time, and one likely to increase.

We have, however, in conclusion, to express our opinion, that the proposal to unite the northern and southern sewage into one channel, in order to obtain an increased volume, with the view of reducing the fall per mile, is one which deserves great praise.

3. Observations on the Plan proposed jointly by Mr. Murray and Mr. R. Mylne.

The plan proposed jointly by Mr. Murray and Mr. R. Mylne divides each side of the river into three drainage areas. On the north side of the river it provides for removing by gravitation the sewage intercepted by high level sewers, over an area estimated at about 22 square miles. This sewage would be carried over the Hackney Marsh near Temple Mills, by an aqueduct which would convey it to a point beyond Barking. It would there be united with the sewage of a low level district, estimated at 15·59 square miles, which would be pumped to Barking from near Abbey Mills. This low level district is bounded on the west by the Grosvenor Canal and Grosvenor Place. The remainder of the drainage of the western district would be conveyed under the river at Battersea to the south side, and then lifted into a high level intercepting sewer at Wandsworth Common.

On the south side, the area to be drained by gravitation occupies 21·86 square miles.

The sewer which intercepts this drainage commences at Wandsworth, and crosses the valley of the Ravensbourne at Lewisham. The western area of the south side, as well as that of the north side, would be received into it at Wandsworth; and the sewage of Battersea, Lambeth, Southwark, and Deptford would be conveyed by a low level drain to near Whitepost-lane, and be there raised into the high level sewer. The united sewage would then be conveyed by a tunnel at the back of Blackheath and Shooter's-hill to near Plumstead, and thence by Erith to the mouth of the River Darent, where it is proposed to be discharged into the river.

The drainage of Greenwich and Woolwich would be conveyed by a small intercepting sewer into the main sewer, near Plumstead.

The proposal to convey the sewage of the southern districts by a tunnel at the back of Shooter's Hill, has been carefully considered by Mr. Murray and Mr. Mylne; there appears to be little doubt that at the level at which the tunnel is proposed to be constructed, difficulties from water need not be apprehended, but if placed at a lower level, it is probable that a good deal of water would be met with.

The part of this scheme to which we would direct especial attention, is the proposal to convey the sewage of the western districts on the north side across the river to the south side, and there to pump the sewage, both for the north-western, and south-western districts, into a high level sewer, which is carried through the less populated districts, in lieu of allowing it to flow through the low-lying and thickly inhabited districts on each side of the river.

We do not consider that the proposed point of outfall would effectually free the river from sewage; and we are of opinion, that in constructing the outfall sewer, it would be more advisable to adopt a line nearer to the main valley of the Thames, and in more immediate proximity with the populated districts.

III. The

III.—The System of Drainage which we recommend, and the Modifications in the Plan of the Metropolitan Board of Works which this System will necessitate.

We have shown that we consider it very inexpedient for the Metropolitan Board of Works to adopt any plan which is based upon the deodorisation or the utilisation of sewage; that if an attempt is to be made to utilize London sewage, it should be made by private enterprise; and that, in any case, provision must be made for the continuous discharge of the liquid residue in case of deodorisation, or the occasional discharge of the sewage in case of irrigation, at some point where it would be unobjectionable.

It therefore now remains for us to state our opinion:—1st. Upon the best point of discharge for the sewage, that is, the outfall: 2d. Upon the mode which we recommend for reaching that outfall: and 3d. Upon the modifications which should be made in the plan of the Metropolitan Board of Works for the internal drainage of London.

1.—*Selection of the Points of Outfall.*

After a careful consideration of this question in all its bearings, we are of opinion that the best mode of disposing of the sewage of the Metropolis is to place it where it will be rapidly and certainly mixed with large volumes of water, and be finally carried into the sea. We consider that the most effectual method of securing this object is to place the outfall at some point in a deep tidal river, where the range of the tide is considerable, where the set of the stream is strongest against the shore, and where its outward flow is assisted by the fresh water from a large drainage area.

There are two points on the River Thames which entirely fulfil these necessary conditions; viz., one on the north side, very near to the Mucking Light-house, in Sea Reach; and the other on the south side, at Higham Creek, in the Lower Hope. At both of these places the water near the shore is very deep, and the ebb tide very strong.

We consequently made some tidal experiments at these places, with the assistance of Captain Burstal, R.N.; * and we also received, from the committee of gentlemen from Erith and Gravesend, the results of a valuable series of tidal experiments made by Messrs. Homfray, their engineers, at the same place. And we also consulted Captain Bullock, R. N., upon the subject, who, by his valuable surveys, is thoroughly acquainted with the River Thames.

The results of these experiments are briefly as follows: at both places the currents are very strong in the ebb tide, and a considerable period of slack water occurs during the flood; and unlike the upper parts of the river, where the tide is concentrated into one stream, the great expansion in the breadth of the river at Sea Reach causes great variations in the set of the currents at different parts; thus, while the ebb tide sets upon the northern shore of Sea Reach, the flood-tide sets upon the southern shore. This was shown by the fact, that floats which entered Sea Reach with the ebb tide set in towards the northern shore, and were not carried up the river again with the following flood tide; whilst a large volume of fresh sea water from the Nore comes up along the south shore at every tide. The strength of the current at both of the above-mentioned places is sufficiently great to prevent any deposit of materials brought down by the sewers from taking place in the bed of the stream; and the great expanse of water, the continual accession of clean water, and the rapidity of current, would ensure the mixing of the sewage with water under the most favourable circumstances, and at a point in the river where the shores are almost uninhabited.

These are the only places in the river, either above or below, which appear to us entirely to fulfil the conditions essential to the object in view; and we have therefore selected them as the points of outfall for the metropolitan sewage.

2.—*Mode of reaching the Outfall.*

In determining the mode of reaching the outfall, the first point for consideration is the velocity at which it is desirable that the sewage should flow in the channel to be provided.

With

* *See* Captain Burstal's Report in the Appendix.

With a view of obtaining reliable facts, to test the results of our general experience on this subject, one of our colleagues, Mr. Blackwell, made a series of experiments at Crofton, on the Kennet and Avon Canal. The locality chosen afforded the command of large volumes of water, and of all necessary appliances for conducting the experiments on a scale of sufficient magnitude to ensure the accuracy of the results.

These experiments are given in Appendix IV., and they confirm the opinion which we previously held, that provided a mean velocity of 2 feet 6 inches per second be maintained in the channel during the daily period of maximum flow of the sewage, there will be no deposit in the channel; and that, with the view of preventing injury to the bed of the channel, it is inexpedient to provide a higher velocity than between four and five feet per second.

The velocity of all streams depends on the ratio between the inclination of the surface and the hydraulic mean depth of the stream; viz. the area of the cross section divided by the wetted surface of the channel at that cross section. Thus, by a proper adjustment of these quantities, a deep and wide stream, with a small inclination, may be made to flow with the same velocity as a narrow and shallow stream with a considerable fall.

The first principles to be observed in the drainage of the metropolis are, that the sewage should be removed with rapidity and certainty, and that the districts should be effectually freed from the risk of floods.

These would be most completely secured by removing the whole sewage by gravitation, without having recourse to artificial means for raising it. But the removal of sewage by gravitation from the low-level districts is only possible provided the present system is retained in which the sewage flows through tidal outfalls, but this involves delay in the removal of the sewage, and necessitates its being discharged into the river at low water: and is therefore incompatible with the principles which we have laid down, and with the purification of the river.

Hence* artificial means for raising the sewage must be resorted to for the low-level districts; but the use of these artificial means is attended with so many risks, even with the high perfection which machinery has attained at the present day, that we are of opinion that it is of the first importance to reduce the areas from which the sewage is to be so raised to within the smallest possible limits.

The expediency of obtaining a large area from which to remove the sewage, without having recourse to mechanical aid, renders it imperative that the inclination of the channel by which the sewage is to be conducted to the outfall should be as small as possible; but we have already shown that the necessary velocity can only be obtained with a small fall, provided the channel be large, and the volume maintained therein be considerable.

We consider, for reasons which we shall state hereafter, that it is desirable to remove the low-level sewage from the western districts on the north side, across the river to the south side. The total daily quantity of sewage and rainfall which we provide shall be removed from the metropolitan district is 185,649,993 cubic feet, of which 98,832,144 is proposed to be removed on the north side, and 86,817,849 on the south side of the river. And the total quantity, including the sewage and rainfall from the additional districts, would amount to 109,290,132 to be removed on the north side, and 101,524,773 on the south side.

A channel capable of conveying the total amount of sewage and rainfall to be removed on the north side, at a velocity of 2 feet 6 inches per second, would be 39 feet broad and 16 feet 6 inches deep; and a channel capable of conveying, at a velocity of 2 feet 6 inches per second, the total amount of sewage and rainfall to be removed on the south side, would be 37 feet broad and 16 feet deep. These channels would require a fall of 6 inches per mile; and in their execution the proportions would be, to some extent, adapted to local circumstances.

The above velocity could, however, not be maintained, unless the channel were nearly full of water, but the amount of the maximum flow of the sewage during dry weather is not much more than one-sixth of the quantity to be removed during rain. We therefore propose to obtain from the Thames at high water the necessary quantity to fill the outfall channels during those times when the flow of sewage is not sufficient to give the required depth and consequent velocity.

* At Chicago, in the United States, the difficulties attendant upon a low level for drainage were overcome by raising the whole town five feet.

velocity. This water would be admitted into the channels, at the head, directly from the river, and from reservoirs formed to equalize the flow.

The average level of high water at Blackwall above high water at Mucking Lighthouse has been ascertained to be about 2 feet, and the tide begins to fall at Mucking Lighthouse at least an hour before high water in London; consequently by the time high water obtains in London, the tide has ebbed at the outfall sufficiently to give in ordinary weather a difference of level of nearly four feet. *See* Appendix III.

The considerations which fix the point at which this outfall channel should commence are—

1st. That in order to secure perfect immunity from floods in this system, it is necessary that the level of the surface of the sewage in London in times of maximum flow during rain should stand above the highest possible tides. We have, therefore, considered it expedient to select 5 feet above Trinity high-water mark as the level to which the sewage should gravitate in the metropolis during the period of maximum storm-flow.

2d. It is not desirable that this large outfall sewer should approach nearer than to the outskirts of the metropolis. On the south side it would terminate in the marshes, close to Woolwich; on the north side, the River Lea would be its proper termination; but, inasmuch as the district between the River Lea and Barking Creek, north of the Victoria Docks, is being rapidly built over, we propose that it should not be carried beyond Barking.

The highest level of storm-waters in the outfall sewer at Barking and at Woolwich would be Trinity high-water mark, and a sewer would rise from this level at an inclination of 1 foot per mile to near Bow, on the north side, and to the Ravensbourne on the south, where the highest level of storm-flow would be 5 feet above Trinity high-water mark, and to these points the sewage on each side of the river would gravitate.

We have carefully considered the expediency of uniting the sewage of the northern and southern districts into one stream, by carrying the sewage from one side across the river. We have also considered the expediency of bringing up the outfall channel on one side of the river to the western part of the metropolis, and of concentrating the whole sewage into this one channel, at some point but little above high-water mark, near Battersea or Chelsea, whence it would flow by gravitation to the outfall. As an hydraulic question, the increased volume which would flow in one channel would be an advantage; and the last-mentioned plan would provide for the extension of the area from which the sewage would flow by gravitation, without having recourse to artificial means for raising it. But, after reviewing all the circumstances, we think that the construction of a sewer, of the very large dimensions required for conveying the whole of the sewage in one channel, would be attended with great engineering difficulties; with uncertainty of construction; and with an increase of cost for works and compensations; and we fear that, instead of simplifying the question, it would render it more complicated.

The engineering difficulties might, no doubt, be overcome by modern appliances; but, considering the enormous extent of the districts, both on the north and south sides of the river, and considering further, that the population of each is daily increasing in an accumulating ratio, we are of opinion that it is more expedient to make each system complete in itself, and to provide each with a separate outfall.

Also, bearing in mind the possibility of the application of sewage to economical purposes, an outfall channel along each bank of the Thames would admit of its more extensive application, and would offer greater advantages than the concentration of the whole in one stream.

We have caused careful surveys to be made, and levels to be taken, on each side of the river, between the metropolitan boundary and the proposed outfalls; and we have selected the lines which we consider most advantageous for the course of the new outfall channels, with reference to the levels of the ground and to the nature of the strata which would be passed through.

These lines are shown on the accompanying plans, No. 1, and may be described as follows:

1st.—On the North Side.

The main outfall channel would commence just beyond Barking, and, skirting along the marsh as far as Purfleet, would pass in a tunnel to Grays Thurrock; it would then continue through the marsh to a point near West Tilbury

Tilbury; whence it would pass in a tunnel, under the spur of land between East and West Tilbury, again into the marsh; and it would be continued in the marsh to the outfall near Mucking Lighthouse.

2d.—On the South Side.

The main outfall sewer would commence close to the boundary of the Ordnance property in the marshes below Woolwich, and be carried through the marsh in a straight line to Erith, to the south of which it would pass, in a tunnel, and thence in a nearly direct line, under the River Darent to Greenhithe. It would then be carried under the high land south of Greenhithe, by means of another tunnel, into the valley at the back of Northfleet; whence a third tunnel to the south of Gravesend would carry it into marshes which extend to Higham Creek, the selected point of outfall.

A wide channel would lead from the Thames to the head of each main outfall sewer, and through this channel tidal water would be admitted into a reservoir during the flood tide, and also into the sewer, to assist the flow whenever it might be necessary.

The great extent to which the sewage will be diluted after the outfall channels have been fed with the tidal water at Barking and Plumstead, will render it a comparatively innoxious stream. For this reason, we are of opinion that it would be inexpedient to incur the expense of covering the channels, except in the neighbourhood of towns, buildings, and crossings of public roads. Efficient fences should be erected for the protection of the channels, and the communication between the lands on either side would be maintained by bridges.

We have considered the probable effect of these works upon the régime of the river, and we are of opinion that it will be inappreciable.

3d.—*The Modifications in the internal System of Drainage of the Metropolis which the Alterations in the Positions of the Outfalls will necessitate.*

The level from which the proposed outfall sewers will allow the sewage to flow, renders it possible to intercept the sewage of an area in the metropolitan districts of about 33 square miles out of 50 on the north side of the river, and of about 48 square miles out of 69 on the south side, which is equivalent to 68 per cent. of the whole area. The sewage so intercepted would flow into the river by gravitation alone. This increase in the amount which can be intercepted in the high-level sewers necessitates some modification in the plan of the Metropolitan Board of Works.

On the accompanying map * we have confined ourselves to showing the area which would be so intercepted. To determine the exact position of the intercepting sewers in the metropolis would require a careful and special study of the various districts. Our time has hitherto been so constantly devoted to the more important points contained in this report, that unless its completion were considerably delayed, we could not do more than generally indicate the course which such intercepting sewers should follow. Economy and public convenience require that the existing main sewers should be as little interfered with as possible. The principle of interception, as first laid down by the late Mr. Frank Forster, and subsequently followed up by Mr. Bazalgette in his present design, is (with the exceptions previously referred to in this report) correct, and must form the basis of any scheme of intercepting sewers through the metropolis.

The general indications of the line of sewers in the metropolis we submit are as follows:

1st.—On the North Side.

The sewer, connecting the metropolitan system with the northern main outfall channel, would terminate at Bow, on the island formed by the branches of the River Lea; and to this point the following intercepting sewers would converge:

1st. A high-level sewer following generally the line of Mr. Bazalgette's high-level sewer.

2d.

* We have derived great assistance in this inquiry from the Ordnance Map of London on the six-inch scale, recently issued by Lieutenant-Colonel James, R. E.; but this map represents London in 1849, and it is extremely desirable that it should be completed down to the present time. Mr. Mylne's contoured maps, in outline, have also been of great service in this inquiry.

2d. A second high-level sewer, to answer the purpose of Mr. Bazalgette's middle-level sewer: and having in view the nature of the ground through which it would pass, the area to be intercepted, and the necessity of avoiding crowded thoroughfares, it would probably be desirable that this sewer should commence at Bow, and follow generally the line indicated on the map by the Commercial-road, Houndsditch, and north of the City, to the valley of the Fleet at the foot of Holborn-hill; thence under Lincoln's-Inn Fields, Long Acre, Piccadilly, and Hyde Park, to Kensington; whence it could be continued, following generally the contour of the land, to intercept the sewage from Acton, Ealing, and Hanwell. The sewage of the spurs of high land which project between the several lateral valleys of the northern district should be carried into this sewer by means of subsidiary lines, as indicated on the map, according to the principle adopted by Mr. Bazalgette.

3d. It is desirable, as far as is consistent with economical working, to keep the low-level districts independent of each other, and to prevent the sewage, as far as possible, from flowing through the thickly inhabited parts of the town. Having regard to these considerations, as well as to the difficulties of the work, we are of opinion that it is unadvisable to construct the low-level sewer proposed by the Metropolitan Board of Works; but we recommend that the sewage of the low-level districts in Hackney Marsh, and in the eastern districts near the Thames, should be collected and raised by artificial means at the point shown on the map; whilst the low-level sewage west of Somerset House should be carried back to nearly opposite Battersea, and then across the river, there to be raised, by artificial means, into a southern high-level sewer. The proposed point of crossing is indicated in the map.

The sewage from the valley of the Lea and from East Ham and Barking, would be discharged into the outfall sewer at the most convenient spot.

2d.—On the South Side.

On the south side the high-level sewer would follow generally the line of Mr. Bazalgette's southern high-level sewer, but it should be carried round the hill at Wandsworth, so as to intercept the sewage from that district. It would then be carried across the River Wandle, above the navigable portion, by an aqueduct, and continued so as to intercept the sewage from the upper parts of Wimbledon and Putney.

This sewer would receive near Wandsworth, as has been stated, the sewage of the low level north-western districts. The principle of keeping the low-level districts, where practicable, independent of each other, and of not permitting a larger quantity of sewage than possible to flow through thickly inhabited parts of the town, induces us to recommend that a low level sewer should be carried back from the Effra along the Battersea-road, and that the sewage should be raised into the high level sewer at the same point as the sewage from the north west low level districts; and we would also raise at that place the low level sewage of Wandsworth, of Putney, and of the low level districts west of the metropolitan boundary, as well as the sewage of the valley of the Wandle.

The sewage of the low level southern districts from the Effra to Deptford, the sewage from Greenwich, and any low level sewage from the valley of the Ravensbourne, should be raised into the high level sewer near the Ravensbourne.

It would probably be desirable that the sewage from Woolwich should be placed in the main outfall channel, near its head.

The horse power provided for lifting the low level sewage at the different stations, is as under:—

	HORSE POWER.
At the River Lea where a portion of the northern low level sewage is lifted - - - - - - - - - -	610
At the River Wandle, where the remainder of the northern and a portion of the southern low level sewage is lifted	2,215
At the River Ravensbourne, where the remaining southern low level, together with the low level Greenwich district sewage is lifted - - - - - - - - - -	1,350

This

This power will be amply sufficient down to the time when the increase of population for which we have provided shall have attained the limit we have assigned, besides allowing an excess of 25 per cent. in case of partial failure of the machinery. The actual present requirements are only to the extent of little more than one-half of the above numbers.

It will be necessary to provide storm overflows for these sewers near the point of interception of all important main sewers; and all these storm overflows should be so constructed, as to convey the water directly into the river without interfering with the low level districts, and to discharge at all times of tide; to ensure this, conduits must be used capable of discharging under pressure directly into the Thames beyond the low-water mark, or the outlets of existing sewers may be made use of wherever applicable.

It will be desirable to provide against accumulations of sewage matter in those parts of the intercepted sewers below the points of interception. This may be done either by occasionally diverting the sewage from the high level sewers through the lower districts, or by making arrangements to command occasional supplies of water for the upper parts of the sewers, or by some other means. The new low level intercepting sewers can be cleansed by the occasional admission of water from the river.

In order to prevent impediments to the flow of the sewage in the line of the main outfall sewer, it is most desirable that means * should be taken to prevent gravel, road material, &c. from entering the sewers, and we propose that the heavier and more solid matters should be separated in some convenient place, and be removed before entering the main outfall channels.

In the prosecution of these works considerable interference with the traffic in the public thoroughfares must be anticipated, as very large quantities of materials and surplus earth will have to be carted through the streets; and, independent of the obstructions which the excavations will cause, the works will probably necessitate the temporary stoppage of some of the thoroughfares, and the diversion of the traffic; and, further considering the magnitude and extent of the main sewers, we doubt the possibility of carrying them into effect without in some parts affecting the stability of contiguous buildings.

The proposed sewers will, in some cases, involve excavations and tunnelling through uncertain and treacherous strata, and difficulties will be encountered with the existing sewers and the lines of gas and water pipes,† which in some of the principal thoroughfares are so numerous and extensive that it will be necessary to remove them temporarily or alter their course during the progress of the work.

We have given considerable attention to the subject of the mode of lifting the sewage out of the low level sewers into the sewers gravitating from the upper districts, and we consider that in order to secure at all times permanent and efficient action, the nature of the sewage requires that the machinery should be of the most simple character. We believe that the ordinary kind of pump is not adapted to raising sewage; but we have received from Mr. William Husband, civil engineer, a very valuable and well-considered report, with a description of a screw pump (illustrated by a model), as well as a description of scoop wheels erected by him in connexion with the drainage of the Haarlem Lake in Holland. Mr. Archibald Slate has also forwarded to us a drawing and description of a form of Persian wheel, which he proposes for adoption in the drainage of the metropolis. Both these documents will be found in Appendix X.

* Extract of letter from Mr. Arntz, surveyor to Westminster District Board of Works, dated 14 July 1857:

"The means adopted for preventing the surface refuse from getting into the sewers of the district, consist in the daily cleansing of every part of the district, together with great watchfulness to prevent the scavengers from sweeping slush down the gullies, and the making it a part of their contract to remove all deposit taken out of the gully pits. These measures have already greatly reduced the quantity of silt deposited in the sewers, and I hope by other steps, all of which cannot be taken at once, to reduce the quantity of solid matter in the sewers to such an extent as not seriously to impede the regular flow of the sewage."

† In illustration of the probable interference with the gas and water pipes, and the existing sewers, we annex sections of the various lines in Parliament-street, Appendix XIII., and from having witnessed the frequent openings of streets of late years, we are able to state from personal observation, that the gas and water pipes are equally numerous in many of the principal thoroughfares of the metropolis; and we are informed that at Charing-cross, at the present time, there are upwards of 30 gas and water mains.

Cost of the Proposed Works.

The following is an approximate estimate of the cost of the works in the metropolitan districts, and of the outfall channels, proposed by us:—

	NORTH SIDE.	SOUTH SIDE.	TOTAL.
	£.	£.	£.
Intercepting and collecting main sewers in the metropolis	1,019,465	1,273,500	2,292,965
Outfall sewers connecting the above with the main tidal channels	350,000	437,500	787,500
Main tidal outfall channels	1,107,000	1,249,800	2,356,800
TOTALS £.	2,476,465	2,960,800	5,437,265 *

If the main outfall channels were carried to the point of outfall selected by the Metropolitan Board of Works, viz. B*, in Erith Reach, the cost would probably be,

	£.
On the north side	1,694,465
On the south side	2,023,500
TOTAL £.	3,717,965

Hence the increased cost of continuing the outfall channels to Mucking Lighthouse and to Higham Creek amounts to 1,719,300 *l.*

We are of opinion that, taking into consideration the magnitude of the works the peculiar difficulties of their construction, and the expediency of not causing too great a demand upon the market for labour and materials, five years, at least, should be allowed for their construction.

District Drainage.

Having thus described the works required for the main intercepting and outfall sewers, it is desirable to draw attention to the fact, that to render the work of drainage complete, much district drainage remains to be provided. (*See* Appendix VII.

We have visited many sites on all sides of the metropolis which are being rapidly built over; and we have found that, as a rule, most inadequate attention is paid to the drainage of the building plots; many of them, before they have been covered with buildings, having been surcharged with the sewage and refuse of adjacent houses. And it will be perceived, from an extract in the note† from the

* Exclusive of charges for superintendence, &c., which we consider may be assumed at four per cent. on the outlay.

† Extract from Mr. Donaldson's Evidence:—A large extent of the area to be drained is full of cesspools charged with decomposing fœcal matter; these are seldom cleaned out or emptied, so long as there is room to make a new one; consequently, in many places in Bermondsey, in Rotherhithe, and in Deptford and Greenwich, the ground is quite honey-combed with them.

Now, at present, the ground being highly charged with water, all this foul matter is kept constantly saturated with water.

Immediately the deep drainage is completed, and the ground generally laid dry to the depth of 12, 14, or 15 feet, the gases from these putrid cesspools will rise to the surface, and escape into courts and alleys, and into the houses, and among the houses, where there is little ventilation, and serious consequences may result.

The emanations from these cesspools laid dry will continue for a time, and then cease to be offensive or hurtful, so long as the ground is kept dry; but let a flood occur, and the ground become saturated again with water, again there would be an emanation of foul gases, first by evaporation from the ground, and then by fermentation, which would result from the contents of the cesspools being saturated with water, and then slowly drying again. And every severe flooding that took place, this evil would be repeated, and no doubt fevers would be engendered from it.

Such a soil once laid dry, must be kept dry, or else it had better be allowed to remain as it is, thoroughly and permanently saturated with water.

Mr. Donaldson said he would urge upon the authorities the necessity of causing *every cesspool to be emptied* before the main drainage be completed, as otherwise he had no doubt but that serious results will arise from the emanation of gases from these putrefactive matters when drained dry. *See* Appendix XI.

the evidence given by Mr. Donaldson, that he anticipates that permanent evil may result from the saturation of the ground with sewage.

The tardiness in carrying out drainage works has been to some extent necessary, pending the determination of the general plan of metropolitan drainage. But, as the execution of the works for the main drainage must occupy some years, it is important that the local drainage should not, on that account, be indefinitely postponed.

Ventilation of the Sewers.

The ventilation of the sewers in the metropolis involves questions of serious importance. The Metropolis Local Management Act* contains provisions to prevent the effluvia of sewers from exhaling through gully-holes, gratings, or other openings of sewers in any of the streets or other places.

The gully gratings originally afforded openings through which the noxious gases generated in the sewers passed up into the streets, when, from an increase of flow in the sewers, or from other causes, these gases were forced out of the sewers.

The foul smells which were perceived at the gully-holes which are situated close to the foot pavement, led to a large number of them being trapped.

The effect of trapping the street gully drains without providing other ventilation of the sewers, is, that the noxious gases generated in the sewers are forced into the houses, when the flow of sewage increases, the syphon traps of water-closets and sinks being the points at which the least resistance is presented to their escape from the sewers. The inhabitants are thus subjected to the poisonous influence of these gases; and the bad smells so frequently complained of in London houses are, in many instances, attributable to this cause. The gases also occasionally cause the death of persons employed in the sewers.

To obviate these evils, the plan has been partially adopted, where the gullies have been trapped, of providing in the middle of the street, untrapped openings into the sewers covered with iron gratings.

These openings for the ventilation of the sewers in the centre of the streets must consequently be endured until a better mode of ventilation shall be adopted, although the foul smells they emit are frequently very great nuisances.

Partial trapping of the gully-hole drains has been adopted by several of the District Boards of Works, in some cases in streets and places where the only openings for ventilating the sewers are either the gullies or the house drains; if, therefore, the gullies are trapped, it is obvious, from what has been stated above, that the foul air and gases will pass into the houses, and very serious consequences may ensue.

The epidemic at Croydon in 1853 was attributed to this cause by Dr. Arnott and Mr. Page in their Report on the Croydon sewers.† And they observe, with reference to the absence of ventilation, that this important element of health and

* Section 71. "Every District Board and Vestry shall, by providing proper traps or other coverings, or by ventilation, or by such other ways and means as shall be practicable for that purpose, prevent the effluvia of sewers from exhaling through gully-holes, gratings, or other openings of sewers in any of the streets or other places within their district or parish."

† Reports by N. Arnott, Esq., M. D., and T. Page, Esq., C. E., relative to the prevalence of disease at Croydon, and to the plan of sewerage. 1853.
In the case of the epidemic at Croydon before alluded to, the sleeping in foul air appears to have been extremely prejudicial; one of the medical practitioners of that town stated, that in the middle of the night he awoke in great uneasiness, and perceived immediately that the cause was a most offensive smell in the room like that of drains; it made him and his wife sick, and this disturbance proved the commencement of an attack of the prevailing illness.
The population of Croydon comprised 16,000 persons; about 1,800 cases of fever, with a mortality of about 60, and very numerous cases of diarrhœa and dysentery, with a mortality of about 10, are reported by Dr. Arnott to have happened during and since the execution there of new drainage works. No doubt some of the cases were attributable to other causes; but the chief mischief, it is generally believed, was occasioned by the sewerage works; and the noxious effluvia in the interior, or in the immediate proximity of the houses, was more injurious than the even more powerful foul air and gases discharged into the open air of the streets.

and comfort which has been generally neglected in dwellings, and almost totally in sewers, must be soon introduced into every plan of sewerage.

When the Legislature empowered the Metropolitan and District Boards of Works to apply traps, coverings, or ventilation, to prevent the effluvia of sewers in the streets, it was certainly not intended that they should, by the means thus adopted, force foul air into the houses, and disregard the ventilation of the street sewers.

We believe the proposed Main Drainage Works, by ensuring a continuous flow in the sewers, will relieve many districts from the effects of the alternate compression and dilation of the air in the sewers; but we attach great importance to the ventilation of all the sewers, and we regret that the time allotted to our inquiry was too short to permit of our investigating this subject more fully.

The Metropolitan Board of Works, as well as the District Boards, might advantageously institute experiments to determine the best plan for removing those gaseous emanations, which must always prevail more or less in a large system of town sewers.

4. The Extent to which Districts adjacent to the Metropolis, which will be benefited by the proposed mode of disposing of the sewage, ought to contribute thereto.

The next point submitted to our consideration is, to what extent districts through which the main outfall channels would pass, can be fairly called upon to contribute towards the expense.

It has been urged upon our consideration with respect to the question of the sanitary state of the Metropolis, that the drainage of the marshes for agricultural purposes could, by means of these outfall channels, be advantageously combined with the drainage of the Metropolis. We consequently inspected several parts of the marsh lands which are drained at the present time by tidal outfalls; these outfalls are generally well adapted to their object, but some are no doubt capable of being improved, so as to dry the marshes more effectually if the occupiers of the marsh lands deemed any alteration advisable. But this is not a settled point; for whilst those persons who cultivate one class of crops desire that the land should be dry, the occupiers of land upon which green crops are grown appear to consider the amount of drainage ample already. As regards the sanitary question, although ague prevails to a considerable extent in the marshes, and on that account, therefore, further drainage would no doubt be beneficial to the health of the few inhabitants they contain, we do not consider that the health of the Metropolis can be so much affected thereby as to make the more complete drainage a matter of public importance, irrespective of the wishes of the owners.

But in many places where collections of houses have sprung up on and adjacent to the marshes, the ditches formed for agricultural drainage have become polluted with sewage, and this sewage eventually flows into the Thames. We may mention as an instance that the Court of Sewers for the levels of Havering, Dagenham, &c. complain of the pollution of the marsh drainage by the extension of houses, the drainage from which passes into the open watercourses, and is highly injurious to health.*

The great facilities for travelling afforded by the railways and steamboats have given a great impetus to building, and to the spread of population along the banks of the Thames.

We

* Mr. Cotton, the chairman, states, that the Court of Sewers for the Levels of Havering, &c. have been in communication with the Local Board of Health for West Ham, with a view to induce them to carry out a plan for draining the houses, &c. in the district, under the provisions of the Public Health Act. And Mr. Rawlinson, the engineer of the Local Board of Health for West Ham, informed us that it was proposed to carry away the sewage in a covered sewer parallel with the open cut of the Victoria Docks, discharging into Gallion's Reach, but some members of the local Board wished to discharge it into the River Lee at Bow Creek; that an Act of Parliament had been obtained for the purpose, but that the works would be in abeyance until it was known what was to be done with the drainage of the metropolis.
With respect to the proposed outfall for the West Ham drainage at Gallion's Reach, we beg to observe, that it is within the metropolitan area, and that so far it is not in accordance with the Metropolitan Management Act.

We are of opinion that the foul sewage, from this population, should not be permitted to flow directly into the Thames, but should be discharged into the main outfall channels at some convenient point on their course; and that the inhabitants of each district benefited by the use of the main outfall channels, should, in consideration of the use made by them of these outfall channels, be rated for the cost of their construction and maintenance in the proportion which the population of such districts may from time to time bear to the whole population using the main outfall channel, and to the expense of the portion of the channel so used.

With respect to the general question of the purification of the Thames, it is quite evident that a large tidal and navigable river passing through a country thickly inhabited, must be polluted to a certain extent; and that it is not possible in practice to exclude from the river the refuse from ships, barges, and other vessels navigating its waters; but we are convinced that a great portion of this contamination might and ought to be prevented, and we are strongly of opinion that the Conservators of the River and the several District Boards of Works should be invested with more extended and comprehensive legal powers than they now appear to possess, in order that they may follow out fixed rules and regulations especially framed for protecting the river and preventing the fouling of the stream; an object, we submit, of paramount importance as regards the sanitary state of the Metropolis and the health and comfort of its inhabitants.

It must also be remembered, that the drainage into the Thames above the tidal portion comprises an area of 3,700 square miles, and that much objectionable matter is discharged into the river and its tributaries from the towns and villages within that area. When these towns shall have become better drained, this pollution must increase, unless a means can be found for mitigating the evil. Doubtless, the easiest mode of disposing of sewage is to allow it to flow into a river; and so long as the amount put in the stream is small, this mode of disposing of sewage is unobjectionable; but when the quantity of sewage turned into the stream is in excess, the water becomes prejudicial to the districts on its banks: hence many rivers in populous parts of the country, have been injured by being polluted with sewage discharged into them by towns near their source.

This subject is beyond the limits of the inquiry referred to us, but we feel it our duty to remark upon it, as one of growing importance, and one which urgently calls for the consideration of the legislature.

Conclusions.

The opinions to which we have been led by our inquiry into the best mode of draining the metropolis, as shown in the foregoing report, are therefore as follows; viz.:—

I.

1. That the influence of the sewage on the river is pernicious.

2. That this sewage is derived partly from the population of the metropolitan district, and partly from the population of other districts, occupying the same part of the main valley of the Thames, or of valleys subsidiary to that main valley; and that the quantity of sewage from the metropolitan district alone, which flows daily into the Thames at the present time, is 15,249,777 cubic feet.

3. That in order to purify the tidal portion of the Thames from sewage, it will be necessary to exclude from it, not only the sewage of the metropolitan district, but the sewage from these other adjacent districts.

4. That the plan of the Metropolitan Board of Works does not provide for the removal of a sufficient quantity of sewage from the metropolitan districts; that the amount of rainfall which it is contemplated by this plan to intercept from the river should be increased; and, that the plan does not make adequate provision for removing from districts adjacent to the metropolis the sewage, which flows into the river within the limits of the metropolitan district.

5. That the prospective population of the metropolitan district, for which provision should be made, is 3,578,089, as compared with 2,362,236 in 1851; the

the population of the subsidiary districts being 401,000 as compared with 154,076 in 1851; the total prospective population being 3,977,532. That the only mode of estimating approximately the probable amount of sewage from the district, is to assume a certain quantity per head of the population. That seven cubic feet per head is the amount for which provision should be made; that it appears from our experiments that half this quantity passes off in eight hours; and that no sewage should be permitted to flow into the Thames in or near the metropolis until it shall have been diluted with five additional volumes of rain water in the surburban districts, and that in the eight hours of the maximum flow of the sewage, provision should be made for removing $\frac{2}{5}$ inches of rainfall in the urban districts.

6. That the large population of the portion of the main valley of the Thames, occupied by the metropolitan district, has so diverted the natural springs, and so saturated the ground with sewage, that with the exception of the water from the Wandle, the Bayeley Brook, the Ravensbourne, and the Lea, it is impracticable to preserve, to any useful extent, pure water from these streams to flow into the Thames.

II.

1. That no system of drainage is adapted for the metropolis, which does not relieve the low level districts from floods, and that the system to be adopted must therefore provide for intercepting the upland drainage; and that, considering the expense and contingencies of raising the sewage by artificial means, and the risk of floods, the area from which the sewage can be removed by natural means should be as large as possible, and the area from which the sewage has to be removed by artificial means should be as small as possible.

2. That the sewage, when collected, must be removed with as little practical inconvenience or injury as possible, either to the inhabitants of the metropolis or to the inhabitants of the districts to which it is conveyed.

3. That the so-called deodorisation of sewage does not remove the highly putrescible soluble constituents from the liquid which passes off; and that, consequently, the liquid, after deodorisation, must be disposed of in the same manner as ordinary sewage water; that we do not believe that the deodorisation of London sewage could be carried on without creating a nuisance; and that no plan would be effectual with the increased volume arising from rain.

4. That the value of the fertilising matter contained in London sewage is undoubtedly great; but that the large quantity of water with which it is diluted precludes the possibility of separating more than about one-seventh part of this fertilising matter by any known economical process; that a copious dilution of the sewage is necessary to the health of the inhabitants of the metropolis; and that therefore the sacrifice entailed by the dilution must be endured.

5. That the application of sewage to land, although it may give good results under favourable circumstances, and where it can be applied by gravitation over limited areas, cannot be expected to afford similar results in or near the metropolis, where it would have to be raised to a great height, and to be conveyed to considerable distances, as this entails a very heavy prime cost and very heavy annual charges; that even if irrigation be assumed to be remunerative, no system would be complete which did not provide either for the reception and application of the sewage at all times to the land, and for the subsequent removal of the liquid, or for its being placed in the river at some unobjectionable point, when not required for irrigation; that this would require, in addition to the arrangements for irrigation, other outfall sewers, almost as extensive and costly as would be required without irrigation; and that a means of placing the sewage in the river in an unobjectionable place would, under all circumstances, be required during rain. That, looking to the character of the districts near the metropolis, it would be extremely difficult to find large and detached areas where it would be possible, by agreement with individuals, to guarantee the constant reception of even a small quantity of the London sewage, while we think it may be a question whether irrigation on a large scale might not occasion danger to the health of the inhabitants of such districts by the pollution of the air of the district, as well as of its springs and streams.

6. That, under these circumstances, and having regard to the inexpediency of making the question of the effectual drainage of the metropolis dependent on commercial

commercial considerations, the only practicable mode of disposing of the sewage of the metropolis is to provide for its rapid removal from inhabited districts, and for its collection in main outfall channels, where private enterprise, under proper control, may be at liberty to utilize it; but that, when not required for purposes of utilization, these channels should provide for its flow in the most expeditious manner into the sea.

III.

1. That it is not desirable, for the reasons stated in the report, that the sewage should be conveyed from both sides of the river through one channel to the outfall.

2. That the proposed outfall at B.* in Erith Reach is objectionable, because it would not effectually prevent the sewage from returning within the limits of the metropolitan boundary; because it would have a deleterious effect on the health of the district; and because it would probably be prejudicial to the navigation.

3. That the best outfall on the north side is a place between Mucking Lighthouse and Thames Haven, in Sea Reach; and that the best outfall on the south side is Higham Creek in the Lower Hope.

4. That in order to intercept the sewage of a large area, a level should be adopted little above that of the highest tides, viz., five feet above Trinity high-water mark, as the level from which the sewage should gravitate at the River Lea on the north side, and at the River Ravensbourne on the south side of the Thames; that the sewage should flow from thence to main outfall channels commencing near Barking, on the north side, and near Woolwich, on the south side, which would conduct it to the outfalls; and that in these main outfall channels use should be made of tidal water near the metropolis to assist the flow, and to effect at the same time the dilution, of the sewage.

5. That the area from which the sewage would be so intercepted and removed, without having recourse to artificial means in the metropolitan districts, is about 81 square miles; and the area from which the sewage would be lifted is nearly 38 square miles.

6. That with reference to the other districts for which these sewers would provide, the population is very large; but that the actual amount of sewage which would be intercepted and removed, without artificial means, cannot be accurately defined without further levels.

7. That the cost of the main outfall sewers will be 3,144,300 *l.*, and the cost of the internal system of intercepting sewers in the metropolitan district will be 2,292,965 *l.*, and the total cost, 5,437,265 *l.* That if the outfall channels were not carried beyond B* in Erith Reach, the expense would be reduced by a sum of 1,719,300 *l.*

8. That taking into consideration the magnitude of the works, and the peculiar difficulties of construction, and having a due regard to economy, the works should occupy at least five years in construction.

9. That all towns and villages near the line of the main outfall sewers should discharge their sewage into these channels, instead of allowing it to pass through the marsh drains into the river.

10. That these districts and all districts round the metropolis which make use of the main outfall channels, should contribute towards the cost of constructing and maintaining these channels in the proportion which the population of such districts may from time to time bear to the whole population using the main outfall channels, and to the expense of the portion of the channel so used.

11. That the pollution of streams by sewage, throughout the whole country, is an evil which is increasing with improved house-drainage; and that it is very desirable that the attention of the Legislature should be directed to the subject with a view to devising means for remedying the evil.

In conclusion, we would impress upon you our decided conviction that if the Thames is to be completely purified, no plan less comprehensive than the one which we have suggested will effect this object. The estimated expense of this plan is considerable; and some improvement upon the existing state of things might possibly be obtained for a smaller outlay; but a diminution in the dimensions of the sewers does not proportionately diminish the cost of their construction; and moreover, the increase of population which is so rapidly taking place in every direction round the metropolis, would necessitate the extension of any less comprehensive plan than the one which we have suggested at no very distant period.

Having thus laid before you the facts which we have obtained and our conclusions thereon, it only remains for us to explain, that in consequence of the very limited time which has been allotted to us for inquiring into this extensive subject, the difficulties of which have increased at every step, we have been precluded from entering as fully as we should have wished into many investigations connected with it; and we trust that this will be our excuse for the omissions which may be found in our report. At the same time we beg to take this opportunity of expressing our obligations to those gentlemen who have largely afforded us the assistance of their experience and knowledge; and we have especially to thank the Metropolitan Board of Works, and their engineer, Mr. Bazalgette, for their unvarying courtesy, and for the great readiness with which they have afforded us information.

We have the honour to be,
Sir,
Your most obedient humble servants,

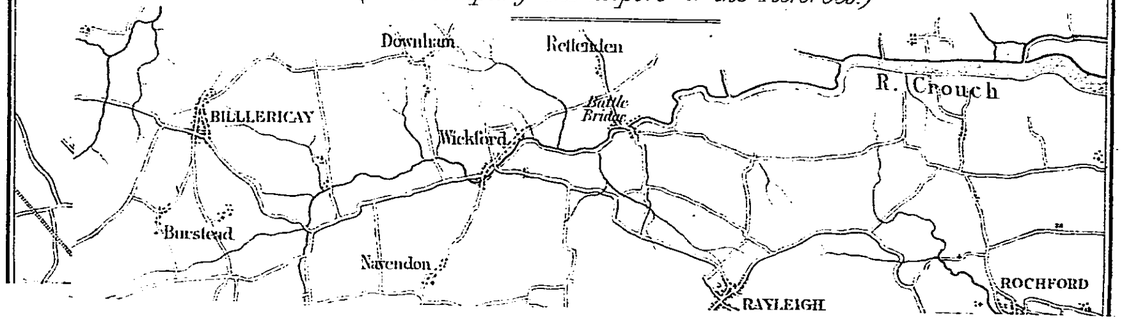
(signed) *Douglas Galton.*
James Simpson.
Thos. E. Blackwell.

The Right Honourable
Sir Benjamin Hall, Bart., M.P.,
First Commissioner of Her Majesty's Works
and Public Buildings.

(signed) *B. Hall,*
First Commissioner.

Office of Works and Public Buildings,
31 July 1857.

PLAN
OF THE
Metropolitan Districts,
And of the other Districts subsidiary thereto;
The Drainage from which naturally falls within the Metropolitan Boundary,
SHOWING THE
PROPOSED POINTS OF OUTFALL
For the METROPOLITAN SEWAGE; and the
Lines of the Proposed Outfall Channels.
And also indicating the direction of the
MAIN LINES OF SEWERS,
Which are required within
The Metropolis.
(To Accompany the Report of the Referees.)

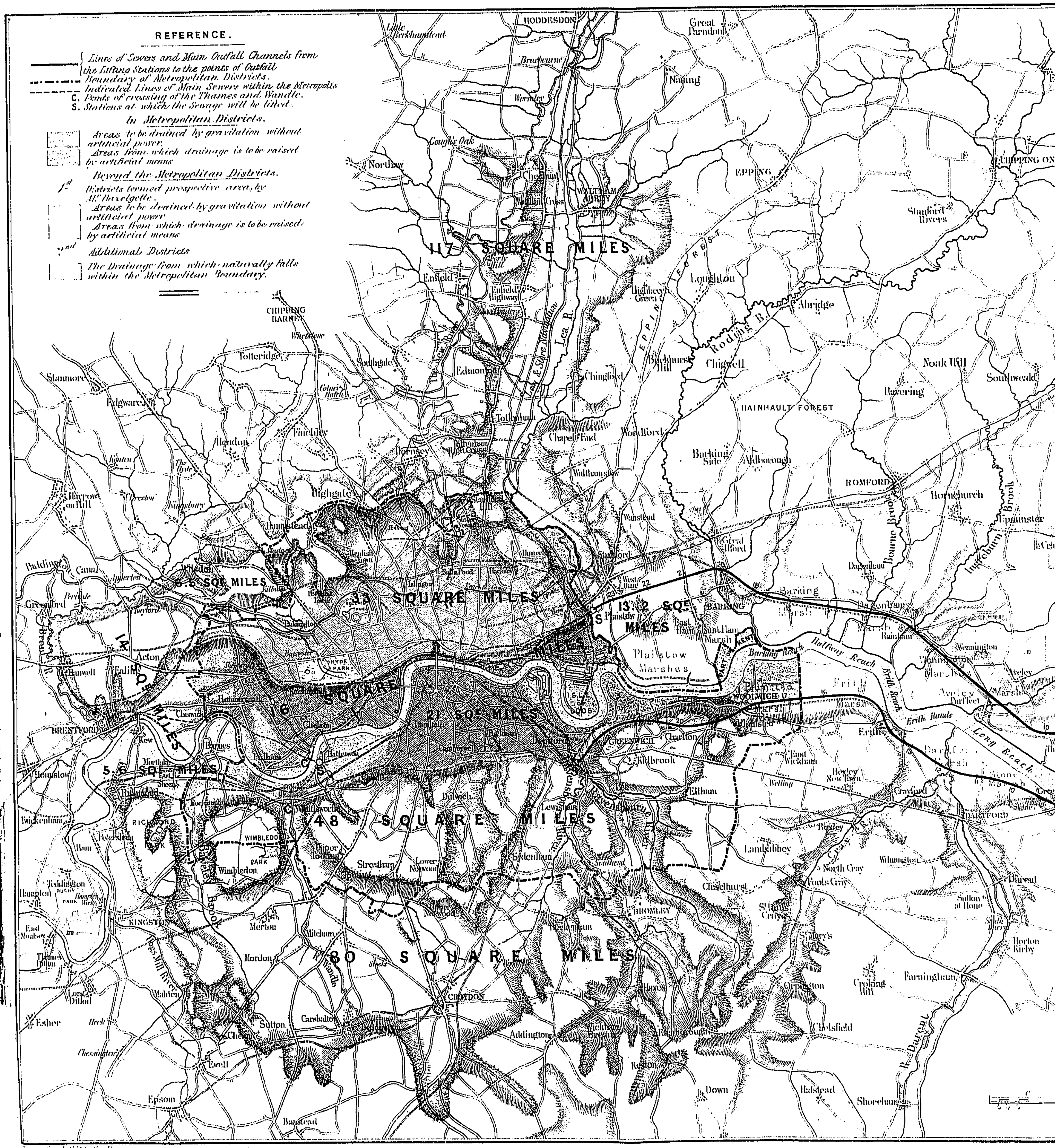


3 2 1 0

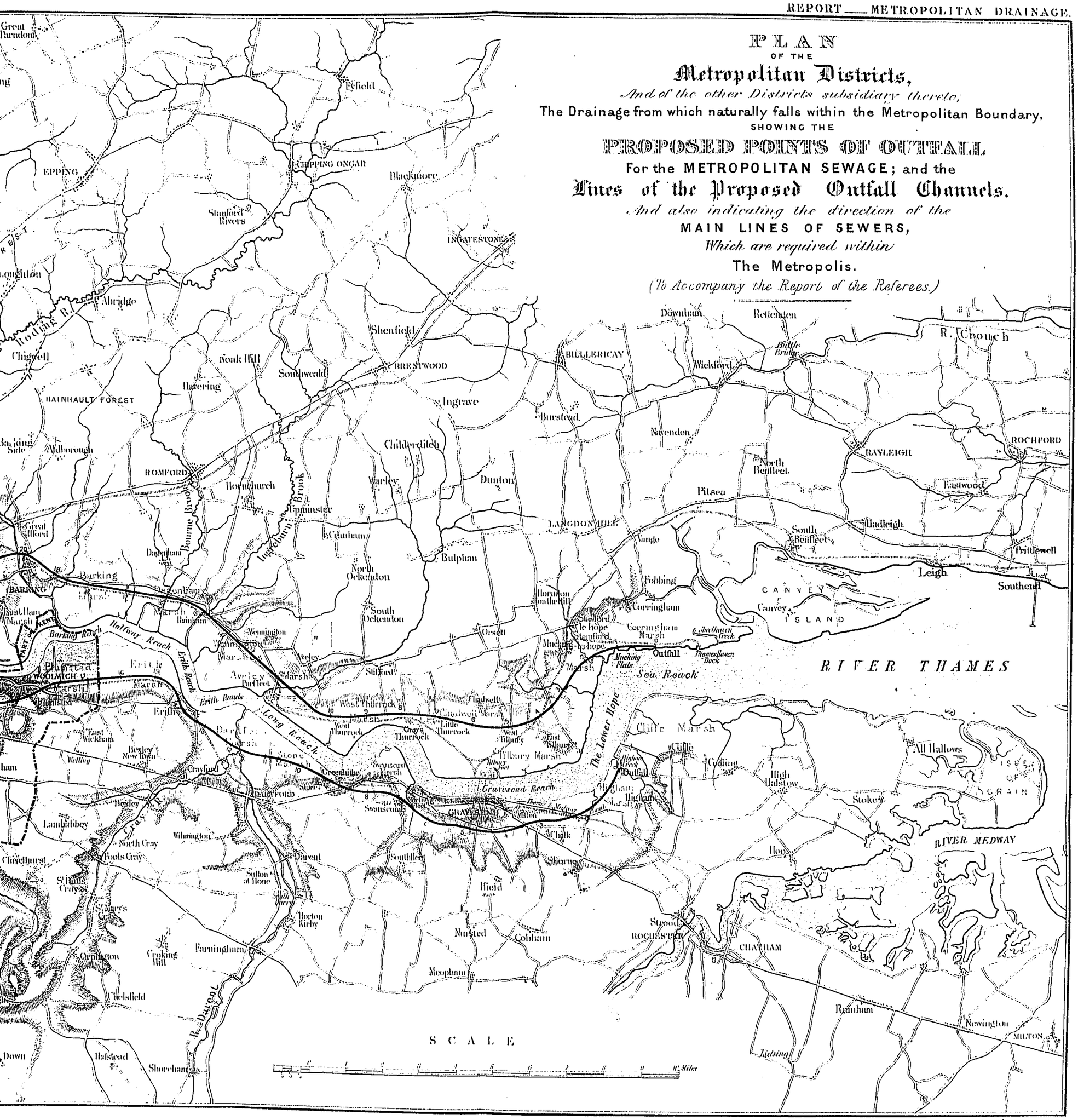
n the Marshes to the East of Barking on the North Side & near the Metropolitan
uncovered when in the Marshes; provision being made in the estimate for
f Towns Buildings & Public Roads

Henry Hansard, Printer.

ed. by The House of Commons, to be Printed, 3rd August. 1857.


REFERENCE.
Lines of Sewers and Main Outfall Channels from the Lifting Stations to the points of Outfall.
Boundary of Metropolitan Districts.
Indicated Lines of Main Sewers within the Metropolis
C. Points of crossing of the Thames and Wandle.
S. Stations at which the Sewage will be lifted.
In Metropolitan Districts.
Areas to be drained by gravitation without artificial power.
Areas from which drainage is to be raised by artificial means
Beyond the Metropolitan Districts.
1st Districts termed prospective area, by Mr Bazalgette.
Areas to be drained by gravitation without artificial power
Areas from which drainage is to be raised by artificial means
2nd Additional Districts
The Drainage from which naturally falls within the Metropolitan Boundary.
117 SQUARE MILES
33 SQUARE MILES
13.2 SQ. MILES
6.5 SQ. MILES
14 SQ. MILES
16 SQUARE MILES
21 SQ. MILES
5.6 SQ. MILES
48 SQUARE MILES
80 SQUARE MILES
HODDESDON
EPPING
ROMFORD
HAINHAULT FOREST
CHIPPING BARNET
BRENTFORD
KINGSTON
CROYDON
GREENWICH
WOOLWICH
BROMLEY
DARTFORD
RICHMOND
Plaistow Marshes
Barking
Erith Reach
Long Reach
Halfway Reach
Lea R.
Roding R.
Epping Forest
Hyde Park
Wimbledon
Bushy Park
R. Darent

PLAN
OF THE
Metropolitan Districts,
And of the other Districts subsidiary thereto,
The Drainage from which naturally falls within the Metropolitan Boundary,
SHOWING THE
PROPOSED POINTS OF OUTFALL
For the METROPOLITAN SEWAGE; and the
Lines of the Proposed Outfall Channels.
And also indicating the direction of the
MAIN LINES OF SEWERS,
Which are required within
The Metropolis.
(To Accompany the Report of the Referees.)

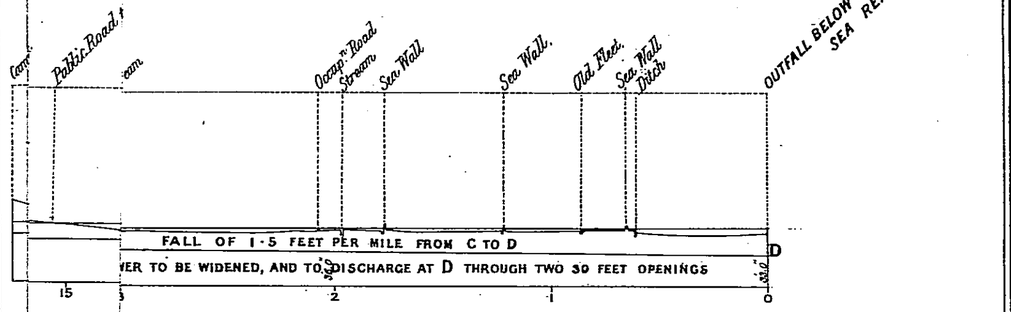


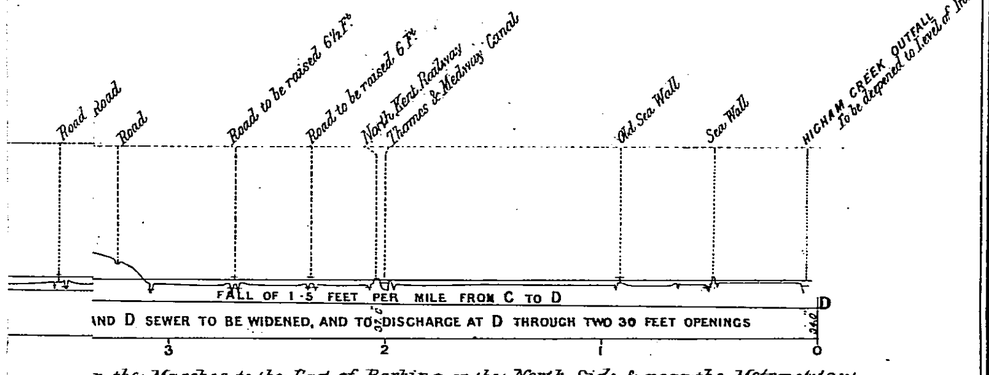
Nº 233. Ordered, by The House of Commons, to be Printed, 3rd August 1857.
Henry Hansard, Printer.

N T

MUCKING

RA





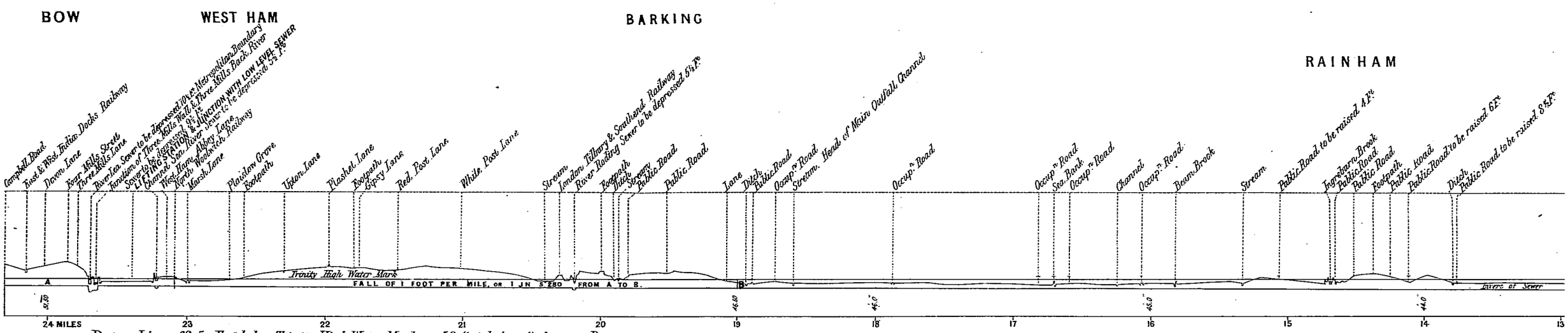
n the Marshes to the East of Barking on the North Side & near the Metropolitan
uncovered when in the Marshes; provision being made in the estimate for
f Towns Buildings & Public Roads

Henry Hansard, Printer.

ed, by The House of Commons, to be Printed, 3rd August, 1857.

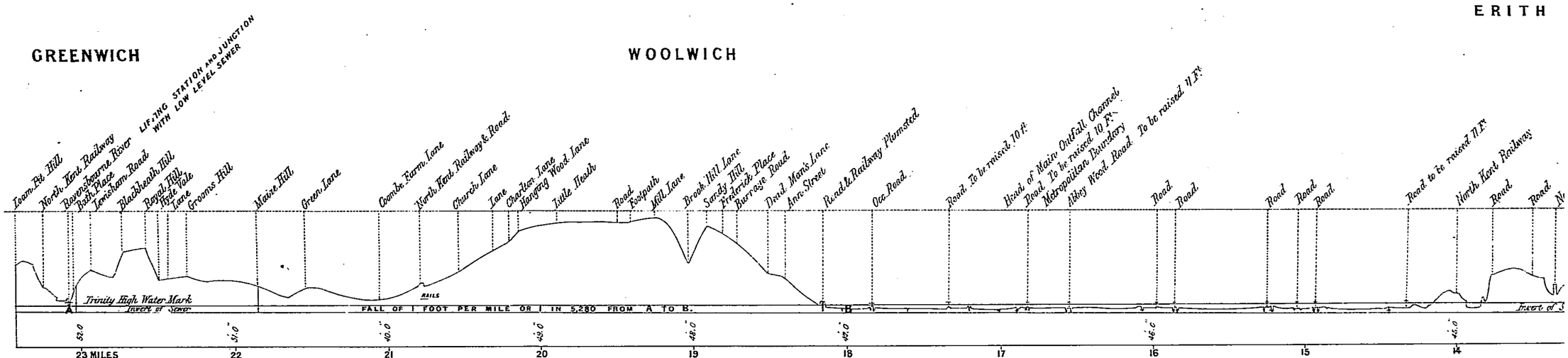
SECTIONS ON THE LINE OF TH

FROM THE LIFT



Datum Line 62·5. Feet below Trinity High Water Mark, or 50 feet below Ordnance Datum.

ERITH



Datum Line 62·5 Feet below Trinity High Water Mark, or 50 Feet below Ordnance Datum.

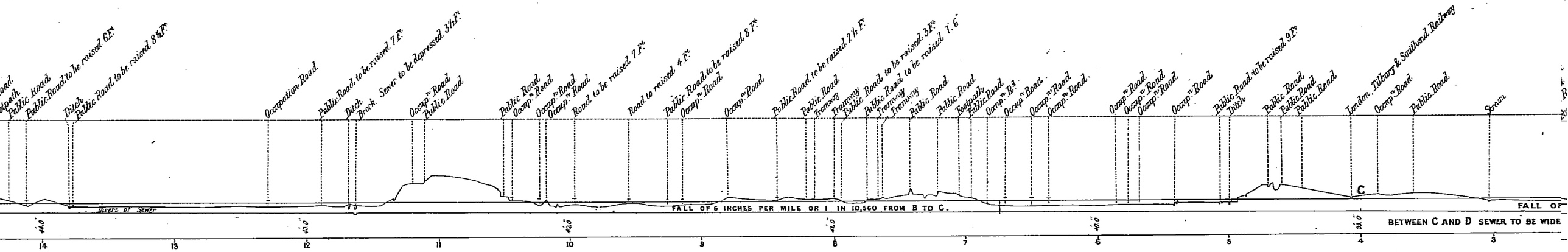
Day & Son, Lith.rs to the Queen.

LINE OF THE PROPOSED SEWERS & MAIN OUTFALL CHANNELS,

FROM THE LIFTING STATIONS TO THE POINTS OF OUTFALL.

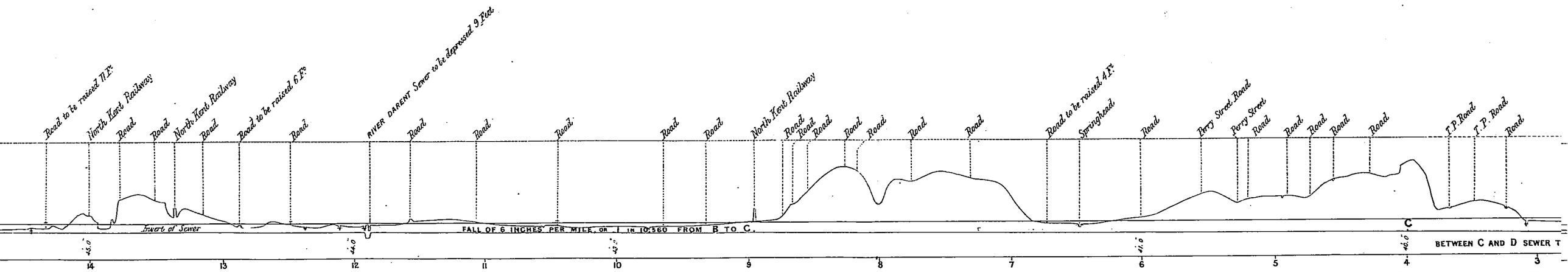
NORTH SIDE.

M PURFLEET CRAYS WEST TILBURY MUCK



SOUTH SIDE.

ERITH GREENHITHE GRAVESEND



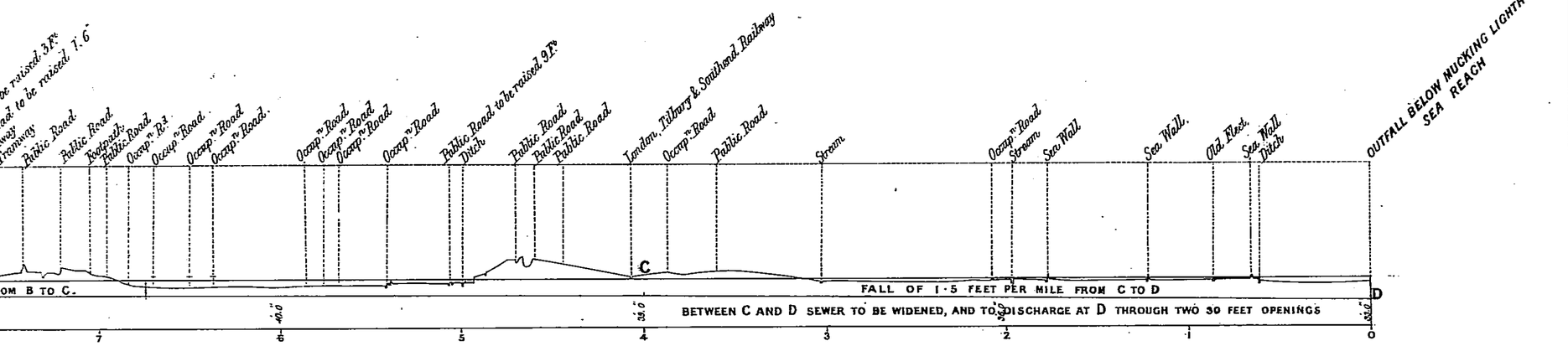
SCALE

Horizontal 1½ Inches to a Mile.
Vertical 160 Feet to an Inch.

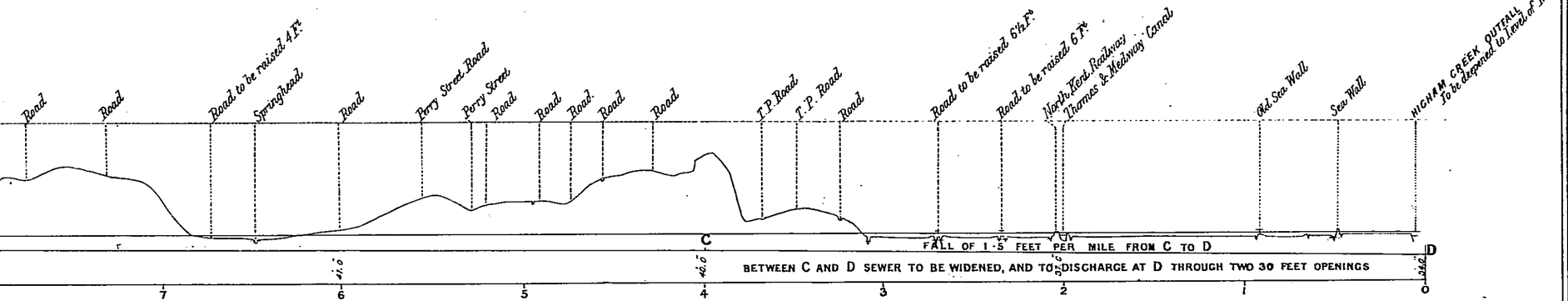
N.B. — *The Sewers to be covered as far as the Junction with the Main Outfall Channels, which commence in the Marsh*
Boundary on the South Side of the Thames — To the Eastward of these points the Channels to be uncovered
covering a total length of about 6 miles on each side of the River in the neighbourhood of Towns Bu

ANNELS,

WEST TILBURY MUCKING



ENHITHE GRAVESEND



N.B.—The Sewers to be covered as far as the Junction with the Main Outfall Channels, which commence in the Marshes to the East of Barking on the North Side & near the Metropolitan Boundary on the South Side of the Thames.—To the Eastward of these points the Channels to be uncovered when in the Marshes; provision being made in the estimate for covering a total length of about 6 miles on each side of the River in the neighbourhood of Towns Buildings & Public Roads

Henry Hansard, Printer.

№ 233. Ordered, by The House of Commons, to be Printed, 3rd August, 1857.