London water supply enquiry : engineer's report on the London water supply from the Thames and Lea, dated 1st September, 1891.

London County Council.

LONDON WATER SUPPLY ENQUIRY.

ENGINEER'S REPORT

ON THE

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FROM THE

THAMES AND LEA.

Dated 1st September, 1891.

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INDEX TO ENGINEER'S REPORT.

London County Council.

Engineer's Department,
Spring Gardens, S.W.
1*st September*, 1891.

LONDON WATER SUPPLY

FROM THE

THAMES AND LEA.

Special Committee on Water Supply and Markets.

20*th July*, 1891.

"Engineer to prepare a report embodying the information "contained in the various reports ordered by the "Committee, and other recent information bearing on "the question of obtaining a further supply of water "from the rivers Thames and Lea."

In compliance with the instruction of the Committee I have the honour to place the following facts before them. In attempting to throw into a connected form the results of the inquiries made during the past nine months, I have not relied exclusively on the various reports received from the several gentlemen whose names will be found in the appendix A, nor upon the information and statistics collected in the Council's office, but have endeavoured to make the report a concise statement of all the data which have come to my knowledge from various sources. I have also endeavoured to embody the opinions of what I may call the highest authorities who have expressed themselves on this matter.

The subject is of the first importance in considering the question of the future water supply of London, because if the Thames and Lea can afford all the water likely to be required, it would be useless to look to more distant sources. On the other hand should it be found that those rivers can yield, even after the construction of costly works, a quantity sufficient only for a comparatively short period, it may be

deemed prudent to concentrate further expenditure on some new source of supply, rather than on an attempt to increase the supply from the Thames and Lea valleys. Further, it may be found inadvisable to depend entirely on a supply derived from a thickly populated area, which, under certain conditions, may possibly become a danger to the health of the community.

The London Water Companies claim that the present state of their works is good, and will continue good for many years; and also that in valuing the undertakings for purposes of purchase, future, but as yet unearned, profits should be included. But should investigation show that no further quantity of water can with safety be abstracted from the Thames and Lea areas, or that a large capital expenditure, either to increase the present or to bring in a new supply, is to be anticipated at an early date, then it is clear that the value of the undertakings of the companies will be materially affected.

Viewing the question broadly, it will be seen that it resolves itself into an inquiry into the quantity and quality of the water that can be derived from the Thames and Lea, including water from the springs, both surface and deep seated, which flow into those rivers; for, as pointed out by the Royal Commissioners of 1869, "*it follows that any water "obtained by tapping the chalk reservoirs that feed either the "River Lea, or the Thames above Hampton, would only* "pro tanto *diminish those streams, and would therefore be "little or nothing gained to the general supply.*"

Thames Valley.

Drainage area.—Above the intakes of the Water Companies at Hampton, Molesey, and Sunbury, the area draining into the River Thames comprises over 3,542 square miles, or 2,267,233 acres, embracing parts of the counties of Berkshire, Buckinghamshire, Hertfordshire, Hampshire, Wiltshire, Surrey, Oxfordshire, Middlesex, and Gloucestershire, with small portions of Sussex, Warwickshire, Bedfordshire, Worcestershire and Northamptonshire.

Geology.—This area, shown on the annexed Map No. 1, may, geologically speaking, be said to consist, first, of the London clay and other tertiary beds, which lie between London and a line passing through Newbury on the west, by way of Reading, Maidenhead and Uxbridge, to near Watford on the east. The river then drains a district composed of the cretaceous formation of chalk, greensand, &c., the boundary of which is a line extending from Swindon on the west, by way of Wantage, Oxford and Aylesbury on the east. Finally above Oxford, in the upper part of the valley, it drains a

district composed of the Oxford clay, great and inferior oolite, &c., which extends from near the Cotswold Hills on the west, to Priors Marston on the north-east.

Rainfall.—The annual rainfall of the valley, as shown by the report of Mr. G. J. Symons, F.R.S., as far as Reading, Maidenhead and Uxbridge, averages about 24 inches; between these places and Tring on the north, and Moreton, Witney, Fairford, Cricklade, Swindon, East Ilsley, Newbury and Basingstoke on the west and south, it runs up to 27½ inches. Above these points, at the head of the valley, it probably averages as much as 32 inches.

River flow.—The average flow of the river at Teddington Weir, a few miles below the intakes of the Companies, would be about 79,000 million cubic feet per annum if it included the quantity abstracted for water supply. This flow would represent nearly 9¼ inches of rainfall actually flowing from the whole of the catchment basin above the intakes. But it need hardly be pointed out that the flow varies very considerably in different years and during different months in the same year. For instance, the corrected discharge at Teddington some times rises as high as 3,000 to 4,000 million gallons a day during periods of autumn flood, and falls as low as 255 to 308 millions of gallons a day during the drier months of the year.

Population.—The valley of the Thames above the intakes of the Companies contained a population—

In 1851	of some	762,000	persons.
In 1861	,,	810,000	,,
In 1871	,,	887,000	,,
In 1881	,,	947,000	,,
and it is estimated that in the present year it considerably exceeds		1,000,000	,,

Besides this human population it is found, from the returns to the Board of Agriculture of 1890, that there are in the Thames valley, above the intakes of the Water Companies—

75,256 horses
265,673 cattle
1,101,095 sheep, and
187,534 pigs.

Quantity of water abstracted.—The average quantity of water abstracted from the Thames for the supply of London in 1858 amounted to 35,387,000 gallons per day, and was increased in 1890 to 90,400,000 gallons, showing a rise of over 154 per cent. during that period.

It should be noted that the whole question of the supply of water from the River Thames was fully investigated by the

Royal Commission of 1869, who say in the 141st paragraph of their report:—"*Considering the whole of the evidence "above referred to, we believe we are justified in inferring in "the first place, that the quantity at present authorised, "namely* 110 *million gallons per day, might safely be drawn "from the main stream of the Thames in its present state; "and secondly, that by means of proper works for storage, "this quantity might be doubled if required.*"

As pointed out in my report of the 8th October last, the Royal Commissioners based this opinion on the assumption (as stated in the 137th paragraph of their report) that the flow of the river never fell below 350 million gallons per day, but as from actual observation it is found that the flow of the river falls as low as 255 million to 308 million gallons a day, and this not on exceptional days, but for periods of a month at a time during some of the drier months, the inferences of the Commissioners have not been justified by experience.

Having given the above brief summary of the salient features of the Thames basin, I must now proceed to deal with them in more detail.

As to the quantity of water abstracted from the Thames by the various Water Companies.

Looking back to the report of the Royal Commission of 1869 I observe that the quantity of water authorised to be abstracted at that period amounted to 110 million gallons per diem. Very considerable obscurity exists as to how this quantity was authorised, and as to how it has since been increased; and although at the recent inquiry before Sir Matthew White Ridley's Committee, the Companies and the Conservators of the Thames were invited very particularly to elucidate their legal powers they carefully abstained from throwing any light upon the subject.

In the reply given to the Royal Commission of 1869, in answer to question No. 3599, Captain Burstall, then the Secretary to the Thames Conservancy Board, stated that each of the five companies were limited to a draught of 20,000,000 gallons a day under arrangements made with the Corporation of London in 1852. By the "five companies" he clearly means the Chelsea, the Grand Junction, the Lambeth, the Southwark and Vauxhall, and the West Middlesex Water Works Companies, but to these I must add the East London Water Works Company, which under their Act of 1867 were authorised to draw ten million gallons a day. This is confirmed by the remarks of the official Auditor, Mr. Stoneham, on pages 264 and 265 of the 18th annual report of the Local Government Board (Appendix B) for 1888–9, from which I gather that in

consequence of an agreement made in 1886 between the Thames Conservancy and the five companies above noted, they were permitted, in consideration of contributing certain sums of money to the funds of the Conservators, to increase their draught in the following proportions, namely—

The Chelsea Company by two million gallons a day, and the Grand Junction, Lambeth, Southwark and Vauxhall, and West Middlesex Companies by four and a half million gallons a day each; the ten million gallons authorised by the East London Water Works Company's Act remaining as before. This brings the total authorised quantity up to 130 million gallons a day.

Considerable doubt exists in my mind as to the legality of this agreement between the Conservators of the Thames and certain of the Water Companies, particularly the West Middlesex and the Chelsea Companies; as I perceive from the West Middlesex Company's Act of 1866, section 8, and the Chelsea Waterworks Act of 1875, section 25, that these Companies are restricted to drawing a quantity not greater than 20 million gallons a day. It is difficult to understand how a mere agreement can set aside a statutory provision in an Act of Parliament, and it is certainly most inexpedient that the Thames Conservancy, a body charged with the custody of the purity and flow of that river, should have a direct money interest in the quantity of water abstracted from it by the Companies.*

In fact, the whole question of the authorisation to draw water from the Thames by the Companies must be fully and carefully investigated before any attempt is made to purchase their undertakings, particularly as there are strong reasons for believing that it would be most dangerous to abstract a much larger quantity than they at present draw, when we have regard to the sanitary state of the river below the intakes. That the maximum quantity which may safely be taken from the river has been reached is shown by the fact that the quantities abstracted in August, 1885, amounted on an average to 31¾ per cent. of the total flow, and on the 3rd August of that year to 37 per cent. of the total volume; and the average quantity abstracted in August, 1887, amounted to 29·65 per cent., and on the 14th of that month to 39·6 per cent.

The figures from which these per-centages were derived are all of an official character, and although they were at one time impeached during the course of the inquiry, they were

* See my evidence on this point reported in the minutes of evidence taken before the Select Committee on the Metropolis Water Supply Bill, question 4,774, page 304.

afterwards fully acknowledged by the counsel for the Thames Conservators.

The abstraction of water is referred to in the eighteenth annual report of the Local Government Board, 1888-9, Appendix B, page 228, where Major-General Scott says—"*It is shown in the table above that the maximum daily "supply which might be supplied in* 1893 *is* 128 *million "gallons, so that for a brief period* 45 *per cent. of the whole "volume of the river would be withdrawn.*"

This estimate it will be noticed is fully borne out by the facts above stated.

The subject of the large quantity of water abstracted in dry weather from the diminished stream of the Thames is of the utmost importance to the health and well-being of the metropolis as a whole, for, as pointed out in my report on London Water Supply of October, 1890, and in the joint report by Sir Benjamin Baker and myself on the subject of the "Main Drainage of London," dated 19th February, 1891, the abstraction of so large a quantity at so critical a period in the height of summer, decreases the power of the river to discharge downwards into the sea any polluting matter which may enter it in its passage through London. The tidal action does not at every tide discharge the whole quantity of polluting matter contained in the river into the estuary at the Nore, but causes it rather to oscillate backwards and forwards through the metropolis, its downward course to the sea being determined by the volume of the upland waters which pass over Teddington Weir.

If further abstraction of water is not carefully guarded against, I fear that a state of affairs may arise to the river which will be most unpleasant and disastrous to the inhabitants of London. That an attempt to take more water is likely to be made may be inferred from the speech of the counsel for the Thames Conservators, which practically sets up the theory that if every drop of water which comes down the Thames were abstracted by the water companies it would do no harm whatever to the tidal reaches of the river within the metropolis.

The quantity of water which the Southwark and Vauxhall Company are authorised to draw from the Thames, according to the evidence of Captain Burstall, is 20 million gallons a day, but we find that this quantity was exceeded (according to the returns of the water examiner) during the months extending from May to December, 1884, and during the whole of the years 1885 and 1886; and that since the agreement above noted was made in 1886, the 24½ million gallons which they now claim the right to draw has been exceeded during the months of June, July, August and

September, 1887, during June and August, 1888, during June, July, August and September, 1889, during May, June, July, August, September, October, November and December, 1890, and during January, February, March and April, 1891. The Company may say that they are not drawing from the Thames more than the authorised amount because they pump from the gravel beds adjoining the bank of the river, but this would be fallacious as such gravel beds are in direct communication with the river.

This excessive drawing of water from the Thames by the above company deserves the most careful attention, for no doubt they will base the value of their undertaking on the quantity of water which apparently they have illegally abstracted from the river, and this may become a most serious matter in the future to the ratepayers of London.

In the last session of Parliament this company applied for an Act for the purpose of raising additional capital. The evidence of their chairman, Alderman Sir Henry Knight, and of their engineer, Mr. J. W. Restler, showed that their statutory powers were more or less exhausted; that they required new filter-beds, new reservoirs, money for the purpose of re-instating their imperfect well at Streatham, and additional engine power; and that some of their mains were not sufficiently strong to withstand the constant pressure. The Council appeared as opponents to the Bill, and were informed by the Committee of the House of Commons that "quantity" and "quality" would be dealt with when the general question of London Water Supply came before them. When, however, the general question was considered, the Committee stated that unfortunately owing to want of time, they could not go into matters of "quantity" and "quality,"* and the Council was thereby precluded from going into the merits of the case. Before the Committee of the House of Lords, the Council was not even allowed a "locus standi."

Considering that before long the public must become the owners of the waterworks, and that the Council is the only body representative of the ratepayers and consumers of water, such a state of things is little short of a disgrace to our legislation, as the effect of the decision of Parliament is to place a company whose powers were practically exhausted and whose appliances were to a considerable extent worn out, in a position of considerable advantage, which will enable them, should they come before an arbitrator, to set up a case for compensation to which, but for this decision, they would be unentitled.

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*Select Committee on the Metropolis Water Supply Bill, Minutes of Evidence, page 269, column 1, line 6; column 2, line 4.

This question of the increased abstraction of water from the Thames by the various companies has long engaged the attention of Parliament, and it will be remembered that in the session of 1888 the Grand Junction Waterworks Company promoted a Bill for establishing an "intake" and pumping-engine on the river Thames, 3½ miles above Windsor-bridge, to abstract a still further quantity. The Water Examiner had pointed out that it was most dangerous to continue to draw more water at the present intake of the Company on account of the polluted nature of the subsoil caused by cess-pools in the gravel beds adjoining such intake. After a full discussion in the House on February 28th, 1888, this Bill was rejected on the second reading, the voting being—For, 104; against, 188; majority against, 84. This result clearly shows that there is a decided feeling in Parliament against the abstraction of further quantities of water from the Thames by the Companies, which is fully borne out by the remarks which fell from Sir Matthew White Ridley during the recent investigation.*

Very careful attention should be given to that portion of the report of the Duke of Richmond's Commission, which states that only 110 million gallons a day can with safety be drawn from the river. It must be remembered that when stating this the Commissioners were under the impression that the minimum flow of the Thames was greatly in excess of what it actually is.

The quantity actually abstracted by the companies averaged for 1890, 90,400,000 gallons a day, and in dry weather often exceeds 100 millions, and I must again call serious attention to the fact that the Water Companies, by being allowed to abstract from the Thames this large quantity of water without giving any compensation in kind, are permitted to do that which would not be granted to any corporation supplying water, although such corporation would not supply the water for profit but in the strict discharge of a public duty.

In my report of the 29th October last on the question of compensation water required by Parliament in the cases of Glasgow, Manchester, Liverpool, Leeds, Halifax, Ashton-under-Lyne and Bradford, I pointed out that the compensation water often amounts to 50 per cent. of the total quantity actually used for water supply, and that in some cases this is equal to as much as 9 inches of rainfall on the catchment basin, which is almost equivalent to the average rate of flow of the river Thames at Teddington Weir, viz., 9¼ inches.

I need hardly again mention the fact that had the London

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* Select Committee on the Metropolis Water Supply Bill. Minutes of Evidence, page 224, col. 2, line 6.

Water Companies been placed under this salutary obligation the cost of their works would have been much enhanced, and, consequently, their profits proportionately reduced; and that, as in the future it is not likely that Parliament will permit any further quantity to be abstracted from the Thames without suitable compensation in water being provided, this should be taken into account when valuing the works of the companies.

As to the control of the existing Companies by the Local Government Board.

In the Appendix marked B will be found a memorandum which was placed before Sir Matthew White Ridley's Committee by the leading counsel for the Companies, Mr. Pember, showing the obligations under which the Companies are placed to supply water, and the control now exercised over them by the Local Government Board.

Under head II., dealing with the control by the Board, sub-section (A), as to new sources of supply, the Local Government Board are empowered to approve or disapprove of sources not specially authorised by the Act of 1852, section 5.

A reference to the Act of 1852 referred to clearly shows that the purpose of such Act was to prevent the Companies taking water from the Thames in the polluted reaches below Teddington weir, and that the new sources of supply therein mentioned were, in fact, points on the Thames above Teddington weir, either at Seething Wells near Kingston, or Molesey and Hampton above Hampton Court weir, and the Act did not contemplate the state of affairs now existing in which the whole subject of the supply from the Thames is called into question.

As to section (B) of the same memorandum which deals with quantity and quality, it is interesting to read the remarks of the Water Examiner appointed under the Act of 1852, section V., and who was practically the executive officer of the Local Government Board in this matter.

The then Water Examiner, the late Colonel Sir Francis Bolton, in the Appendix to the Third Annual Report of the Local Government Board, 1873-1874, page 452, says—"*By "the Act of* 1871, *section* 35, *however, the Board of Trade*" (now the Local Government Board) "*may act, without any "memorial, if they know of any failure in the* QUALITY *of the "water, but similar power as to deficient* QUANTITY *is not "therein provided for.*"

And on page 455 of the same report, he continues—"*The "principal duty of the Water Examiner under the Act of "*1871 *is to ascertain whether or not the companies have com- "plied with the requirements of section* 4 *of the Act of* 1852,

" and enacts that every company shall effectually filter all " water supplied by them within the metropolis for domestic " use, before the same shall pass into the pipes for distribu- " tion."

And again, in the Seventeenth Annual Report, 1887-1888, Appendix B, page 127, Major-General Scott, the Water Examiner who succeeded Sir Francis Bolton, says:—*" Apart " from the special and temporary appointments as inspector, " referred to above, and outside the range of his statutory " duties in connection with filtration, the Water Examiner " has no official powers of inspection or inquisition as respects " the works and concerns of the water companies. By legis- " lative enactment, the companies hold the position of trading " corporations, dealing in a commodity for consumption and " general use. They have extensive powers and privileges, " but in law, no monopoly of supply. Duties in regard to the " supply are imposed on them, and they are liable to pecuniary " penalties for default in the performance thereof.*

" The Directors of the several companies are under " no statutory obligations to supply the water examiner " with particulars of their works, management, or water " supply, on which to frame his monthly or annual report, or " for any of the general purposes of that officer as distinguished " from those connected with filtration, and the scope of such " reports must in many respects be regulated and defined by " the nature and extent of the information which the Directors " consider it expedient to supply, and which again are " naturally determined in a great degree by considerations of " policy common to all commercial enterprises."

In the same report, pages 134 and 135, Major-General Scott, speaking of the river Lea, says—*" It is especially " desirable that notes should be taken of the autumn and " winter discharge* 1887-88, *because the rains to a great " extent failed during that season, and it is on the autumn and " winter rain that the supply for springs mainly depends. I " have been unable to obtain information on this subject. The " discharges at Fielde's Weir are calculated and recorded by the " River Lea Conservancy Board, but the Board deem it " inexpedient to comply with my request to be supplied with a " copy of the record for the purposes of this report.*

And even on the subject of filtration the powers of the Water Examiner appear to be very limited, for there has been a standard remark copied month by month in his reports for some time past to the following effect—*" Nevertheless, under " existing circumstances, turbid water must of necessity be " sometimes admitted, and filters are then overtaxed."*

It will thus be seen that when we read the memorandum of the Companies in conjunction with the official reports of the

Water Examiners, we are led to the conclusion that the powers of control over the Companies are far more limited than the latter would wish the public to believe.

Population of the Thames Valley.

The total population of the Thames Valley above the intakes of the companies at Hampton, Molesey and Sunbury has increased since 1851 from 762,000 to over 1,000,000 persons, or at the rate of 32⅓ per cent. in 40 years.

But this mode of stating the case does not clearly represent the actual facts, for the population is not equally distributed per square mile or per acre, but a large proportion reside in some 202 towns and villages, each with a population exceeding 1,000 persons, and which amounted in the whole—

In 1851 to	480,000	persons.
In 1861 ,,	532,000	,,
In 1871 ,,	610,000	,,
In 1881 ,,	684,000	,,
and is estimated at the present time to be	752,000	,,

From these figures it will be seen that the urban population bore a proportion to the total number of inhabitants of—

63	per cent in	1851.
65	,,	1861.
69	,,	1871.
72	,,	1881.
and say 75	,,	1891.

So that not only has the total population increased since 1851 by 32⅓ per cent., but there has been a marked increase in the proportion residing in towns and villages.

In the total 202 towns and villages of 1,000 inhabitants and upwards, we find that the population has increased from 480,000 persons to 752,000, or at the rate of 57 per cent. during the past 40 years. If now, however, we turn our attention strictly to the towns and villages situated on the banks of the Thames, and which are 29 in number, we perceive that their population has increased from 122,247 in 1851 to 202,083 in 1891, or at the rate of 65⅓ per cent.

Again, if we turn to the principal towns and villages situated on the tributaries of the Thames, and which amount to 83 in number, we observe that the population in 1851 was 189,964, and that in the present year it is estimated at 383,096 persons, showing an increase at the rate of 101½ per cent. From these figures we see that during the past 40 years the total population of the Thames Valley has increased 32⅓ per cent.; the inhabitants of the 29 towns and villages situated on its banks have increased 65⅓ per cent. of the

population, and those of the 83 towns and villages situated on the tributaries have increased at the rate of 101½ per cent.

But if we look at some of the individual towns on the Thames we find that

Staines has increased	...	...	106	per cent.
Egham	,,	...	...	125	,,
Reading	,,	...	...	128	,,
Caversham	,,	...	...	139	,,
Clewer	,,	...	...	152	,,
Weybridge	,,	...	...	196	,,

during the past 40 years.

The bearing of these facts on the question of London water supply is of paramount importance, as it will be observed that the population is concentrating itself into towns and villages, which are increasing with great rapidity; and that these towns and villages are principally situated either on the Thames itself, or upon its tributaries. Consequently, they must all inevitably drain directly into the streams and river from which the inhabitants of the metropolis receive their drinking water.

As before noted, besides this human population, there is a total animal population in the district referred to exceeding 1,600,000.

Flow of the River Thames and possible future increase of the supply by means of storage reservoirs.

It will have been noted that the Royal Commissioners of 1869, in paragraph 141 above quoted, conclude with the words "*and consequently that by means of proper works for storage "this quantity might be doubled if required.*"

I have already mentioned that in dry weather for days at a time the companies draw over 100 million gallons daily, representing some 30 to 40 per cent. of the total flow of the river at Teddington Weir.

It is hardly likely that Parliament will long permit this state of affairs to continue, and if the suggestion of the Royal Commissioners of 1869 is to be carried out, the construction at some point in the valley of the Thames, above the present intakes, of reservoirs for the storage of flood water must be undertaken. In other words, some attempt would have to be made to store up flood water against periods of extreme drought, either to afford an increased supply to London, or to provide proper compensation for the quantity abstracted from the river.

I must here draw your attention to the nature of this flood water. It is always highly polluted, discoloured, and often obnoxious to sight, to taste, and to smell. And the question arises how far it would be safe to store for future use this highly-polluted water; for whatever may be said with regard

to the purifying action of the flowing river on organic impurity that may be passed into it, the question is quite different when it is proposed to store up for many months in large reservoirs the most polluted water which comes down the stream.

Considering how thickly inhabited the Thames valley is, and how the present water companies have found it impossible to use flood water for domestic purposes, this proposal to store it up in large reservoirs hardly commends itself to my judgment as a wise or prudent step.

Messrs. W. Whitaker, B.A., F.R.S., and A. H. Green, M.A., F.R.S., in their joint report recently presented to you on the geology of the Thames basin, and the possibility of constructing therein reservoirs for the storage of water, have pointed out that the large areas occupied by the chalk and oolite formations do not lend themselves to the construction of storage reservoirs, as it would be almost impossible to make such reservoirs trustworthy and watertight, and in the upper part of the valley above Oxford, where the river flows over a clay formation, they have noted that the configuration of the ground is such that were an attempt made to form reservoirs, they would have to be of large extent, probably some thousands of acres, and of but slight depth, and that consequently, as the water was drawn down in the summer months, huge swamps would be formed, which undoubtedly would be the cause of complaint if not of actual danger to the surrounding population.

On page 6 they say—"*There seems then to be but little "prospect of constructing reservoirs for the impounding of "flood water in any part of the Thames valley.*" And again in conclusion, on page 20, they say—"*The valleys of the "Thames and its tributaries are not fitted for the construction "of storage reservoirs, there being no good sites for the forma- "tion of dams across them.*"

On this subject Sir Robert Rawlinson, K.C.B., who is by no means an authority to be overlooked in considering this subject, states in his evidence before the Committee for County Purposes of the Court of Common Council, on the question of water supply, 1890, page 208—"*If there are lakes, the water "from these may be taken; or artificial reservoirs may be "made in the valleys; but there are no such means available "in the valley of the Thames, the storage of water being in the "lime strata of the oolites and chalk; and to be brought into "use must be intercepted or be pumped from deep wells and "headings.*"

I have myself known the Thames valley for the greater part of my life. I have also for many years been engaged in the construction of large storage reservoirs, and I can safely say that I know of no sites in the valley suitable for storing water for the domestic supply to the metropolis, and I ask

you to note that up to the present time no engineer who has had any considerable practice in the construction of large impounding reservoirs, such as these now under consideration would have to be, has ever given his opinion in favour of such a scheme.

I therefore fear that the Council must not hope to find in the construction of storage reservoirs a solution of this most difficult question. It will be noted that the suggestion of the Royal Commissioners of 1869 is a general one; they received no evidence as to the sites of proposed reservoirs, nor to the cost entailed in their construction, nor to the mode in which the water would be brought into the metropolis were such reservoirs constructed.

Although the water companies who now supply London have been often at great straits to increase their supplies, and have had the advantage of the advice of competent and talented engineers, I am unaware that any of them have at any time suggested definite storage works in the Thames valley.

One fact, however, should be kept in mind, that were such storage works possible or expedient, they could not be constructed at such an altitude as to deliver a supply of water by gravitation in the metropolis, so that in the future as in the past pumping would have to be resorted to, with its continued annual cost of over £127,000, in addition to the enormous initial expenditure which storage works would inevitably render necessary.

Chalk and other Spring Water in the Thames Valley.

As suggested by Sir Robert Rawlinson in the passage above quoted, the water if brought in from this source must be intercepted or pumped from deep wells and headings. But the Royal Commissioners of 1869, in paragraphs 146 and 147 of their report, say—"*We do not agree with those who expect to "get an almost unlimited increase of quantity of water by "simply tapping the natural reservoirs in the chalk, for the "supply to them must obviously be limited by the amount of "rainfall. Moreover, as the water which penetrates into the "reservoirs, raising the water line more or less above the level "of the adjoining valleys, ultimately in greater part finds its "way by springs into streams at the lower level of the district, "any water drawn from the store by artificial means will most "probably be at the expense of those streams. If this be true "it follows that any water obtained by tapping the chalk "reservoirs that feed either the river Lea or Thames above "Hampton would only* pro tanto *diminish these streams, and "would therefore be little or nothing gained to the general "supply.*"

We have seen that at present in dry weather the companies draw over 100 million gallons a day, or say 40 per cent of the total volume of the Thames, at Teddington. Were this quantity or any similar amount drawn from wells in the upper valley of the Thames above Reading or Oxford, (and in the future we certainly shall require a larger amount if the consumption is to increase at the rate of 154 per cent in the next 40 years as in the past) it would not mean that 40 per cent only was taken out of the stream. On the contrary, the volume of water in the river would be enormously decreased, and as its flow above those points is, owing to its smaller drainage area, comparatively small, there would probably be taken from the upper valley a supply more than equal to the total average summer flow of the river.

Were this done, two things would have to be provided for—one, the construction of suitable storage reservoirs to compensate the river *below* the point at which the water was abstracted: and the other, securing that the abstraction of the water from the wells did not injure the general water supply of the district lying at *higher* levels than the places from whence it was drawn.

The practicability and the prudence of constructing storage reservoirs in the Thames valley I have dealt with above, but I must point out that there are already grave complaints to the effect that the pumping now going on in the valley of the Lea is affecting not only the springs and rivers, but also the general character of the water supply to the county of Hertford. We know also that powerful combinations of mill owners and residents on the banks of the Mole, the Wandle, and the Colne, are fully organized to prevent the abstraction of further quantities of water from those rivers, and like combinations would undoubtedly result on any serious attempt to abstract from the valley of the upper Thames the spring and other subterranean waters which now feed the tributaries of that river.

One of the difficulties sure to arise would be that claims for compensation in kind would be made, which it would be impossible to meet. On the chalk and oolite formations, out of which we are supposing the water to be abstracted, it is impossible to construct reservoirs, and as the abstraction of so large a volume of water by means of headings and wells, as suggested by Sir Robert Rawlinson, would have the effect of lowering the line of saturation in the district generally, it would be necessary to provide for the cases arising from the drying up of the springs, wells, and streams which at present flow down to the river, but which would be intercepted by this mode of abstracting the water.

Looking nearer to London than the upper valley, I find

that the Intra and Extra Metropolitan areas are, according to the Report of the Water Examiner for May, 1891, supplied with water to the extent of 179,908,849 gallons a day, of which only 25,383,525 gallons or 14·11 per cent. are drawn from springs and wells, which is but a small proportion of the total quantity supplied. London is also surrounded by small companies or corporate bodies, who at present derive their water supplies from the chalk, greensand, &c., such as—South-West Suburban, Alperton and Sudbury, Colne Valley, Watford, Barnet, St. Albans, Hertford, Tottenham, Herts and Essex, South Essex, Richmond, Leatherhead, Dorking, Epsom, Sutton, Reigate, East Surrey, Limpsfield and Oxted, Westerham, Sevenoaks, Gravesend and Milton, and we can hardly expect that these various companies and corporate bodies would stand passively on one side, were it proposed to take from their several districts the large volume of water which would be required in the future for the supply of London.

The Kent Company, which at present supplies a portion of the County of London and a considerable area outside, draws its supply entirely from chalk wells, and it has increased its supply from this source from about 3½ million gallons daily in 1858, to nearly 12½ million gallons daily in 1890, or by more than 260 per cent.

Such an extensive draught on this district cannot long be continued, and complaints are made that certain of the streams in the area of the Kent Company, which formerly broke out at higher levels, now flow at a considerably less altitude. From the Upper Lea Valleys similar complaints are heard, owing to the excessive pumping from the wells of the New River and East London Companies.

This is an indication that the general line of saturation in the chalk is being lowered, and it would therefore hardly be prudent to calculate upon obtaining any very large increase from this source, such as would be contemplated were it proposed to abandon the open rivers Thames and Lea as a means of supply.

Undoubtedly the quality of the water derived from these wells is the best which is supplied to London, but it is very hard, being about 22 degrees on Clarke's scale. It should, however, be borne in mind that as the districts in which the wells are situated become more thickly populated (and some of the Kent Company's wells are situated in already populous districts) the possibility of contamination reaching even the deep-seated wells from which the chalk water is drawn must be anticipated.

On pages 105 and 106 of the Sixth Report of the Royal Commissioners on the Pollution of Rivers (Domestic Water Supply

of Great Britain) is given a list of 25 deep wells which were found to be polluted. Among those in the chalk there is that at Carisbrook Castle, Isle of Wight, 240 feet deep; that of the Kent Water Works Company at Charlton; a well at the railway station at Gravesend 70 feet deep; a well at Great Bookham, Surrey, 101 feet deep; a well at Harwich 380 feet deep; and a well at Colchester 400 feet deep.

These facts are a warning that too much reliance must not be placed on the good quality of the water from these deep chalk wells remaining of a permanent character, should the districts in which they are situated become thickly populated.

In the 12th Annual Report of the Local Government Board, 1882–1883, will be found a table prepared by Dr. Frankland showing that the well waters of the Kent Company already give indications that occasionally their good quality is to a slight extent invaded by contaminating matter.

Supplies to be obtained from the gravel beds of the Thames Valley.

It has been suggested that a large amount of water could be obtained by pumping from the gravel beds which extend over the Thames valley at points between Slough and Windsor and the present intakes of the Companies.

It is alleged that these gravel beds are supplied from the chalk formation which is said to outcrop beneath them, and that the water so derived does not join the Thames until it reaches some point below Teddington weir; and, consequently, that a large volume could be abstracted for the supply to London without in any way interfering with the natural flow of the river.

The whole subject of this proposed supply was discussed during March, 1891, before the Institution of Civil Engineers on a paper read by Mr. John Thornhill Harrison, M. Inst., C.E. The result of that discussion was not very favourable to this mode of obtaining a supply of water.

As I before noted, and as pointed out by the Royal Commissioners of 1869, any water abstracted from the springs which feed the Thames is *pro tanto* abstracted from the river itself, and it is clear that should the water level in the gravel beds be pumped to a lower level than that in the adjacent river, it would not only be intercepting water which would otherwise flow into the stream, but be actually abstracting direct from the river a considerable quantity of the water flowing in it.

To my mind, however, it is not clearly proved that the water exists in the quantities estimated by Mr. Harrison, and I also fear that it has not been proved on a sufficiently

solid basis that the water breaks out in the bed of the Thames in sufficient volumes to warrant us in expecting to obtain a supply adequate for our wants from this source.

When I come to speak of the pollution of the subsoil of the Thames Valley at present existing, and which may be expected generally to increase, it will be seen that, under any circumstances, even supposing the water to be available, it could only be obtained at a certain amount of risk. This would be especially the case in dry weather, as then doubtless a large amount of drainage and cesspool water flows into these gravel beds.

LEA VALLEY.

Drainage Area.—Above the intake of the East London Waterworks Company the area draining to the river Lea may be said to comprise about 497 square miles, or 318,000 acres, embracing parts of the counties of Hertfordshire, Bedfordshire, Middlesex and Essex.

Geology.—From the point of its junction with the Thames near Blackwall to the source of the New River Company's intake below Hertford, the river flows over the London clay formation with certain associated post-tertiary beds. Above that point to Dunstable, Luton, Stevenage, Buntingford, and above Bishop Stortford, the flow is from the chalk formation.

Rainfall.—East of a line drawn roughly from Tottenham northwards by Ware to Barkway in Hertfordshire, the rainfall may be said to be about 24 inches, while westward of the same line it may be said to average 25 to 26 inches.

River Flow.—In this case, for reasons presently to be described, it is almost impossible to estimate what the actual flow of the river would be, so that I am not in a position to state what proportion the quantity abstracted by the water companies bears to the total flow of the stream.

In the Eighteenth Annual Report of the Local Government Board, 1888-1889, Appendix B, the Water Examiner reports that "*each summer the whole of the volume of the Lea is "practically used up by the New River and East London "Companies for the supply of their districts, and in addition, "they derive about* 15 *million gallons daily from wells, and "the East London Company* 10 *million gallons from the "Thames.*"

This fully bears out the opinion and evidence of the late Mr. Greaves, Engineer of the East London Waterworks Company, which I quoted on pages 5 and 6 of my report of the 8th October last.

Population.—The total population of the Lea Valley in 1851 was 131,535. It was estimated to have increased to 172,721 in the present year, showing a growth equal to 31⅓ per cent. in the 40 years up to date.

But of this total population it appears that 94,618 persons resided in 33 towns and villages exceeding 1,000 in population in the year 1851, and it is estimated that the population of these 33 towns and villages has increased to 139,770, or by 47·7 per cent. in the year 1891.

Of these towns 13 are situated on the main stream of the Lea, and seven of the more principal ones on its tributaries.

Besides this human population, I find from the report of the Board of Agriculture for 1890 that there are in the Lea Valley above the intake of the East London Company—

11,810 horses,
27,410 cattle,
111,217 sheep, and
28,122 pigs,

making a total animal population of 178,559.

As to quantity of water abstracted from the Lea by the New River and East London Waterworks Companies.

These Companies claim the right to draw an unlimited quantity of water from this river.

In 1858 they abstracted 40⅓ million gallons a day, and in 1890, about 72,800,000 gallons daily. Of this latter quantity probably 13¼ million gallons is drawn from deep seated springs by means of wells and pumping.

Considerable obscurity surrounds the legal powers of these companies to take water from the river; and, like their sister companies on the Thames, they have entered into certain agreements with the Conservators of the River Lea. Whether these agreements are strictly lawful or not, I will not attempt to question, but from what I have been able to gather from the various Acts of Parliament governing the matter, I have formed the opinion that the whole subject requires the most careful and detailed inquiry before the public are in any way committed to the purchase of the undertakings of these two companies.

The Royal Commissioners of 1869 made a very full and careful inquiry into the possibility of obtaining further supplies from the Lea, and they sum up their conclusions in the 144th paragraph of their report in the following words—

"*We believe that we ought not to calculate on any material "increase from this source, and that we may consider the "quantity which the Lea can contribute to the supply to "London is not more than* 50 *millions of gallons daily.*"

We now find that the two Companies are drawing from the Lea nearly 73 million gallons a day, and that they cannot obtain the full quantity they require from this source is proved by the fact that the East London Company has

established works on the Thames at Sunbury, from which river it is authorised to abstract 10 million gallons a day, and actually does abstract a large quantity.

One mode in which the companies upon the river Lea have increased their supply is by sinking deep wells in the chalk, from which they pump water which they cannot otherwise obtain from the river itself. Undoubtedly the source from whence this chalk water is derived is that portion of the valley in the county of Hertfordshire above the intake of the New River Company.

In the 18th Annual Report of the Local Government Board, 1888–1889, Appendix B, the Water Examiner remarks, "*Assuming that a sufficient supply can be drawn from under-ground sources, it is doubtful whether there will not result a depletion of the springs which feed the Lea, and a corresponding reduction of the volume of discharge of that stream.*"

This statement of the Water Examiner is fully borne out by the evidence collected by the Hertfordshire County Council, and which would have been laid before the Committee recently presided over by Sir Matthew White Ridley had time permitted the Committee to go into the questions of quantity and quality.

It is sufficient here, however, to note that almost all the authorities in the upper valley of the Lea have declared their intention, should the works of these Companies be handed over to a public body, to ask that some restriction should be placed upon the amount of water drawn from this source. I fully share the opinions of these bodies. I consider that the Companies should never have been permitted to exceed the 50 million gallons per diem mentioned by the Duke of Richmond's Commission in 1869, and I am also of opinion that no public body should be compelled to purchase these two Companies on the basis of the unlimited supply which they claim to derive from the river Lea.

Pollution.—As to the pollution of this river I can but refer to the evidence under the heading of "Thames and Lea Valleys—Pollution," and to state my perfect concurrence in the opinion arrived at by the Royal Commission on Domestic Water Supply, 1874. Page 429, paragraph 4 of the report of the Commission states:—"*We therefore recommend that the Lea should also be abandoned as a source of potable water. This measure is less urgent than the relinquishment of Thames water, but the sanction of your Majesty's Government ought not, in our opinion, to be accorded to any further expenditure of capital upon the supply of Lea water to the Metropolis.*"

Owing to the continued abstraction of almost the whole volume of the Lea, the lower reaches of the river are, as is

well known, in summer reduced to a disgusting state of impurity.

Possibility of constructing reservoirs in the valley of the Lea.

As the upper part of the valley of the Lea and its tributaries above Hertford is entirely composed of chalk I feel certain from my experience in the construction of storage reservoirs that they would be impossible in such a situation. Nor do I find that they have ever been proposed by any engineer sufficiently acquainted with the subject to speak with authority.

I need not therefore trouble you with any further observations on this matter.

Thames and Lea Valleys—Pollution.

It is inevitable that a population, as noted above, of about 1,200,000 human beings, and over 1,800,000 animals, must pour into the Thames and Lea a large amount of more or less clarified sewage, although the analysis of London water after filtration shows but a small trace of this pollution, and although the death rate of the metropolis does not show, apparently, any large mortality due to this cause. This however only emphasises the well known fact that a large population can for a time with impunity drink the sewage, more or less diluted, of healthy persons and animals. The really important question is—What would be the effect on the health of the metropolis were the clarified sewage, which is continuously poured into both rivers, to flow from districts where epidemics prevail? This question cannot at present be authoritatively answered, as chemical analysis is powerless to detect the presence of the germs of such diseases in water.

It should be borne in mind that under the pressure of public opinion and through the agency of the Thames and Lea Conservancy Boards, efforts have been made to cause many of the towns to clarify their sewage before passing it into the river.

But this clarification, even when carried out in the most perfect manner, abstracts from the sewage only the more solid particles of organic matter in suspension, which amounts to about $\frac{1}{5}$th to $\frac{1}{6}$th of the total. Consequently there passes into these rivers, in a state of solution, from $\frac{4}{5}$ths to $\frac{5}{6}$ths of the dissolved organic matter, in fact the great bulk of it, and exactly that portion of it which would in the case of epidemic disease probably prove the most dangerous to human life.

It is well to note here that the powers of the Thames Conservancy Board to compel persons and public bodies to clarify their sewage does not extend over the whole area

drained by the Thames, in fact, it only covers the Thames itself as far as Cricklade, and its tributary streams a distance of 10 miles up from the river.

It must be remembered that the Thames Conservancy receive annually from the various Water Companies the sum of about £18,000 for performing the duties above spoken of, and there can be little doubt that a large proportion of this amount has been expended by the Conservators in improving the navigation of the upper river and increasing the traffic on it. Year by year the river Thames is becoming more and more what may be called the "aquatic playground" of the metropolis. This means the increase of all kinds of craft among which "house-boats" form no insignificant feature; and although strict rules are made by the Conservators to prevent the fouling of the river, yet from my observation I fear that such rules are honoured more in the breach than in the observance.

I can hardly, in any circumstances, consider a navigable river a satisfactory source of water supply, but the special conditions affecting both the Thames and the Lea are such as to render both rivers objectionable as the source of supply for the largest and richest city in the world.

Additional sewage contamination takes place where systems of sewage irrigation are adopted, which merely have the effect of depositing the solid matters in the sewage on the areas of the sewage farms. The solid matter is inevitably washed into the streams in times of heavy rainfall, besides which, the fluid part of the sewage tends to pollute the subsoil through which it passes. And this is fully acknowledged by the Water Companies which supply London, for it is found impossible (so foul and discoloured is the stream during periods of rainfall) to supply flood water for consumption in the metropolis.

In the Nineteenth Annual Report of the Local Government Board Appendix, B, page 233, for 1889-90, this is noted, and the Water Examiner remarks :—"*A marked feature of the river "supplies is the very large increase of impurities, both "suspended and in solution, which results when the rivers are "in flood.*"

And again, lower down the same page, he says :—"*Seeing "that in the valleys of the Thames and Lea there are towns, "villages, and detached houses, the drainage from which "reaches the water courses in a foul or more or less imper- "fectly purified condition, and that manure is largely used in "the fields, it is manifest that the rivers must carry away "impurities of animal in addition to those of vegetable origin. "This being the case, there exists always the possibility of the "introduction of specific matter of a noxious character, and*

"hence the necessity for ceaseless effort in the interests of "sanitation within the areas referred to."

It is not only by *directly* polluting the streams that danger is to be apprehended, for besides this direct pollution of the river there is another source of danger which is rapidly on the increase. Towns and villages in the Thames Valley, anxious to avoid the expense of systems of main drainage, with all the attendant trouble and anxiety attached to the purification of the effluent water, are resorting to a system of house drains and cesspools not connected with any system of drainage. Where this is done the sewage finds its way into a subsoil often composed entirely of gravel. This has received the attention of the Water Examiner, who in his report for May, 1887, makes the following remarks:—*"The "construction of houses and cesspools has recently been "commenced on land immediately adjoining and nearly "surrounded by that owned by the Grand Junction Water "Works Company, and in which conduits have been placed for "the purpose of collecting subsoil water and conveying it to "the engine wells to be mingled with the general supply. But "the extension of cesspool drainage in any shape or form into "this locality must have the effect of rendering the water "derived from the gravel beds in the river valley above the "premises of the water companies unsafe, and must necessarily "ruin the source of supply which is now being utilized "generally by the Grand Junction Company, but to some "extent also by the Southwark and Vauxhall Waterworks "Company."*

In the 18th Annual Report of the Local Government Board for 1888—1889, Appendix B, are the following remarks:—*"It must, however, be borne in mind that this, like all shallow "sources of water in porous subsoils is liable to become fouled by "the spreading of pollution over the surface, and it is only while "the integrity of the ground in respect of pollution is assured "that resort can be had with confidence to this means of supple- "menting the water supply."*

In a report to the Local Government Board on the sanitary condition, &c., of the Staines Rural Sanitary Authority's area, dated the 21st March, 1891, after stating that cesspools are generally sunk in the district under examination, Dr. Blaxall goes on to say:—*"The general "filthiness of the soil and water in the Staines Rural Sanitary "District is probably a matter of more than local concern. "Besides the rain that falls on the district large volumes of "water course through the river gravel which forms the subsoil, "and into this gravel is washed the contents of several thousand "cesspools purposely dug in the gravel for convenience of dis- "charge thereinto.*

"*The water thus befouled goes directly or indirectly into the "Thames. Entering the Thames at various parts of the ten "miles where the district abuts on the river the principal and "most direct flow of water through the gravel bed of this district "would seem to be from west to east, and its discharge to be "mainly into the lower portion of the boundary of the river in "the neighbourhood of Sunbury.*

"*At a short distance below this neighbourhood, on the "southern bank of the river, are situated the pumping stations "of certain great London water companies.*"

It is not however merely by sewage discharge and cesspools that the river, and the subsoil draining into it, receive pollution. Not only is there in the case of the Thames valley a large population,—the great bulk of it, as we have seen, resident in towns and villages on the immediate banks of the river and its tributaries,—but as in the course of nature this population dies and is buried, the decaying bodies add another source of possible pollution to the district.

If we assume that the total population above the intakes in the Thames and Lea valleys is 1,200,000, and the death rate is 15 or 16 per 1,000 per annum, there must be annually from 18,000 to 19,000 corpses buried within the watershed. It has been seen that the great bulk of the population is massed along the river banks, and it follows that these bodies will mainly be deposited in graveyards adjacent to the river.

There must always be a large number of bodies in process of decomposition. The time required for the completion of this varies under different circumstances, such as mode of burial, nature of subsoil, &c.; but from investigations which I had to carry out a few years ago, I am led to believe that a period of about ten years must elapse before bodies are thoroughly decayed.

Should this be the case in the Thames and Lea Valleys, it must be the fact that there is always going on the decomposition, putrefaction and decay of about 180,000 to 190,000 dead human bodies.

Not only do the fluid products of decomposition pass into the subsoil, but there can be little doubt that they pass more or less directly into the river and its tributaries, as the graveyards cannot be far distant from the towns upon their banks. But the evil may not quite stop here, for in the case of certain diseases such as anthrax or splenetic fever, as Pasteur has shown, the germs of the disease may re-appear on the surface of the ground long after the burial and decay of the bodies.

Besides this large number of dead bodies proper to the valleys of the Thames and Lea above the intakes, there is also a con-

siderable number brought from the metropolis and buried in the Woking cemetery within the drainage area and above the intakes of the water companies.

Were any epidemic, such as typhoid, cholera, or the like, to break out in the Thames and Lea Valleys, pollution of an exceedingly dangerous character might result from clarified sewage discharge into the streams; by contamination of the subsoil due to cesspools; or by the infiltration from the bodies of dead persons into the streams, and this latter source of danger might last for a considerable period after the more violent epidemic had passed away.

It is often stated that the water of a flowing river, which has become polluted by sewage, has the power of self-purification, and no doubt in a certain limited sense this may be the case; but quite apart from any such theory in regard to the flow of the Thames through its thickly populated valley, it would be very interesting to know if the river does or does not increase in impurity as it flows downwards.

The answer to this inquiry is given in a paper recently read before the International Congress on Hygiene and Demography, by Dr. Percy Frankland, F.R.S. :—"On the present state of our knowledge concerning the self-purification of rivers."

To avoid complications as to the suspended organic matter, Dr. Frankland had caused all his specimens of water to be taken on the same day, from twenty-five points in the Thames between Oxford and Hampton. These samples were filtered through filter paper, so that the results expressed in parts per 100,000, show only the dissolved organic matter.

Notwithstanding the large increase in the volume of the river due to the tributary streams, the Cherwell, Kennet, Colne, Wey, &c., Dr. Frankland's analyses show as between Oxford and Hampton the following increases in amount of impurity in the river—

Organic Carbon from	...	0·136 to 0·451
,, Nitrogen from	...	0·039 ,, 0·082
Ammonia from ...	...	0·000 ,, 0·024
Nitrates and Nitrites from	...	0·178 ,, 0·222
Combined Nitrogen from	...	0·217 ,, 0·324
Chlorine from ...	...	1·060 ,, 1·700

These figures show a total percentage of impurity of 1·630 at Oxford and 2·803 at Hampton, being an increase of 1·173, or say 72 per cent. The only substance which had apparently decreased was the harmless salts of lime. This decrease is shown by the total hardness which had fallen from 21·80 to 18·9, and is practically due to the greater dilution of the water owing to increased flow from the tributaries.

Alluding to his table of analyses above quoted, and speaking of the theory of self-purification of rivers, Dr. Percy Frankland says:—"*It will be seen that the idea of any striking destruction of organic matter during the river's flow receives no sort of support from my experiments, the evidence is in fact wholly opposed to any such supposition.*"

And speaking also of a similar set of experiments on the flow of the Ure and Ouse, above York, he says:—"*There is not the slightest support to the theory of self-purification.*"

But be the theory correct or not, there is clear evidence in Dr. Percy Frankland's experiments that the river Thames becomes more polluted as it flows downwards from Oxford to the points of the Companies' intakes at Sunbury, Molesey and Hampton.

Under Mr. Shirley Murphy, the Medical Officer of the Council, exhaustive and searching inquiries into the existing sources of pollution of the Thames and Lea are being made by Drs. Ashby, Fosbroke, and Turner, the Medical Officers for Reading, Worcestershire, and Hertfordshire respectively. These reports will be analyzed, and placed before you by Mr. Murphy, but I may state for your information that they show evidence of pollution from water-closets, privies, crude sewage, flow from sewage farms, manure, house-boats, manufacturing refuse, slaughter-houses, and the like.

I have prepared for the Medical Officer's report the attached plan (No. 2) of the Thames and Lea basins, which shows by black dots the various points at which contamination has been detected. As might be expected from the density of the population, sources of contamination exist over the whole area drained by the Thames and Lea above the intakes of the companies, and particularly so on the banks of those rivers and their tributaries.

Instances of Pollution of Water Supplies.

The question now arises, are there any cases in which it has been clearly proved that disease has resulted from drinking water becoming infected from any of the above causes?

The following facts are on record—

Lausen, Valley of the Ergolz, Switzerland.

This village contained in 1872 about 819 inhabitants, and was considered remarkably healthy. With the exception of six houses, it was supplied with water from a spring which rises above the village at the foot of an oolitic mountain called the Stockhalder. On 7th August, 1872, ten of the inhabitants were seized with typhoid fever, and during the next nine days 57 other cases occurred, the only houses escaping being six which were not supplied by the water

from the spring. The disease continued to spread, and in all 130 persons were attacked.

A careful investigation was made into this outbreak, and it was discovered that on the other side of the mountain there was situated a village called Furlenthal containing six farm-houses, and traversed by a stream, the Furlenbach. Now there was reason to suppose that water from the Furlenbach found its way under the Stockhalder into the heads of the fountains supplying Lausen. It was noticed that when the meadows on one side of the Furlenbach were irrigated, the flow of water from the Lausen spring was increased, and eventually it was proved beyond the possibility of a doubt that water passed from the Furlenbach to feed the Lausen spring.

On the previous 10th June one of the peasants at Furlenthal had fallen ill with typhoid fever. On 10th July a girl in the same house was taken ill, and a boy was also attacked in August. In the middle of July the meadows at Furlenthal were irrigated, for the second hay crop, with water containing the excreta of the above patients, and within three weeks this was followed by the outbreak at Lausen.

From the care with which it was worked out the whole of this investigation is well worthy of the most careful attention. I am indebted for the above facts to the *British Medical Journal* of the 13th March, 1880.

Nagpoor, India.

It has fallen within my own experience to note several severe outbreaks of cholera from contaminated water, and the almost entire cessation when the cause of the disease was abolished.

The city of Nagpoor, the capital of the Central Provinces of India, contained a population of about 84,000 persons, and previous to 1872 was supplied with water from an open tank or reservoir, the water in which was derived and collected during the monsoon from a more or less populous drainage area.

Previous to 1872, cholera may be said to have never been absent from the city of Nagpoor, and it became so bad that the construction of works for bringing water from an entirely new source was decided upon, and upon these works I was engaged. The new source was an uncontaminated drainage area in the immediate neighbourhood of the town; the only village in the gathering ground having been bought up and its inhabitants removed so as to prevent any possible source of contamination to the new supply.

The effect of substituting pure drinking water for the previously contaminated supply is given in an official publication dated 3rd November, 1882.

In the seven years *previous* to 1872, and to the introduction

of the new supply, the deaths from cholera in the city of Nagpoor amounted to 1,264.

In the seven years *after* the introduction of the new supply the deaths from cholera fell to 177, and some of these were no doubt imported cases from the surrounding districts.

Nor was this decline in the city due to the general disappearance of the disease from the surrounding districts, for we find that in the district outside the city, in which there was a population of about 500,000, the deaths from cholera in the seven years before the introduction of the new supply amounted to 4,369, and in the seven years after its introduction to 6,428. So that notwithstanding the fact that the epidemic was more rife in the surrounding districts, the effect of introducing a pure water supply was effectual in checking the disease in the city itself.

It should be remarked that this case was in no way complicated by questions of drainage, as in neither the period before nor after the new supply was introduced, did any system of drainage exist in the city.

Towns and Cities in Spain.

The cholera outbreak in Spain in 1885 forcibly illustrates the way in which river water is the carrier of disease and death, and how the spread of epidemics can be prevented by a pure water supply.

Granada—Situated on and deriving its water supply from the rivers Genil and Darro, this city had in 1885 a population of 76,000, and only one-tenth of the city was drained.

Cholera attacked the city from July to September, and as many as 450 cases a day occurred. There was a total of 6,471 cases and 5,093 deaths during the period named. The cholera passed down the valleys of the Genil and Darro, spreading disease and death wherever their waters were used for drinking.

Murcia, situated on the river Segura, from which it derived its water supply, suffered badly. The first outbreak occurred at the baths of Archena, situated about 25 miles further up the river which carried the disease to the town.

From *Alicante* the disease was carried to *Jativa* on one of the tributaries of the Jucar, down which valley it flowed with the water, attacking the various towns and villages, until it reached the town of *Alcira*, which suffered badly.

Valencia, on the river Turia, from which it derives its water supply at a point three miles above the city. The water is filtered and stored in covered reservoirs. The town is well drained, and out of a population of 143,861 in 1885, there were 4,234 cases of cholera between May and September, and the disease was brought by the river.

Saragossa, on the Ebro, from which its water supply was derived, had a population of 84,500 persons, and the town was not drained. There were 10,000 cases of cholera in this city, but the spread of the disease was checked by the authorities stopping the supply of river water, as before the outbreak they had ample notice of the prevalence of cholera in the towns and villages higher up the river Ebro.

Turning now to towns in the cholera districts, but which had good water supplies, we have the following instructive facts—

Madrid, with a population of about 400,000, suffered severely in the cholera outbreak of 1865; the cases running up to as many as 800 to 1,200 per day; but in the outbreak of cholera in 1885 the total number of cases that occurred from May to September was only 2,207 with 1,366 deaths, or less than those which happened in three days in 1865.

After 1865, the new water supply from Lozoya, 50 miles distant in the Guadarama Mountains, had been introduced, and this and a pure spring called La Fuente de la Reina were the sources of supply in 1885, some twelve older and suspicious sources having been closed by the authorities, and the Lozoya and De la Reina waters put under Government guards to prevent contamination. It should be noticed that a good system of drainage exists in Madrid.

Toledo, having a population of 20,000, was supplied by pumping from the Tagus, which flows round the city. This city is quite undrained, and higher up the Tagus or its tributaries are situated Madrid and Aranjuez, where the cholera was very bad in 1885. The Governor seeing the very suspicious nature of the water, stopped the pumps and compelled the inhabitants to resort to certain springs for their supply. This very strong measure was rewarded by keeping the total number of cases down to 200, and the deaths to only 100.

Seville, with a population of 135,000, is situated on the Gaudalquiver, and it has no drainage. The city is mainly supplied with good water from a place nine miles east of the town by an old Moorish aqueduct. Notwithstanding its dirty and undrained state, it almost entirely escaped the cholera epidemic, though the disease raged in the surrounding country and in the towns further up the river.

Jerez, which lies between Seville and Cadiz, also escaped, as it had an excellent water supply brought from a spring in the mountains, at a cost of £300,000.

Malaga, with a population of 115,882, was very dirty and undrained, and in a worse sanitary condition than Seville. But a new water supply had recently been introduced from some springs at Torremolinos, and the town was consequently almost free of cholera.

From these facts we see that when cholera breaks out on the banks of a river, it passes rapidly down the stream attacking the persons who use its waters for drinking; that towns such as Toledo, Seville and Malaga, with absolutely no drainage and situated in the middle of an infected district, almost entirely escaped the epidemic, because their water supply was pure and not drawn from a river; and that although towns had good drainage and filtered water, as Valencia, yet, as their water supply was derived from a river flowing through an infected district, such towns suffered seriously.

It is surprising to find that although Spain is considered rather a backward country as regards sanitary science, yet the authorities were fully alive to the danger of water supplies derived from rivers flowing through populous valleys.

The above facts are derived from the "British Medical Journal, 1886"; from a contribution to "Nature" of June, 1886; and from the reports of Mr. Geo. Higgin, M.Inst., C.E., an engineer of great experience in the construction of large works in Spain, who sums up his observations as follows—"*To "insure immunity from contamination the only real and "practical method appears to be that of capturing the water "at a pure source and conducting and delivering it in such a "way as to render it impossible that any specific germ or "poison should have obtained access to it. In the matter of "cholera, for instance, with the experience of Valencia and "Saragossa before us, one cannot feel any confidence in water "which is taken from a river liable to so many sources of "contamination as is the Thames, and it is at least doubtful "whether any system of filtration would be capable of "eliminating cholera-poison from such waters. It is ex-"tremely probable that simple filtration through sand will "not do it.*"

England and Wales.

Turning now to cases within the United Kingdom, some valuable information is contained in authentic official documents.

In the Report of Dr. Greenhow to the General Board of Health, 1858, at page 60, speaking of diarrhœa, he says:—"*In the districts which suffer the high diarrhœa death-rates, "the population either breathes or drinks a large amount of "putrefied animal refuse.*"

And at page 64 he again remarks:—"*The excess of "mortality has in all places been co-incident with one or "other of two definite local circumstances: (a) the tainting "of the atmosphere with the products of organic decomposition*

" *especially of human excrement, or (b) the habitual drinking* " *of impure water.*"

In the Second Report of the Medical Officer of the Privy Council for 1859, on page 61, he remarks :—" *If the diarrhœa* " *death-rate of England is reduced to that which prevails* " *among the healthier part of the population, typhoid fever* " *(now probably the cause of at least* 15,000 *annual deaths)* " *will be reduced in more than equal measure.*"

In the Sixth Report of the Medical Officer of the Privy Council for 1863, that gentleman found, in the numerous reports sent in to him as to outbreaks of fever, evidence that, " *invariably, in greater or less extent, the population* " *was breathing the stench or drinking the filtrate of its own* " *decomposed excrement.*"

Kirkby Stephen.

In the Second Report of the Medical Officer of the Privy Council, 1859, page 35, is given an account of an outbreak of fever from a polluted well, from which resulted eleven deaths and other attacks over one seventh of the population.

Theydon Bois, near Epping.

In the Eighth Report of the Medical Officer of the Privy Council, 1866, page 29, there is an account of an importation of cholera from Weymouth, which states that the choleraic discharges from the patient had soaked from a water-closet into a well used for drinking water. This caused 12 cases of disease, and nine deaths.

Guildford.

The Tenth Report of the Medical Officer of the Privy Council, 1867, page 10, contains the following remarks with regard to an outbreak of typhoid fever :—" *The distribution of* " *the disease, especially during the first fortnight of the* " *epidemic, so nearly corresponded in area with the particular* " *section of the public water supply of the town as to raise the* " *strongest suspicions that this section of the water supply was* " *at fault, and eventually these suspicions became a certainty.*"

Of the 1,675 houses in this town, 330 had exceptionally received their water from a high service reservoir filled from a new well. This well was within 10 feet of various channels in the porous and fissured chalk stratum through which the leakage from a 12-inch drain had percolated, and thus contaminated the well.

The persons residing in or frequenting the above 330 houses constituted the part of the population on which the epidemic influence had almost exclusively fallen, causing 500 cases and 21 deaths.

Wicken Bonant.

We learn from the Twelfth Report of the Medical Officer of the Privy Council, 1869, that at this place there was an outbreak of fever from a polluted well which intercepted water, into which, within a distance of 250 yards, sewage matter had been discharged, causing 45 cases and 4 deaths.

The Medical Officer of the Privy Council, in mentioning the above case among many others says, at page 16—"*The "experiences of* 1869, *substantially uniform with one another "and equally in accord with previous observations, repeat "again and again the general lesson, that the infections here "mentioned denote excremental poisoning.*"

And further on, at page 17, he says—"*It has long been "among the most fixed of the certainties which have relation "to civilised life that wherever human population resides the "population cannot possibly be healthy, cannot possibly escape "recurrent pestilential diseases, unless the inhabited area be "made subject to such skilled arrangements as shall keep it "habitually free from the excrements of the population.*"

And again, on page 21, he says—"*Not only is it now "certain that the faulty public water supply of a town may be "the essential cause of the most terrible epidemic outbreaks "of cholera, typhoid fever, dysentery and other allied dis- "orders; but even doubts are widely entertained whether "these diseases, or some of them, can possibly attain general "prevalence in a town except where one faulty water supply "develops them.*"

In the appendix to the Second Report (new series) of the Medical Officer of the Privy Council will be found over 100 cases of towns and villages that have been desolated by fever owing to defective and polluted water supply.

A similar return to the above, and containing a great number of examples of excremental poisoning, of which the two following are the most striking, is given on page 99 of No. IV. (new series), 1875.

Lewes, Sussex.

A large epidemic of enteric fever, due in the first instance to pollution of the town water supply by water drawn from the Ouse, which receives the town sewage, and mainly spread by suction of polluting matter into the water pipes of an intermittent water service.

Over Darwen, Lancashire.

General high rate of mortality from enteric fever. Public water supply polluted by soakage from drain into which excreta from enteric fever patient had passed.

Nunney.

From Parke's Practical Hygiene, 7th edition, page 67, we learn that very polluted water had been used for years by the inhabitants without causing fever; that a person with enteric fever came from a distance to the village, and the excreta from this person were washed into the stream supplying the village. Between June and October, 1872, no less than 76 cases occurred out of a population of 832 persons, all of those attacked drinking the stream water habitually or occasionally. All who used filtered rain or well water escaped, except one family, who used the water of a well only four or five yards from the brook.

Caterham and Redhill.

From the Ninth Annual Report of the Medical Officer to the Local Government Board, 1879-80, page 78, it appears that in January, 1879, an outbreak of enteric fever took place at Redhill and Caterham, about 350 persons suffering from the disease. This district was supplied from a well sunk in the chalk belonging to the Caterham Waterworks Company.

It would appear that about the end of 1878 or the beginning of 1879 the Company were employed in sinking a new well and driving an adit to connect it with the old boring. One of the men employed in this work had been previously suffering from enteric fever, and some portion of his excreta in some way got into the water in the well in which he was at work. From the careful investigations of Dr. Thorne Thorne it was clearly proved that this disease was communicated by the drinking water to the 350 persons who were attacked. Twenty-one of the cases ended fatally.

From examinations which were subsequently made it was shown that although these people were infected from this source, yet chemical analysis was powerless to detect the germs of the disease which existed in the water.

Bangor.

In the Twelfth Report of the Local Government Board, supplement page 72, we learn from the report of Dr. Barry that an outbreak of enteric fever was caused by the discharge from a patient which polluted the stream about 700 yards above the intake and filters of the Bangor water supply, and 548 cases and 42 deaths in the town and its immediate neighbourhood occurred.

Norwood.

From the Medical Supplement to the Twelfth Annual Report of the Local Government Board, 1882-83, page 84, in the report of Mr. Power it is stated that 35 cases of enteric

fever occurred in 14 houses. The cause of the outbreak was traced to the contents of a contaminated cesspool, which travelled 40 feet through the gravel soil into a well which supplied one house with drinking water.

Hitchin.

In the Medical Supplement to the Thirteenth Annual Report of the Local Government Board, 1883–84, page 79, a report by Mr. Power states that nearly 100 cases in the town, with seven deaths, were caused by the pollution of the public water supply by an overflow pipe, from the pumping station into the river Hiz. By this means an occasional reflux of the impure river water into the receiving tank occurred.

Beverley.

The Medical Supplement to the Fourteenth Annual Report of the Local Government Board, 1884–85, page 112, contains a report by Dr. Page, which states that 231 cases and 12 deaths were due to enteric fever caused by the specific contamination of the water supply of the Beverley Water Works Company by drainage from a sewage farm percolating through the soil, and from the effluent water which naturally drained toward the Company's reservoir and well. On page 25, the fact is stated that the water supplied by the Company was analysed and declared pure, notwithstanding this contamination.

Mountain Ash, Glamorganshire.

In the Medical Supplement to the Seventeenth Annual Report of the Local Government Board, 1887–88, page 59, a report by Mr. Spier states that over 500 cases of enteric fever, with a mortality of 6 per cent., were caused by the lateral in-suction of the specific poison of enteric fever into water pipes "running full."

Cradley.

The Medical Supplement to the Nineteenth Annual Report of the Local Government Board, 1889–90, page 51, contains a report by Dr. Gresswell, which states that 113 cases and 16 deaths from enteric fever were caused by the pollution of the water of the town well supplied from a sandstone hill, in the superficial layers of which are the graves of the cemetery.

Dr. Gresswell says at the conclusion of his report—

"*It especially deserves notice that this very water supply "was emphatically pointed out to the authority by Dr. Ballard "in* 1873 *as a source of grave danger; that the epidemic of "enteric fever in* 1877 *and* 1878 *was ascribed by Dr. "Thompson, then Medical Officer of Health, and by several*

"*other medical practitioners, to the pollution of this said water,*
"*and Dr. Parsons spoke in no hesitating terms of the danger*
"*to which Dr. Ballard had previously called the attention of*
"*the authority; and the vicar in the pulpit and elsewhere*
"*stated that the persons who drank of the water were drinking*
"*'dead men's bones,' nevertheless the water continued in use.*"

Houghton-le-Spring, Durham.

In the Medical Supplement to the Nineteenth Annual Report of the Local Government Board, before referred to, on page 61, in a report by Dr. Page, it is stated that 275 cases and 26 deaths from enteric fever occurred.

The epidemic was practically confined to the area of the Herrington water supply, and was traced to a well sunk to a depth of 330 feet into the sand-stone strata of the coal measures, from which the water was pumped into the service reservoir.

The well had become polluted by drainage from a farm-house, which flowed a distance of three-quarters of a mile in a fissure of magnesian limestone.

Doncaster.

Dr. Alfred Hill, in his evidence on the Cheltenham Water Bill for 1878, page 156, question 2710, stated—

"*The river Don flows from Sheffield and Rotherham to*
"*Doncaster. In* 1866, *according to Dr. Sieman's report,*
"*there was cholera from July to October in Sheffield; the*
"*epidemic commenced* in July, was very bad in August*
"*and September, and ceased about the* 10*th of November,*
"*which was about a fortnight after it had ceased in*
"*Sheffield. I think that is a very clear illustration of the*
"*effect of the cholera on infected sewage carried down a*
"*distance of between* 15 *and* 20 *miles, from one town to*
"*another, and carrying the disease with it.*"

Valley of the Tees.

It appears from Dr. Barry's interim report to the Local Government Board on an epidemic prevalence of enteric fever in several towns situated in the valley of the river Tees in south Durham and north Yorkshire, dated the 12th January, 1891, that during September and October, 1890, serious outbreaks of enteric fever occurred in the valley of the Tees. The cases numbered from 200 to 300 a fortnight, and were confined almost entirely to the users of the river Tees water as supplied from the mains of the Darlington Water Works and of the Stockton and Middlesborough Water Board. Dr. Barry concludes his report on the above-mentioned epidemic by saying—

* In Doncaster.

" *I have personally no hesitation in attributing the epidemic* " *of enteric fever in the lower Tees valley to the water pumped* " *from the river Tees during the fortnight ending August* 23rd " *at a time, namely, when the river was in flood, and when* " *it must have contained abundance of excremental matter.* " *And I consider that as long as water for drinking purposes* " *is drawn from the Tees, the condition of that river* " *remaining as at present, so long will there be the danger* " *of the occurrence of similar epidemics to that described in* " *this report in the districts thus supplied with Tees water.* " *There can be no question that if the sewage and excremental* " *and other refuse of the various towns and villages above the* " *pumping station were prevented from passing into the Tees,* " *the danger of specific pollution of the water would be very* " *greatly reduced; but even under these circumstances it is still* " *doubtful whether the water pumped from a river at a point* " *upwards of* 40 *miles from its source is anywhere in this* " *country a desirable supply for drinking purposes.*"

It should be noted that the town of Barnard Castle drains into the Tees 13 miles above the intakes, and that all the water of the above supplies is filtered before it is delivered to the consumers.

London.

Turning now to the Thames and Lea valleys, there is ample warning of what may possibly happen in the future, contained in the evidence as to the causes of violent epidemics which have occurred in past years.

The great cholera epidemic which lasted from February to October, 1832, caused a total of 5,275 deaths, but at that early period in the study of sanitary science there were but few facts available to trace the outbreak to its true source.

In the cholera outbreak of 1849 the deaths of 14,125 persons were caused, and in the epidemic of 1854, 10,708 persons died.

As to the origin of these latter outbreaks there is abundant evidence in Mr. Simon's report on the cholera epidemics of London as affected by the consumption of impure water. I take the following from this report (see footnote at page 295 of the Ninth Report of the Medical Officer to the Privy Council, dated the 31st March, 1867):—

" *The great field of activity of cholera south of the Thames* " *in* 1848-49 *and* 1853-54 *was supplied by two water com-* " *panies, the Lambeth and the Southwark and Vauxhall.* " *The former before* 1853 *drew its supplies from the Thames* " *near Hungerford Bridge, the latter from the Thames at* " *Battersea. In* 1848-49 *the recipients of the Lambeth* " *Company died at the rate of* 12·5 *per* 1·000, *the recipients* " *of the Southwark at the rate of* 11·8. *Before the outbreak*

"1853-54 *the Lambeth Company had removed its source* "*of supply from the Thames at Hungerford Bridge to the* "*Thames at Thames Ditton. When the epidemic again broke* "*out it again localized itself in the districts of former activity* "*south of the Thames and also prevailed with great violence* "*north of the river in St. James, Westminster. But the* "*deaths among the recipients of the Lambeth Company were* "*only* 3·7 *per* 1,000, *although the deaths among the recipients* "*of the Southwark Company were not less than* 13·0 *per* "1,000. *The unusual prevalence of the disease in St. James,* "*Westminster, it is known, was caused by the water of the* "*Broad Street pump. Since* 1854 *the Southwark Company* "*has also obtained its supply from a purer portion of the* "*Thames than the river at Battersea.*"

I also draw attention to Appendix A to the Report of the General Board of Health on the epidemic of cholera in 1849, where Dr. Sutherland states, at page 14, "*In nearly* "*every city or town affected this element has been more or less* "*prominent, and the number of most severe and fatal outbreaks* "*of cholera were referable to no other cause except the state of* "*the water supply.*"

And again, lower down on the same page, he says, "*I* "*have known water pronounced to be chemically wholesome* "*occasion the death of a large number of persons, although I* "*never met with an instance in which the microscope did not* "*detect the presence of a considerable amount of organic* "*matter.*"

Referring now to the epidemic of 1866, when 5,577 deaths occurred, I quote the following from page 295 of the Ninth Report of the Medical Officer to the Privy Council dated the 31st March, 1867, before mentioned, "*There* "*remains for examination the probable influence of the water* "*supply. Not one of the conditions named in the previous* "*sections, and believed to be liable to affect the progress and* "*development of epidemic cholera, the disease being present,* "*will account for more than very limited fluctuations of the* "*outbreak, or for its localization in any particular spot in a* "*restricted degree only. Any combination of these conditions* "*is, moreover, equally inefficacious in explaining that peculiar* "*localization and fluctuation in the east districts of the* "*metropolis to the solution of which this report is specially* "*directed.*

"*By a process of exclusion the condition remaining for* "*investigation, the water supply, is thus freed from the* "*principal sources of disturbance which, it is presumable,* "*might most mask its influence upon the outbreak.*

"*From the commencement of the localization of cholera* "*in the East Districts the probable association of this circum-*

"*spection with an impure water supply was forced upon the* "*mind. The predominant lesson derived from the outbreaks* "*of* 1848-49 *and* 1853-54 *was, that the localities of chief* "*prevalence of the disease were mainly, if not solely,* "*determined by the degree of impurity of the water supply.*

"*The application of this lesson to the recent outbreak* "*was not the less compelled by the transference of the chief* "*fields of localization from districts south to districts north of* "*the Thames, the former having changed markedly in two* "*respects only in the interval between the recent and preceding* "*epidemics, namely, in the character of their water supply,* "*which was obtained from much purer sources, and the freer* "*removal of their sewage by the completion of the Southern* "*Main Drainage works.*"

This outbreak was clearly traced to the impurity of the water supplied by the East London Company, and the subject is again summed up on page 331 of the report above quoted, as follows—"*Neither the meteorology of the period, nor* "*altitude, nor the nature of the soil, nor density of population,* "*nor filth, nor the state of the sewerage, nor locality, affords* "*any explanation of the peculiar localization of the outbreak* "*in the east districts.*

"*There is but one condition known which might become* "*capable of propagating cholera common to the whole area of* "*the outbreak, namely, the water supply.*

"*The sudden and virtually contemporaneous development* "*of the outbreak over the entire area of prevalence indicated* "*a medium of propagation common to, and capable of rapid* "*diffusion over the whole area; its sudden declension indicated* "*the temporary efficiency to this end of such a medium. The* "*area of prevalence approximated with remarkable closeness* "*to a particular field of water supply, and there are facts* "*which seem to prove that this approximation was not* "*accidental. It is known that immediately prior to the out-* "*break in the east districts of the Metropolis and neighbouring* "*districts across the Lea, impure water was distributed over* "*this field of supply, and it is highly probable that this water* "*was charged with choleraic poison.*"

The history of the London waterworks shows that originally their water was drawn from the Thames, near London Bridge, Hungerford Bridge, and at Battersea, Hammersmith and Kew. The sources of supply were then moved up to Thames Ditton above Kingston; and were subsequently again removed still higher to the present intakes at Hampton and Molesey, above the confluence of the river Mole.

All these various removals up stream have been made for the purpose of obtaining a purer supply, and were consequent upon the river at the then existing intakes having become

more and more polluted, as population increased upon its banks. I have already noted the opinion of the Water Examiner as to the inexpediency of continuing the pumping from the gravel beds near the site of the present works at Hampton, and have directed attention to the attempt that was made in 1888 by one of the Companies (the Grand Junction) to remove its intake to a point above Windsor.

But the question arises, Can these repeated removals of the sources of intake be with advantage much longer continued in an upward direction? I have shown that above the present intakes is massed an enormous population on the banks of the river, and that this population is continually and rapidly increasing. The removal of the present intakes higher up the river would therefore only bring them into closer contiguity to many of the larger towns such as Oxford, Reading and Windsor, which are necessarily the greatest sources of pollution.

In the cases of Valencia, Bangor, Darlington, Stockton, and Middlesborough, as well as in the reports of Mr. Higgin, grave doubt is, to say the least, thrown upon sand filtration as an efficient preventative of disease. Sand filtration may arrest the living microscopic organisms, but it appears to be unable to stop the passage of the still smaller germs from which these organisms develop.

The instances already given prove, if proof be required, that water is a most potent element in the dissemination of disease. There is little doubt that drinking water contaminated by the sewage of healthy persons, even in small quantities, may not be dangerous at the time, although it may possibly predispose the water-drinkers to an attack of some acute epidemic should such break out. The annals of medical science throughout the world convey serious warning on this subject, but it must be admitted that up to the present time chemical science has been unable to detect in water the specific forms in which disease is communicated.

On this subject I would invite attention to the report by the Medical Officer contained in the supplement to the Eleventh Annual Report of the Local Government Board, 1881-1882, at page xxi., who, in remarking on a series of experiments that had been carried out by Dr. Cory to ascertain the amount of pollution and infectious matter present in certain drinking waters, both naturally and artificially produced, makes the following remarks, viz.—"*The lesson is taught afresh and "significantly by Dr. Cory's report that while we must ever be "on the watch for the indications that chemistry affords of "contaminating matters gaining access to our waters, we "must (at any rate until other methods of recognition are "discovered) go beyond the laboratory for evidence of any*

"*drinking water being free from dangerous organic pollution.*
"*Unless the Chemist is well acquainted with the origin and*
"*liabilities of the water he is examining, he is not justified in*
"*speaking of a water as 'safe' or 'wholesome' if it contain*
"*any trace whatever of organic matter; hardly indeed even if*
"*it contain absolutely none of such matter appreciable by his*
"*very delicate methods. The chemist can, in brief, tell us of*
"*impurity and hazard, but not of purity and safety. For*
"*information about these we must go, with the aid of what the*
"*chemist has been able to teach us, in search of the conditions*
"*surrounding water sources and affecting water services.*"

The subject of the danger arising from the use in the future, as population increases in the Thames and Lea valleys, of water drawn from those rivers, deserves most careful attention, for it must be remembered that the London water supply involves the first necessary of life for 5¾ million persons, or nearly one-fifth of the total population of England and Wales.

In dealing with the vital interests of so vast a population it should constantly be borne in mind that there can be no justification in adopting permanently any source of supply liable to serious contamination, and which may in given circumstances be the certain means of spreading epidemics disastrous to the whole community.

Supplies to other Municipal Towns.

At this point I may remark that as regards its water supply I consider London to be in a most backward condition. The evidence of all our large towns where the water supply is in the hands of a public authority, and where the fulfilment of a public duty and not the earning of a dividend for the benefit of shareholders is the first object in view, teaches us that so important is the unimpeachable purity of the water considered, that many towns have gone to great distances, and spent, as compared with London, much larger sums of money to secure a pure supply.

In the case of Manchester, the existing supply is derived from the uncultivated and uninhabited hills in Longdendale, lying between Derbyshire and Cheshire; and for the new supplementary supply which it is now introducing, the Corporation have considered it judicious to go a distance of 100 miles to Thirlmere for the purpose of securing an almost uninhabited and uncultivated catchment area in the neighbourhood of Helvellyn. In order to prevent as far as possible any chance of pollution in the future, the Corporation have purchased the area, some 11,000 acres in extent, which drains to the lake and its tributaries, so that they may be in a position to prevent any building, and contamination arising therefrom.

Liverpool, in like manner, has gone to the Vyrnwy in North Wales, and brought in a supply from a place 76 miles distant with a like object; and not content with securing a district at present uncontaminated, has also considered it wise and prudent to secure by purchase the right to prevent contamination arising in the catchment area of 18,000 to 20,000 acres which discharges into their reservoir.

Glasgow, similarly, has gone to the uninhabited mountains which drain into Loch Katrine, and which, fortunately, are too steep and too barren to allow of population or cultivation.

In my own experience, when administering the water affairs of the town of Bradford, the Corporation considered it advisable, although the great bulk of their water is derived from uncultivated and unculturable areas, to purchase some hundreds of acres which might possibly be the cause of future pollution. And in the Bradford Act of 1890, the Corporation obtained powers to introduce a new and additional supply, and in order to secure purity resorted to the almost uninhabited and uncultivated moorlands at the sources of the river Nidd on the slopes of Great Whernside, distant 40 miles from the town.

It is also for this reason and to prevent London securing one of the best and purest available water supplies from the Upper Wye in Radnorshire, that Birmingham is about to apply to Parliament for the necessary powers to obtain water from that district, a distance of about 80 miles from Birmingham.

In contemplating the time, scientific skill, enormous capital expenditure, and lengthened parliamentary enquiries, which have been devoted to this subject by the elected Corporations of our largest and most enlightened municipal towns, it may be asked, has all this been wasted in striving after a sentimental standard of purity? May it not rather be inferred that London, which has hitherto been without a representative municipal government, has been neglected by being left so long in the hands of irresponsible commercial companies, whose first object naturally is to make a profit at the least cost to themselves without perhaps giving sufficient attention to the possible consequences to the millions of persons whom they supply.

Conclusion.

To my mind the whole question is not one requiring to be elucidated by chemical analysis. I consider that the facts given in this report, supported as they are by the evidence of high authorities, are sufficient to throw deep suspicion on the London water supply, derived as it is from such questionable sources. I cannot but concur with the report of the Royal Commission on the Pollution of Rivers (Domestic Water

Supply of Great Britain), 1874, which in referring to the water supply to London from the Thames states, at page 429, "*we therefore recommend that the Thames should as "early as possible be abandoned as a source of water for "domestic use, and that the sanction of your Majesty's "Government be in the future withheld from all schemes "involving the expenditure of more capital for the supply of "Thames water to London.*"

It will now be for the Council very gravely to consider, with these facts before them, what course they will adopt with regard to the future water supply of London from the rivers Thames and Lea. At present no doubt the death rate of the metropolis is low, and as far as analysis is concerned, the water appears to be wholesome. But it has been shown that analysis without the previous history of the water is taken into account, is no guarantee of purity; and it is evident that the inhabitants of London are living under conditions as to their water supply which might lead to an outbreak of epidemic disease that for extent and severity would be almost unparalleled in the history of the world. And there are serious reasons, on entirely other grounds, for limiting the supply derivable from the Thames and Lea, even were those waters considered perfectly pure and wholesome.

ALEXANDER R. BINNIE,
Chief Engineer.

LONDON WATER SUPPLY

FROM THE

THAMES AND LEA.

APPENDIX A.

Pamphlets and Reports presented to the London County Council.

Metropolis Water Supply—

By Richard Hassard, M.I.C.E.
,, Arthur W. N. Tyrrel, M.I.C.E.

Dated January, 1891.

Preliminary Report on the possibility of obtaining a Supply of Water for London within the Thames Basin—

By W. Whitaker, B.A., F.R.S.
,, A. H. Green, M.A., F.R.S.

Dated 1891.

Reports on Rainfall—

The Upper Watershed of the Wye.
,, ,, Severn.
The Watersheds of the Thames and Lea.
,, ,, Dartmoor.

By G. J. Symons, F.R.S.

Dated December, 1890.

As to Pollution of the Thames between the intakes of the London Water Companies and Oxford—

By Dr. Alfred Ashby, Medical Officer of Health, Reading.

Report on Upper Thames Basin—

By G. H. Fosbroke, D.P.H. Cambridge, County Medical Officer for Worcestershire.

Dated April, 1891.

On the Valleys of the Lea and its Tributaries—

By Dr. George Turner, Medical Officer for Hertfordshire.

1st Report on the Flow of the River Thames, etc., etc.—

By Prof. Henry Robinson, M.I.C.E.

Dated February, 1891.

2nd Report—by the above—dated March, 1891.

On Outbreaks of Cholera in Spain—

By George Higgin, M.I.C.E.

Dated 24th July, 1891.

Report on the character of Bacteria in London Water—

By Dr. Klein.

Dated 29th April, 1891.

Report "as to whether the supply of Water in the Chalk is or is not diminished"—

By Edward Easton.

Dated 25th April, 1891.

And various Statistics and Data, prepared by the Engineer.

APPENDIX B.

Copy of Memorandum supplied to Sir Matthew White Ridley's Committee, Session 1891, by Mr. Pember, Q.C., leading Counsel to the Water Companies.

MEMORANDUM

AS TO

METROPOLITAN WATER COMPANIES.

I.—As to the obligation to provide and supply Water throughout their Districts.

II.—As to the control now exercised by Public Department over the Companies.

I.—As to the obligation to provide and supply water for domestic purposes.

(i.) The Companies must, under the provisions in their special Acts, at their own expense, lay mains and bring pure and wholesome water to every part of their district, when required to do so by owners and occupiers, who will take a supply for three years, and whose aggregate annual water rates will be not less than one-tenth of the expense of providing and laying such mains; and in those mains the Companies must, under penalties, keep on Sundays, as on other days, sufficient pure and wholesome water for the domestic use of the inhabitants, Metropolis Water Act, 1871, sec. 6. The Companies are not required to lay, at their own expense, communication pipes into the premises of the consumers, this, as stated below, falls on the consumer, and most of the Companies are exempted from obligation to supply water in any part of their district for the time being supplied by another Company.

(ii.) The owner or occupier of a house, in a street where any main is laid, may lay communication pipes between his premises and the pipes of the Companies; and when he has done so, and paid or tendered his rate, which is a percentage (fixed in the Companies' special Acts, but varying in the case of different Companies), on the annual value of the premises,

with fixed maximum charges for closets, baths, &c., the Companies must, under penalties, furnish him with a sufficient supply, Waterworks Clauses Act, 1847, ss. 43 and 48 to 53.

The annual value, outside the Metropolis, is determined, in case of difference, by two justices, Waterworks Clauses Act, 1847, sec. 68, and, inside the metropolis, is declared by Torrens' Act of 1885 to be the rateable value as appearing in the poor rate valuation list.

Note.—The law as stated in pars. (i.) and (ii.) is applicable to all the Companies, though with slight variations of detail in the case of particular Companies.

(iii.) By the Metropolis Water Act, 1871, the Companies are under heavy penalties bound to provide a constant supply of pure and wholesome water, if required by the Metropolitan Authority, or, in certain cases, by the Local Government Board (ss. 7, 8 and 11).

The Metropolitan Authority is, in the Metropolis, the London County Council; in the City, the Corporation; in the Urban Sanitary Districts outside the Metropolis, the Urban Sanitary Authority; and in Rural Parishes, the Vestries.

(iv.) By the Waterworks Clauses Act, 1847, ss. 37 to 43, the Companies are bound to fix fire-plugs within certain prescribed distances, and to keep in all pipes to which a fire-plug is fixed a sufficient quantity of water for—

Cleansing sewers and drains,
Cleansing and watering streets,
Supplying public pumps, baths and washhouses,
Extinguishing fires.

The supply for extinguishing fires is given gratuitously, the London County Council having, within the Metropolis, power as to form, dimension, &c., of fire-plugs under the Metropolitan Fire Brigade Act, 1865, sec. 32, and as to form, dimension, position, number, &c., of Hydrants under the Metropolis Water Act, 1871, sec. 34.

II.—As to control now exercised by Public Department.

The Metropolis Water Acts, 1852 and 1871, conferred large powers of control on the Board of Trade, which powers under the Public Health Act, 1872, were transferred to the Local Government Board.

(A) *New Sources of Supply.*—No Company can resort to any new source of supply, until they have given previous notice to the Local Government Board, who may appoint an inspector to visit and inspect; as to sources specially authorised by Parliament, to examine whether the directions in the special Act have been complied with; and as to new sources,

not so specially authorised, to examine whether they are capable of supplying good and wholesome water for domestic purposes. On his report, the Local Government Board are to certify their approval or disapproval of sources not so specially authorised; if disapproved of, the Company may not use the new source, sec. 5 of 1852.

(B) *Quality and quantity.*—Provision is made in ss. 2 to 5 of 1852 for covered reservoirs within 5 miles of St. Paul's Cathedral, for covered aqueducts, and for filtration of water (other than from wells) used for domestic purposes. If there be a complaint from twenty householders as to the quality or quantity of water for domestic use, the Local Government Board may appoint a competent person to inquire and report, with powers to inspect and examine the waterworks: if he reports that the complaint is well founded, the Local Government Board are to give notice to the Company, who must, within reasonable time, remove the grounds of complaint, ss. 9 to 13 of 1852. The Local Government Board may by sec. 35 of 1871, on their own initiative, institute an inquiry into the quality of water at any time, with similar powers as if a complaint had been made. The Local Government Board are also to appoint a Water Examiner, with power to examine whether the water supplied for domestic use is efficiently filtered, sec. 36 of 1871.

(C) *Constant supply.*—It has already been stated that the Local Government Board can in certain cases enforce a constant supply.

(D) *Regulations* for the purpose of preventing waste, misuse or contamination of water, and of prescribing fittings, may be made by any Company with the approval of the Local Government Board, and on failure by any Company to make, or when required to alter, regulations, the Board may appoint a competent person to make or alter regulations, ss. 26 of 1852 and 17 to 19 of 1871.

(E) *Financial Control.*—Every Company has to make up and forward to the Local Government Board, and to certain officials, and to keep for sale, statements of account in the form, and containing the particulars prescribed by the Local Government Board, and that Board are to appoint an Auditor to investigate the accounts, distinguishing and certifying share and loan capital, the amount of new capital, and its expenditure. If he finds the accounts incorrect in principle or detail, he may require correction before giving his certificate, and the payment of future dividend is to be suspended until the correction be made and certificate given. The Companies are bound under penalties to give facilities, produce vouchers, and afford information, to the auditor, and

questions between him and the Companies may be referred to arbitration, ss. 37 to 42 of 1871.

It will thus be seen that with regard to the quality and quantity of water an effective practical control is vested in the Local Government Board, by the foregoing provisions, under which the Board may be required to, or may of their own motion, institute inquiries, and compel the Company to remedy any default, under heavy penalties. Again, as regards finance, the sections in the Act of 1871 relating to accounts and capital, the restrictions as to dividend in the Waterworks Clauses Act of 1847, ss. 75 *et seq.*, and the provisions now inserted in special Acts which seek fresh money powers, are such as to impose considerable restrictions on the Companies in the interests of the consumer; who is, in fact, assured of a reduction in the price of water proportionate to the successful working of the Companies.

26*th June*, 1891.

London County Council.

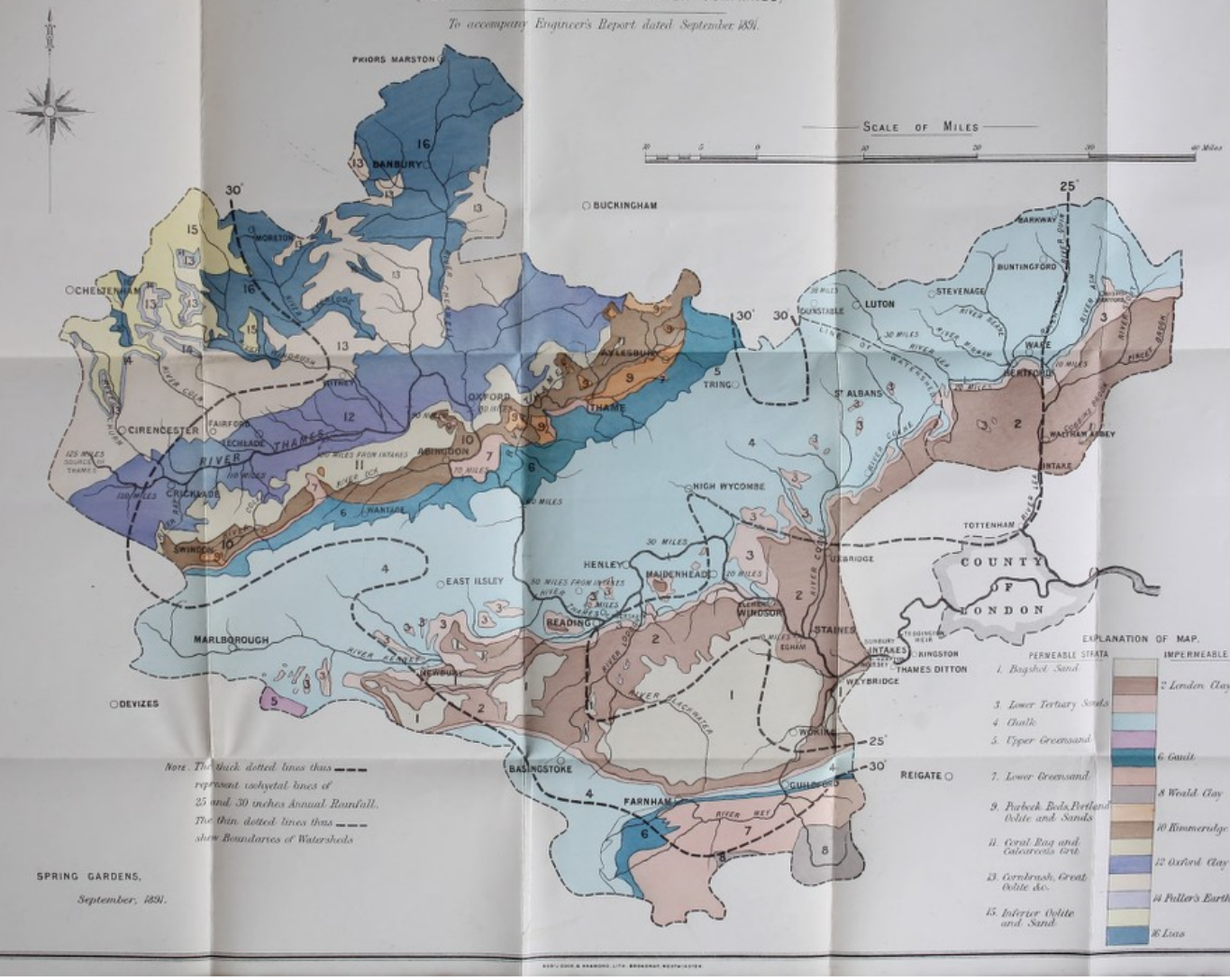
No. 1.

LONDON WATER SUPPLY FROM THE THAMES AND LEA

Geological Sketch Map of the Thames & Lea Basins

[Above the Intakes of the Water Companies]

To accompany Engineer's Report dated September 1891.



SPRING GARDENS,
September, 1891.

London County Council.

Nº 2.

LONDON WATER SUPPLY FROM THE THAMES AND LEA

Sketch Map shewing

Sources of Pollution in the Basins of the Thames and Lea.

Above the Intakes of the Water Companies

From personal investigations by Dr.s Ashby, Fosbroke and Turner

TO ACCOMPANY ENGINEER'S REPORT DATED SEPTEMBER 1891

SPRING GARDENS,
September, 1891.

Note: Sources of Pollution are shewn thus ●
Boundaries of Water Sheds thus ---