PART II.

ON SOURCES OF SUPPLY OTHER THAN THE MOUNTAINOUS DISTRICTS OF ENGLAND AND WALES.

65. Your Majesty's Second Commission commanded us to inquire "whether there are "other districts, in addition to the high districts of England and Wales, from which a good "supply of unpolluted and wholesome water can be obtained."

Several plans or proposals, of various degrees of magnitude, having for their object to supply the metropolis, wholly or partially, from sources of this character, have been mentioned to us by the parties named in the following list. It will be convenient to divide these into classes, as follows:—

Class I.

From the River Thames or its Tributary Streams.

1. Mr. McClean, from the Thames near Henley.
2. Mr. Bailey Denton, from the higher parts of the Thames basin.
3. Mr. Brown, from the same.
4. Mr. Bravender, from the same.

Class II.

From the Lee.

5. Mr. Mylne, from the upper part of the Lee basin.

Class III.

From the Chalk and Oolite Formations in the Basin of the Thames.

6. The Rev. J. C. Clutterbuck, from the chalk and oolitic area of the Thames basin.
7. Mr. Homersham, from wells in the chalk around London.
8. Mr. P. W. Barlow, from certain chalk springs in North Kent.
9. Mr. Meeson, from chalk springs at Grays in Essex.

Class IV.

Miscellaneous.

10. Mr. Thos. Hennell, from the chalk and Bagshot sands of the neighbourhood of Basingstoke and Farnham.
11. Mr. G. W. Ewens, from certain chalk springs near Havant.
12. Mr. Telford McNeil, from the Bagshot Heath district.

A plan proposed by Mr. A. S. Ormsby, to collect water from artificial drainage surfaces, does not appear to come within the scope of our inquiry.

Some of these projects are merely suggestions, and none of them have been prepared with the completeness and detail of the larger plans. It will, therefore, not be necessary to notice them at the same length.

CLASS I.

From the River Thames or its Tributary Streams.

66. Several projectors, considering that the Thames when it reaches Hampton has become polluted by the drainage of the land and towns above, have proposed to take the water at higher points, generally combining with their propositions other suggested arrangements for the improvement of the supply.

Mr. McClean's Plan.

5498 et seq. 67. Mr. McClean, M.P., Civil Engineer, gives a description of a plan which he brought forward in 1849 and 1850, in conjunction with the late Mr. Blackwell, who was for many years engineer of the Kennet and Avon Canal. It is illustrated by a plan and section which are printed in Appendices T (1) and T (2) to our report.

Mr. McClean's proposition is to embank and canalize the Thames above Medmenham (between Henley and Great Marlow), so as to form, in the present channel of the river, a long series of impounding reservoirs, which would be advantageous not only for storing water but also for improving the navigation. He would then take the water from the lowest of these pounds, 105 feet above low water in London, and proposes thus to obtain a supply of 200,000,000 gallons a day.

The drainage area included is 2,500 square miles, and the mean annual rainfall is estimated at 26 inches.

The aqueduct would be a canal 36 miles in length, the last five miles to be covered. It would be 40 feet wide by 12 feet deep, and is intended to deliver the water in London at about the level of the Paddington Canal, or the New River head, from which level Mr. McClean assumes all the low part of London might be supplied by gravitation, that necessary for the higher parts being pumped to elevated reservoirs at Hampstead and Clapham.

Mr. McClean believes that the quality of the water taken at Medmenham would be very satisfactory.

The estimate for the plan when brought forward was 1,500,000*l*., excluding the pumping parts of the scheme.

Mr. McClean gives further details, and says he has no doubt that by storing the flood 5637.
waters in the upper reaches of the Thames more water may be obtained than can ever be
required; and that by embanking the river in the way he proposes he would increase the 5718–21.
quantity by preventing the water going out on the lands and inundating them, whereby a great deal is lost and the quality much deteriorated.

Mr. Bailey Denton's Plan.

68. Mr. Bailey Denton's plan, which is illustrated by a map, Appendix V., is thus generally described by him:—

"I am prepared to show that the upper streams of the Thames basin, the tributaries of the Thames, are 1532.
capable of supplying the metropolis if supplemented by storage, and that that storage would partly consist of the water of under-drainage and the water of drainage by arterial improvements from the upper lands which form the margin of the Thames basin. I should state, however, that my proposal is to take from the Thames and its tributaries, at points above which water may be obtained in positive purity by the proper exercise of conservancy, all that may be required for the supply of London, having stored in winter the surplus waters of that period of the year in order to repay the river system in summer what may be required to maintain it at a fixed standard height."

With respect to the quantity of water available he makes the following remarks:

"To give some proof that there is water sufficient, I would just mention these facts to the Commission. 1547.
The area of the watershed of the Thames is 3,300,000 acres, the population we may take at 4,500,000, the average rainfall is 26 inches, the minimum is between 19 and 20 inches, and that minimum is disposed of in this way—3 inches support the perennial supply of the river, that is to say, maintain the river in summer at the ordinary height; taking 3 inches from 20 there remains 17, and of that 17 we find by information of various sorts that a very large share runs off to the sea in winter; but, beyond the fact that this accretion occurs when the rivers are full, there is another fact, that whatever water is taken by under-drainage from the atmosphere it is so much positive increase to the river supply, and as under-drainage proceeds so will the supply be increased."

"I propose to collect the water from the higher portions of the basin, that is, from the oolitic sources on the 1557.
north of the Thames, say from Cricklade to Oxford, and from the various streams rising in the chalk throughout the whole of the area of 3,300,000 acres. It is not possible to state the quantity of water discharged by springs from the water-bearing strata of the Thames basin, but it is pretty accurately known that, while $1\frac{1}{2}$ inches of rain maintains the ordinary summer flow in the river from April to September inclusive, at least 4 inches runs off during the remaining six months from October to March inclusive, without taking into consideration excessive floods. The ordinary winter flow, in fact, compared with the ordinary summer flow is as $2\frac{1}{2}$ to 1. No dogmas as to loss by evaporation and other causes touch this fact, which manifestly proves, when the discharge drainage water is taken into account, the capability of storing in winter all that can possibly be required for compensation in summer."

"My proposal embraces three sources of supply with a means of future augmentation, viz., the upper sources 1651.
of the Thames giving 100,000,000 daily, the Lee giving 60,000,000, the Wey and the Mole giving 40,000,000, making 200,000,000 daily, exclusive of the Colne and the Wandle, which with storage may provide a share at some future time."

"I have already observed that there is almost a total absence of any reliable gauging of the Thames and its 1662.
tributaries, but we do know this from the evidence of Mr. Stacey before the Rivers Commission, and a remarkable fact it is, that the general summer average volume at Wolvercot, which is just above Oxford, is 73,000,000 gallons *per diem*; but in the dry summer, 1865, it was reduced to 62,000,000 gallons. But the winter flow is represented by very different figures. On the 2nd of January 1863 the quantity flowing down was 321,000,000 gallons, which is represented as the ordinary winter flow; it increased gradually in five days to 350,000,000, 430,000,000, 588,000,000, 636,000,000, 702,000,000, and 742,000,000, which was the highest it arrived at. I submit that that must go some way to prove the capacity of the Thames basin to supply water if the surplus be stored in winter, to compensate the rivers for what may be taken out of them in summer. It will be observed that Mr. Stacey represents the ordinary winter flow at Wolvercot as about $4\frac{1}{2}$ the ordinary summer flow, instead of $2\frac{1}{2}$ times as I prefer to take it."

At Lechlade the Thames and Severn Canal joins the Thames, and higher up the North Wiltshire Canal joins the Thames and Severn Canal. Mr. Denton proposes to purchase those canals and utilize them for the collection of the waters of the Thames above, and then to bring the water from Lechlade to London by a conduit, 127 miles in length. This conduit would collect the waters from the various tributaries, the Coln, the Leash, the Windrush, the Evenlode, the Cherwell, and the Ray, into a concentrating reservoir just below Oxford; then, passing down from Oxford to London, the Ock would be in the same way brought under contribution, as well as the Thame, the Loddon, and the Hertfordshire Coln. The main conduit would start from Lechlade at a height of about 220 feet above ordnance datum, and would bring the water to Hampton, where Mr. Denton proposes to deliver it to the present water companies, for them to raise to high-service reservoirs for distribution by gravitation.

He proposes to have compensating reservoirs on the impervious bed of the Oxford clay.

The Wey and the Mole would have a separate system, and be added, when the demand increased. The water from the upper portions of each stream would be brought down by a channel above the surface of the ground of the main valley, so that no flood water or polluted water could enter.

1603. He proposes to intercept the sewage in two ways; for a certain distance up each contributing stream it would be by open drains, but above that (and in fact wherever it would be more economical), there should be compulsory power to raise and apply it to the hills, so as to favour a complete absorption of the sewage into the soil. Mr. Denton says—

1620. "Such a plan must be preferable to irrigation on low meadow ground, where the effluent water, passing *over* instead of *through* soil, must always be charged with a certain proportion of sewage in solution, if not also in suspension. A study of the geological character of the upper portions of the Thames basin—the chalk and the oolite—will satisfy you that, maintaining as they do the river system of the Thames, they are capable of absorbing sewage to any amount, with benefit rather than injury to the springs themselves."

The cost of the works is estimated by Mr. Denton at about 5,320,000*l*.

He does not propose that the cost of the interception of the sewage should form any part of his scheme, as in two years the towns will be bound to carry it out themselves.

6838 et seq. 69. *Mr. T. C. Brown* of Cirencester has given valuable data as to the rainfall in the upper part of the basin of the Thames, from 1845 to 1868; it varied from 19·9 inches in 1854 to 48·8 inches in 1852, and the mean of the 23 years gave 30 inches. He gives information as to the sources of water in the Upper Thames district, and suggests that London might be supplied with pure water, for drinking purposes only, to the extent of say six to nine millions of gallons per day from these sources, conveying it to London by pipes along the Great Western Railway.

App. H. 70. *Mr. Bravender*, land agent and surveyor at Cirencester, who has also devoted
6888 et seq. careful attention for a long period to the upper part of the basin of the Thames, gives important geological and hydrological information on the subject, which will be found in his evidence and in Appendix H.

Regarding the springs in the oolites, we may make the following extracts:—

6906. What is the sum total of those various springs which you have described; you have described Boxwell spring which gives a yield of above 1,000,000 gallons a day, and you say that the pump at the Thames head delivers 3,000,000 gallons a day; can you enumerate the other springs?—There is a spring at Ewen which gives the same as Boxwell spring, or a little more than 1,000,000 gallons. There is Ampney spring at Ampney Crucis, two miles east of Cirencester, which is thrown out from the fuller's earth by a fault, and which gives out an enormous quantity. I find in April /66 I measured the entire flow near the mill and found it to be considerably more than 20,000,000 gallons in the day; and yesterday I visited this spring and carefully measured the flow of water, and find that upwards of 30,000,000 gallons were passing the bridge near the mill. I also visited Bibury spring and found it discharging rather more than the one at Ampney Crucis. There is a spring about a mile above that at Ablington which I have also gauged, and that gives out quite enough to turn a mill; the discharge is more than 2,000,000 gallons. Then there is a spring above Winson from the same source which gives out about a million and a half. The Bibury, Ablington, and Winson springs are on the Coln, the Ampney spring is between the Churn and the Coln, the Ewen spring falls into the Thames at Ashton Keynes and does not get into the Churn.

6907. What are the limits of height above the sea within which those springs occur?—They are all about the same level as Cirencester, or a little higher, from 300 to 380 feet above the sea.

He proposes to add about one-third to the present supply of the water companies, by collecting water in the valleys of the Churn, the Coln (Gloucestershire), the Windrush, and the Ock, and conveying it by a conduit or pipes to London.

Mr. Bravender estimates that about 9 to 11 inches of the mean annual rainfall is available over the whole district.

CLASS II.

From the Lee.

71. The possibility of increasing the supply from the basin of the River Lee, by storage reservoirs or otherwise, has been alluded to by several witnesses, but the only definite plan laid before us for this purpose is the following:—

Mr. Mylne's Plan.

72. Mr. R. W. Mylne, son and formerly assistant of the late Mr. Mylne, who was for 50 years engineer of the New River, has proposed a plan for increasing the supply of water from the basin of the River Lee, which is described at great length in his 4972 et seq.
evidence, and is illustrated by the map, Appendix Z.

He proposes to make the drainage area better available by collecting the streams and chalk springs into impounding reservoirs to be formed at various places, but principally at Enfield Chase, which, being on the London clay, is, he conceives, more favourable for the purpose than any sites that can be found on the Lee proper.

This plan would, he states, bring 70,000,000 gallons daily into London, in substitution for the present supplies of the New River and East London companies, adding therefore about 28,000,000 gallons. This would be, he says, a minimum on the driest years.

The cost of these works, excluding compensation, is estimated by Mr. Mylne at 1,250,000*l*.

The following extracts from Mr. Mylne's evidence will illustrate the nature of his plan:—

"In contradistinction to the view recently put forward, that no means of storage could profitably be carried out without descending as low in the valley as Broxbourn or Waltham, it is herein suggested that a considerable quantity from the upper tributaries mostly of pure spring water might be diverted and transferred by gravitation from a point above Hertford direct to convenient sites for reservoirs at Enfield Chase on the 4995
London clay beyond and altogether outside of the watershed of the upper portion of the Lee basin, and a further quantity might be impounded within the basin in the valley of the Rib. It is proposed to make diversion cuts on the before-named four tributaries, viz., the Lee proper, the Mimram, the Beane, and the Rib, and convey the collected quantities along an artificial channel to a point in the valley 2½ miles above Hertford; the total contributing area would be 246 square miles, giving an average daily yield of 43,000,000 gallons, but it is only proposed to take 40,000,000 gallons, and to convey that volume in a direct line to London through a tunnel and covered channel 5½ miles in length into reservoirs proposed to be made on Enfield Chase. The two proposed reservoirs to be made, into which the waters would gravitate, will cover an area of 270 acres, and will contain, including the tunnel, 1,391,000,000 gallons with a top-water level of 130 feet above Trinity high-water mark and a maximum depth of 37 feet of water. . . . . . . In order to increase the extent of reservoirs on Enfield Chase, and to bring a higher water level into use for distribution, it is proposed to construct four further reservoirs at the additional height of 36 feet, and to lift into them by steam power a considerable portion of the collectable quantity entering into the two gravitation reservoirs previously described. These will cover an area of 340 acres and will contain 1,249,000,000 gallons, with a top-water level of 166 feet and a maximum depth of about 38 feet of water. The total storage capacity of the six reservoirs on Enfield Chase would therefore amount to 2,640,000,000 gallons or 423,552,000 cubic feet. The execution of the tunnelled part would be throughout its length entirely in chalk and being near to the upper surface of the chalk and overlaid with tertiary sands and intersecting the local disturbance already alluded to, as well as across the general dip of the chalk, no doubt a considerable quantity of water may be expected. It is assumed that from the tunnel works, with the additional seven square miles of gathering ground at its southern end, together with the Lee tributaries, it will secure a total daily yield of at least 47,000,000 gallons. The storage capacity necessary for securing a uniform daily flow has been ascertained at Feilde's weir to be for 118 days 66,000,000 gallons a day, and inasmuch as the volume is proportionably much larger and more constant from the upper tributaries, it is estimated that a provision of 90 days' storage would be quite sufficient for the intended gathering ground. On the Rib it is proposed to adopt the plans designed by the late Mr. Rendel for the reservoir below Standon, which exceeds 200 acres, and would hold above 500,000,000 gallons, with a maximum depth of 20 feet of water. . . . . . . Besides the works contemplated for the diversion of the upper tributaries of the Lee, it is intended to retain the New River channel for the flow of the Chadwell spring, and to collect all the springs issuing from the west bank of the valley between Amwell and Rye House, and lift them by steam power about 10 to 15 feet into the New River; also to purchase the water rights of the copious springs which now work Hoddesdon Mill and to collect those and others in the locality, and lift them also from 15 to 20 feet into the New River. Those sources, it has already been stated, may be calculated upon to yield the respective quantities of 4,500,000, 6,000,000 and 8,000,000 gallons per day, and out of the gravels and sands near Hoddesdon, where the water is assumed to absorb and soak away into the sands under the London clay, a quantity of at least 4,500,000 may be estimated, and could be lifted into the New River at a height of not more than 20 feet. A very much larger quantity from this source might possibly be obtained, but perhaps only effectively by longitudinal adits or driftways up the sides of the valley, works which are not contemplated in the present scheme. The collective quantity of all these strictly spring waters could be secured at a very small cost, and would amount in quantity in dry seasons to about 23,000,000 gallons per

day, a volume equal to the present flow in the New River, and therefore, notwithstanding the proposed abandonment of all further abstraction of water out of the Lee at Ware, the New River would remain in its present condition as to volume as far down as Enfield, where further works are suggested. . . . . . With regard to the manner of distributing the total daily yield of 47,000,000 from the store reservoirs and 23,000,000 gallons from the New River, in all 70,000,000, there are various modes of division that might be made, but considering that two companies have to be provided for, it is suggested that the East London Company should have 30,000,000 delivered over 24 hours, from filter-beds placed at the foot of the high-level reservoirs, and pipes from thence to Stamford Hill, delivering at the level of 112 feet into a service reservoir. The East London Company have a small reservoir at Stamford Hill, and I propose by means of a large main to deliver there at the level of 112 feet, and from thence the distribution over the whole of the East London district would be by gravitation, except perhaps a small area immediately in the vicinity of Stamford Hill itself."

5000. "The advantages to the East London Company are, that the water would be drawn from a purer source than at their present intake, being freed from the valley drainage and future cost of diverting it, and obtaining a gravitation supply in lieu of pumping, and the New River Company would have an increase and improved supply, freeing them from the necessity for many years to come of looking to the river Thames or other distant sources, but confining their endeavours to within the legitimate and as yet unutilized valley waters of the river Lee."

5024. "That would be 63 days' storage on Enfield Chase, with a further storage on the river Rib."

CLASS III.

From the Chalk Formations in the Basin of the Thames.

73. Many witnesses have alluded to the great natural storage of water in the porous strata, chiefly the chalk, which form so large a portion of the drainage area of the Thames basin. By reference to the geological map (Appendix Y.), and to the evidence of
3041. Mr. J. T. Harrison, it will be seen that out of 3,676 square miles of surface no less than 1,047, or two-sevenths of the whole, consist of the chalk downs so well known, and extending so widely over this part of England. These strata absorb and store a large portion of the rainfall; and although much of this store finds its way by springs into the streams, and so already contributes to the supplies drawn from them, there has always been a desire on the part of those interested in water collection to go in preference directly to the stores themselves.

The water in the chalk round London has repeatedly been proposed as a source of supply, either wholly or partially, for the metropolis. The New River was constructed to take advantage of chalk springs, and a large portion of the water it at present conveys comes from this source.

It is on record that in 1827, Martin, the artist, proposed to bring the water of the Colne (the principal chalk river to the north of London) to the metropolis, and Mr. Telford, in 1834, proposed to supply London from the Verulam and the Wandle, both effluents directly from the chalk. A few years later, in 1840, a company was started called the London and Westminster Water Company, who chose Watford as their source, backed by a strong approving report from the late Robert Stephenson; and some years later this was revived under the name of the London (Watford) Spring Water Company.

The Chemical Commission of 1851 devoted considerable attention to the examination of the chalk water, and recommended it strongly as the best supply for the metropolis, on the ground that the quantity was large, and the quality superior to that of any other water that could be obtained. The following extracts from their Report will illustrate their views on the subject:—

"The water which it is proposed to bring from the neighbourhood of Watford, for the supply of the metropolis, claims consideration as being entirely spring water, and has a peculiar scientific interest as representing the pure primitive basis of the river water which is at present consumed. A supply of water of the same description is also offered from the south side of the river, to be derived from the chalk strata upon the line of the South-eastern Railway, and the quantity attainable on either side is said to be so considerable as to exceed the actual requirements of the metropolis. Of the chalk district, which surrounds London on all sides, and covers an area of not less than 3,000 square miles, the upper strata appear to be charged with water to a height of several hundred feet above the level of the sea. This water issues again in numerous natural springs, or may be reached by moderate boring. The daily yield of single springs or of artificial wells in some parts of this district is remarkable for its quantity, often amounting to 300,000 gallons, and occasionally rising to 1,000,000 gallons and upwards; a copiousness of flow, which is referred to the chalk rock being highly pervious to water, from its fractured and cavernous state. This chalk spring water is not to be confounded with the water of the deep wells of London, although the latter are carried into the chalk strata below the clay, but differs as completely in composition from the latter as any two waters can well do. Nor does any evidence exist of a relation or dependence of the London deep wells upon the water of the chalk districts; nor reason to infer that the yield of the latter would be restricted within the narrow limits of the former. Indeed, all grounds for comparison of the two waters will disappear if it is true, as many well-informed persons believe, that the

deep wells of London draw their supplies chiefly from the sands under the blue clay and above the chalk, the water of which sands appears to flood the upper beds of the chalk. The superposition of the thick mass of strata which form the London clay, certainly alters considerably the condition of the chalk below it, and renders it no longer comparable with the water-bearing strata of chalk in Hertfordshire and Kent, which are not so covered, and are situated above the level of the sea. The whole original supply of the New River Company, from the Chadwell and Amwell springs, was water of the kind under consideration, and a very sensible proportion of the present large supply of that company is still spring or well water of the same nature."

"On comparing the Watford spring water with the New River water and Thames water as supplied by the water companies, a considerable similarity is observed in the character of their saline constituents. The lime is in larger quantity in the spring water, but then it is nearly if not entirely in the state of carbonate. The earthy sulphates, which give rise to permanent hardness, are almost entirely absent from the spring water. The general character of this supply may be further described as follows:—

"1. The spring water contains no matter in suspension to cause turbidity or colour; its clearness and brilliancy are unexceptionable.

"2. It possesses a desirable coolness, having at all seasons a temperature between 50° and 52°.

"3. The amount of organic matter it contains is inconsiderable, and of a kind which appears to be incapable of undergoing putrefactive decomposition, so that it may be safely disregarded.

"4. The salts which it contains would not interfere with its use as a beverage. It is indeed a choice water for drinking."

We have received the four following propositions for utilizing this source.

74. The *Rev. J. C. Clutterbuck*, who has paid much attention to this subject, gives his 1782 et seq.
views upon it at considerable length.

He believes that considering the large chalk springs issuing at high levels in various places round London, it would be possible to find in such springs a considerable quantity of water, of good quality. The most reliable sources are springs in the chalk, and speaking of their abundance he says:—

"Along all valleys in which rivers run, the Kennet, for instance, the chalk streams are fed from their 1836.
sources down to the place where they deliver themselves into the river, because they run just on the springs, and are fed as they go. You may not see very large springs, but you will see an immense gathering of water in the course of the river by the discharge of the water from the springs."

He disapproves, however, of obtaining the water from the chalk by pumping, in regard to which he says:—

"You would obtain a certain quantity, but it would be at the expense of the rivers; the rivers would 1837.
cease to flow. When my advice has been asked I have invariably said, Take the water as it flows above ground, and do not tamper with it below; that is what I have invariably said, and I believe it is sound advice."

By taking the water as it flows down the rivers, and by an arrangement of reservoirs, he considers there might be an immense storage of water in the upper districts.

The springs in the chalk under London have, he considers, been over-taxed, and the consequence has been an unnatural depression of the water. Any hope of obtaining a supply for the metropolis from this source would in his opinion be a failure.

75. *Mr. Homersham*, civil engineer, who has supplied Caterham and other districts with 6762 et seq.
water drawn from the chalk areas round London, proposes to supply the metropolis entirely with spring water from the chalk, and to do away with the present supply taken from the Thames. He believes that there would be no difficulty in getting from this source a very large quantity. The cost would be small, by reason of the readiness and cheapness with which water can be obtained from the chalk in well-selected situations. He considers that any objection to the hardness of chalk water may be obviated by the use of Dr. Clark's softening process, in which he has had considerable experience.

The water at Caterham appears by Dr. Frankland's analysis to be remarkably free from App. AX
organic matter. (2.)

76. *Mr. P. W. Barlow*, civil engineer, believes that the ultimate solution of the difficulty 5959 et seq.
of supplying London will be found in the chalk. He has found several powerful springs issuing from the chalk on the south side of the Thames; in one small district near Gravesend they amount to 10,000,000 gallons per day. He believes that by driving a tunnel parallel with the river, 20 miles long, from Lewisham to Gravesend, or a little beyond, 60,000,000 gallons per day might be obtained.

77. *Mr. R. Meeson* has given us an account of large springs issuing from the chalk pits 6863 et seq.
at Grays, in Essex, and which furnish an abundant supply. The water is of good quality, limpid and of uniform temperature, very similar to that of the Amwell springs, but rather harder, being 16·6° of Clark's test. About 450,000 gallons per day are at present used to supply Brentwood and Romford and parts adjacent. About

7,000,000 gallons per day have, however, been raised, and Mr. Meeson believes the springs would supply 10,000,000 at least.

We add some extracts from Mr. Meeson's evidence:—

"The water springs are situate in the chalk pits at Grays in Essex, about a mile distant from the Thames. When undisturbed they rise to a height varying from about four feet to eight feet below Trinity high-water mark. . . . . . . The depth of water which passed over the gauge, which was 3 feet 8 inches wide there, was $5\frac{1}{4}$ inches, so that the quantity then obtained every 24 hours exceeded 2,100,000 gallons, besides that used on the works. This quantity was delivered daily, the engines being worked day and night, ceasing for only a few hours between Saturday evening and Sunday morning. During the week the water was lowered about 12 feet, and it then became possible to excavate the chalk to that additional depth over a small space; but when the engines ceased working the water speedily rose to its former height, and it occupied an entire day and night so to reduce the water as that work might be resumed; and throughout the entire remainder of the week the springs yielded the supply I have mentioned, which was all that the pumps then in use were capable of delivering. . . . . . . These operations have been carried on now for many years, yet notwithstanding so large a quantity has been pumped daily into the Thames, no perceptible alteration has taken place in either the quantity or quality of the water."

CLASS IV.

Miscellaneous Schemes.

Mr. Hennell's Plan.

1913 et seq. 78. Mr. Thomas Hennell proposes to bring 14,000,000 gallons of water per day to London, in extension of the present supply, from the Basingstoke Canal, and from sources adjacent to it, aided by storage reservoirs to hold 840 millions of gallons. He would purchase the canal from the company and use it as a conduit, forming a paved brick channel throughout its length.

He calculates that six-sevenths of the water would come from the chalk at the Basingstoke end of the canal, where it is 252 feet above ordnance datum, and the remainder from the district of the Bagshot sands between Farnborough and Woking. The quantity might, however, be largely increased.

In answer to questions respecting the springs intersected by the canal in passing through the chalk below Basingstoke, Mr. Hennell states:

2013. "To take first the Whitewater; that I found in October contained, in round numbers, 10,500,000 gallons. I propose to take one-third of that, and that is rather the largest of the three principal sources."

2014. "I measured the stream again last week, and I found 14,500,000 gallons daily. Then, in addition to that, there are the Mapledurwell and the Newram springs within a mile of Basingstoke."

2015. "The Mapledurwell springs contain 1,980,000 gallons. There are springs east and west of the village; those which are on the east side of the village I cannot conveniently take, because they are at a low level, but they unite afterwards, and therefore I take two-thirds of the western springs only, which would be equal to one-third of the whole. They unite before they come into any stream where they would be required, and therefore I take two-thirds of 1,980,000, that is 1,320,000. Then the Newram springs contain, in round numbers, 4,500,000, of which I take two-thirds; that is 3,000,000."

2016 "The entire total is 28,296,000."

The water would be conveyed by the canal to a point near Weybridge, from whence a conduit eight miles long would have to be made to Thames Ditton, where the water would be received by the companies and pumped for the supply of the town.

The estimated cost, including the purchase of the canal, is set down by Mr. Hennell at 280,000*l.*

Mr. Ewens' Plan.

3685 et seq. 79. Mr. G. W. Ewens points out the existence of certain springs in the chalk from Emsworth to Bedhampton near Chichester, from which he believes a large quantity of pure water might be obtained of a quality very similar to New River water. He mentions springs of this kind at Emsworth, Havant, Bedhampton, Brockhampton, and Langbourne, and adds:

3699. "There are six streams formed by nine separate series of springs; each of these streams flow into the sea at an average distance of half a mile from the spot from whence they take their rise. There are eight flour mills driven by these six streams."

The water might be pumped into large reservoirs on Portsdown Hill and near Petersfield, and conveyed by a conduit to London.

Mr. Telford McNeil's Plan.

5815 et seq. 80. Mr. Telford McNeil proposes to give a supply of 200,000,000 gallons daily by intercepting water from the Thames at Teddington, raising it 200 to 380 feet, and conveying it in an open channel to the Bagshot sands, through which it is to be made to filter, and from which it is to be conveyed back in a closed conduit to London, and

again pumped into reservoirs at Norwood and Hampstead. The estimate is something above 6,000,000*l.*

Remarks on the above-mentioned Plans.

81. The chief feature of Mr. McClean's plan is the mode by which he proposes to effect the storage in the Thames, and this may deserve consideration whenever it may be found necessary largely to increase the quantity of water drawn from the river. The plan for taking the water from Medmenham would be very expensive, and, probably, of doubtful utility as regards quality (for reasons that will hereafter be shown), while it would be open to the objection of depriving the 37 miles of river between Medmenham and Hampton of a large proportion of its dry weather volume.

The plan of Mr. Bailey Denton, a gentleman of very large experience in drainage matters, is remarkable on account of the manner in which he proposes to deal with the sewage. His opinions also as to the mode of increased storage are valuable.

Mr. Brown and Mr. Bravender point to the value of the springs in the oolites as subsidiary sources of supply.

The plan of Mr. Mylne for increasing the supply from the Lee presents some ingenious and novel features. By the proposed mode of collection he would obtain the water in a state of greater purity than at present, while the mode of storage also claims advantages over former plans. We question whether the quantity Mr. Mylne estimates could be rendered available in the driest seasons, but if any measures should be considered desirable for enlarging and improving the supply from the Lee, his plan would deserve consideration.

With respect to the water sources in the chalk formations we shall speak more at length hereafter. Mr. Meeson's springs at Grays deserve special mention on account of the practical use already made of them by him.

Mr. Hennell's plan has some novelty, but the water might probably be more advantageously utilized for other towns nearer the line of canal.

Mr. Ewens calls attention to some fine springs; they are too far away to be of use for London, but might probably be of value to towns in the neighbourhood.

GENERAL REMARKS ON THE SOURCES AND SPRINGS IN THE THAMES BASIN.

82. It may now be well to review all the resources of the Thames basin before we proceed to consider the important question of the future supply of the metropolis.

83. In order to explain the geological and physical features of this tract of country we have had prepared the large map of the Thames basin marked Appendix Y (1). It is drawn on the scale of six miles to an inch; it shows by colours the various geological formations; and it has contour lines marked upon it at every 100 feet difference of altitude, by which the levels of the ground at the various parts of the basin may be seen. Another corresponding map, Appendix Y (2), has the contours shaded, by which the varying elevations of the ground are made more distinct.

84. The drainage of the Thames valley above Kingston extends over 3,676 square miles; this area receives an average annual rainfall of about 27·2 inches, and one-third of the quantity due to this rainfall flows down the Thames at Hampton.

This delivery is the result of very complex conditions. One third of the area consists of impermeable clays, and two-thirds (or about 2,450 square miles) of permeable oolitic limestones, sands, and chalk. From the former, the rainfall, after allowing for evaporation and for vegetation, flows off at once, and whenever in excess gives rise to floods, whereas the rainfall on the latter is at once stored up, and its ultimate delivery through springs to the streams and rivers is spread over weeks or months. To this cause is owing the permanence of flow of a river draining a permeable rock district, compared with the irregular delivery of a river draining an impermeable district, and it is a consideration of great importance in a question of water supply.

85. In order to indicate the extent of the underground reservoirs formed by the permeable strata, and the sources on which the springs depend for their supplies, we have constructed a series of sections, shown in Appendix Y (3). A complete and elaborate survey would be necessary in order to give the exact lines, whether of the surface of the ground or of the levels of the underground water, but these sections will serve to give an

idea, sufficiently approximate for our object, of the extent and capacity of the underground reservoirs on which the streams depend for their supplies during periods of drought.

86. All permeable formations tend necessarily, by the absorption of rain, to become charged with water up to the level generally of the streams and rivers of the district; and further, owing to the resistance experienced by the rain water in passing through the strata, the water, wherever the ground rises above the level of the rivers, accumulates therein in proportion to the length, breadth, and height of the range of hills, so that instead of the line of underground water level presenting a flat surface between two valleys, it presents a curved surface varying according to certain conditions. Taking the lowest point of escape as determining the permanent level above which all the water tends to run off in springs, the height of the curve above this level gives the head of water on which the springs depend for their supply. The rise of the water being from the circumference of the hills to the centre, the underground reservoirs form more or less dome-shaped masses, the surface of which is constantly fluctuating in proportion to the difference between the amount of rain percolating through the strata and the quantity of water which escapes by the springs.

In the district we have to deal with, the crown of the curve often rises 50 to 200 feet or more above the permanent spring levels, while the actual height of the curve is known to vary in accordance with the variation in the rainfall, in many cases as much as 50 to 80 feet or more. Where the conditions are favourable to a large underground reservoir the springs hardly ever run dry. Mr. Beardmore, as the result of many years' observations in the chalk district of the Lee, sees reason to believe that the storing power of the chalk hills there holds out at least 16 months.

The darker water lines in the sections represent the upper portion of the head of water accumulating in the hills, and serving to feed the higher and smaller springs; the next shade shows the larger portion which goes to feed the lower and more perennial springs. The portion of the sections over which the faint water lines extend represents theoretically those portions of the permeable strata which are permanently charged with water, and from which wells can always draw a supply—in sand strata at once, and in the more compact limestones and in chalk as soon as any of the intercommunicating fissures or crevices are reached, unless any excessive exhaustion has produced a local depression of the water level.

Further, some of the water below the lines of permanent level inland has a slow underground movement to still lower levels, unless intercepted or thrown out by faults in the strata or by some other cause. This underground drainage is not, however, coincident with the surface drainage; and while some of the water-bearing strata of the Thames basin are not available as underground sources of supply by means of wells at or near London, other strata, on the contrary, out of the London basin, are so available from the circumstance of the dip of the beds being towards London. The extent of this underground area supposed to centre towards London is represented by dotted lines on the map, Appendix Y (1).

Where the permeable strata only cap the hills the springs issue of course on the sides of the valleys at the junction of the impermeable strata.

87. In the order of superposition the highest permeable strata near London, excluding the superficial beds of gravel, are—

The *Bagshot Sands*, which are from 100 to 350 feet thick and extend over an area of 211 square miles. As these strata consist almost entirely of loose quartzose sands, the underground water oozes out commonly at their junction with the London clay, and is rarely conducted into any particular channel of escape so as to form springs, and the loss by evaporation is large. There are in fact throughout this area no springs of any importance; only a few small tributaries of the Thames and the Wey have their sources in this district, and the supply to the wells is not large. The water generally is soft and pure, but in some places it is ferruginous. We cannot look to these sands for any additional water supply, (although they attracted a good deal of attention a few years since,) for the whole of the water now delivered by them passes into the Thames or the Wey. None passes elsewhere underground.

The *London Clay* underlies the Bagshot sands and forms a great impermeable bed from 400 to 450 feet thick.

Lower Tertiary Sands.—These beds, which are only from 50 to 100 feet thick, are of no importance so far as springs are concerned at their outcrop, but they have been useful sources of supply to some of the deep wells under London. Owing, however, to the great increase in the number of these wells, and the fall in the level of the water, the underlying chalk is now generally resorted to as the better source of supply. In many places round London where they have not been so drawn upon they still yield a good supply of water.

88. The *Chalk*, from its large area (1,047 square miles above Kingston, but more than double that in the whole basin); from its great thickness—500 to 1,000 feet—and from its peculiar lithological character, forms a very important source of water supply, both by springs and by means of wells. Almost all the rain falling on its surface is absorbed or percolates through the fissured surface. So close is its texture that the bulk of the rain takes weeks and months to filter down to the level of the water line in the interior of the chalk hills—a line the depth of which below the surface of the ground may vary from 100 to 300 feet according to the height of the hills. The water thus stored escapes in several ways—some by the streams rising within the chalk district,—some by springs feeding directly the larger rivers flowing through it,—another portion overflows at the outer escarpment of the chalk,—and a larger portion issues near its junction with the tertiary strata. A certain quantity also passes underground, supplies the wells, in the central tertiary area, and escapes in part at still lower levels at more distant points.

Where the rise of the bottom of the valleys is more rapid than that of the line of water level, the valleys assume the character so common in chalk districts, of dry valleys. Others of these valleys tap the springs in their lower part, whilst the upper part of the same valley is dry. In these cases the head of the stream will often change its position two or three miles higher or lower in the valley, accordingly as the rise and fall of the water level in the hills are influenced by the rainfall. Where the deeper and larger river valleys traverse the chalk area and intersect the line of water level, these valleys become fringed on the river level with a series of springs, as the Thames in its course from Wallingford to Taplow, the Lee above Broxbourne, the Ravensbourne, the Cray, and the Darenth, and the Thames again from Woolwich to Gravesend.

The springs along the line of outcrop of the chalk marl and gault being on a higher level than any others, the head of water supplying them is much smaller than that supplying the springs on lower levels within the chalk area, and consequently with few exceptions these springs are small. They are, however, extremely numerous. Almost every little village under the range of the chalk downs in Wiltshire, Oxfordshire, and further eastward, has its spring near the foot of the chalk hills. These collectively would furnish a considerable quantity of water, but they are too scattered and wide apart to be available for any general purpose. There are, however, a few large springs amongst them. There is one, for example, at Cherhill near Calne. This spring never fails, and is said to yield from two to three million gallons of water daily. It is represented at the end of section No. 4, Appendix Y (3). There are also copious springs near Ellensborough, at Barton-in-the-Clay near Prince's Risborough, near Swindon, and at many places along the foot of the North Downs of Kent and Surrey.

Another and more important class of springs are those which escape along the inner edge of the chalk along or near the line where it passes under the tertiary strata, and again where it approaches the sea level. These springs are all placed on relatively low levels, and derive their supplies from the large head of water which extends in the chalk hills beyond them up to the outcrop of the beds underlying that formation. As the difference of level between these exterior and interior springs varies often from 150 to 300 feet, the latter are necessarily much more powerful and permanent, and will continue to run long after most of the others have become dry. Among the more copious and remarkable springs of this class are those at Chadwell near Ware, Otter's pool near Watford, Froxfield near Hungerford, Beddington and Carshalton, Orpington, Grays Thurrock, Springhead near Gravesend, Ospringe near Faversham, besides a number of smaller ones. The origin and source of supply of some of these springs are indicated in the sections.

In the neighbourhood of London the wells in the chalk form an important auxiliary source of water supply, and they might, no doubt, be considerably increased in Kent without interfering with the springs in the valleys above London, as the store from which those wells draw their supplies overflows in numberless springs along the Thames below London at levels where they are not generally available.

The lower beds of the chalk are so argillaceous as often to hold up the water and to lose their ordinary permeable character.

89. The *Upper Greensand* forms so much a part of the lower chalk, and is so slightly developed near London, that we have grouped it with the chalk. It is only in Wiltshire that it acquires an importance entitling it to be considered apart. Under London it becomes also so argillaceous as to lose its water-bearing character.

The upper and lower Greensands are separated by 100 to 200 feet of impermeable clay, known as the *Gault*. The numerous small streams rising at the foot of the chalk hills have their source generally in springs thrown out by the chalk-marl, or the gault.

The *Lower Greensands* form a mass of siliceous sandy strata from 200 to 500 feet thick, and with an available area of above 500 square miles. Cropping out both to the north and south of London conformably to the chalk, which is known to pass below the tertiary strata under London, it was supposed that the Lower Greensands were also continuous below London, in the same way as the Lower Greensands of the plains of Champagne pass under Paris at the depth of 1,800 feet. The experience, however, obtained at Kentish Town, at the deep well sunk through the chalk a few years since by the Hampstead Company, showed that although the tertiary strata, the chalk, and the gault followed in regular order, a change took place at the base of the gault, and instead of the lower greensands, a series of red and grey sandstones were met with. These were bored into for a thickness of 188 feet without passing through them and the work was abandoned. (Appendix, Y 3, Section No. 2.) No organic remains were discovered to indicate the age of these sandstones, and the hand specimens were insufficient to determine the question. They may have belonged to some member of the New Red Sandstone, or possibly to the Old Red. In any case they seem to form part of an underground ridge of old secondary or palæozoic rocks which, ranging from Belgium, pass under the chalk at Calais and Harwich, at both which places they have been met with, and probably extend under London in the direction of Somersetshire. The width of this belt can only be determined by experiment.

It is known that the Lower Greensands exist at Reigate and are about 450 feet thick, and that they occur again in Bedfordshire with a thickness of about 200 feet. In both cases they dip towards London, disappearing beneath the gault. We know that they do not exist under London (Kentish Town). It follows, therefore, that in the one case they cease at some point between Reigate or Merstham and London, and in the other between Baldock and London. As at both ends they are of considerable thickness, and the gault is continuous, it is certain that the greensands must range from these outcrops some way towards London, probably thinning off gradually against the flanks of the underground ridge of old rocks. So far as they continue, so far will they form a valuable and copious water-bearing bed, the water from which would overflow at the levels lower than that of their outcrop. The extent of their underground range could only be determined by boring. It might be as far as Croydon, or even still nearer to London. The same would happen to the north of London, but the distance there is greater, the beds are not so thick, and the conditions generally are less favourable. The great purity of the water from the Grenelle and other artesian wells in the Lower Greensand is well known, and there is reason to suppose that the quality of the water obtained from the same formation in the vicinity of London would prove equally good. The excessive length of filtration would at all events ensure freedom from organic impurities.

The quality of the water flowing from the Lower Greensands is excellent for all domestic purposes, being bright and limpid, of a degree of hardness varying only from about 3° to 9° of Clark's test, and generally very free from organic matter. A considerable amount of evidence on the quality of this water was collected by the Board of Health in 1850.

The springs in this formation are not very numerous, owing to the prevalence of sandy beds, but in some of the more stony beds there are some fine springs, as for example:—

1. The springs in Bradbourne Park and at Riverhead near Sevenoaks.
2. Several springs near Dorking.
3. Spring at Weston Street.
4. Spring at Moorhead Park near Farnham.

90. To the south of London a great thickness of *Weald clay* separates the Lower Greensand from the *Hastings sand* of the weald of Kent and Sussex; but although these beds are thick they are very local, only partially permeable, and are of no avail.

91. The strata which next succeed are only developed in the north and north-west of the London basin.

The *Portland Stone and Sands* are from 35 to 50 feet thick, and are, in some places, of local importance, but none of the springs would be available for distant purposes.

The *Kimmeridge Clay* is impermeable and from 250 to 300 feet thick.

The *Coral Rag* and *Calcareous Grit* are from 20 to 50 feet thick and give rise but to a few small springs. These beds thin off as they range to the east and south-east, so that in Buckinghamshire and probably underground in Berkshire the Kimmeridge and Oxford clays come into contact, and the coral rag ceases to exist.

The *Oxford clay* is impermeable, and attains in Oxfordshire a thickness of 400 to 500 feet.

92. The *Great Oolite* and subordinate beds may for our purposes be taken together. They form in Oxfordshire an important group of permeable strata 250 to 300 feet thick. They have a collecting area of about 300 square miles, and give rise to a number of fine springs, amongst which those of Ampney, Bibury, Boxwell, and Thames Head have been described by Mr. Bravender and Mr. Brown, and are stated by Mr. Pole to have been yielding at the time of his visit probably not less than 10 million gallons of water daily.

Most of the springs of this series are thrown out by the *Fullers Earth*, an impermeable bed of no great thickness in this district—40 to 60 feet—and persistent only over a limited part of the area. (See section No. 3.)

The *Inferior Oolite* and underlying sands reposing on the lias form another important water-bearing formation. They are from 300 to 320 feet thick, and extend in the Thames basin over about 180 square miles. As the hills of this formation rise 230 to 300 feet above the valleys and have a considerable range, the head of underground water is large and furnishes several important and perennial springs, such as those of Syreford, and the Seven Springs, of which the yield is stated by Mr. Pole to have been at the time of his visit from three to four million gallons of water daily. (See section No. 3.)

These various oolitic strata consist of beds of rubbly limestones, soft freestones, sands and fissile sandstones, through which the water passes chiefly by fissures; and although often traversing a great thickness of strata, it is not filtered to the same extent as it is in the chalk and Lower Greensands.

Mr. Hull has shown* that the inferior oolite and underlying sands, which in the neighbourhood of Cheltenham are about 320 feet thick, thin off as they range eastward, and probably die out about the centre of Oxfordshire. In the same way he shows that the great oolite and accompanying beds, there about 300 feet thick, also thin to the eastward, and they apparently do not extend more than a few miles further east than the inferior oolite.

It follows that the underground passage of water through these oolites, which might, had these formations ranged in full force eastward, have been carried as far as London, the dip being in that direction, is stopped by the thinning out of those beds, and by the closing in, as it were, of the Lias, Oxford clay, and Kimmeridge clay. Although, therefore, the surface drainage of the Cirencester and Bampton districts runs into the Thames valley, the subterranean water channels are intercepted and do not reach London, and the oolitic series must be excluded as a possible source of supply by deep wells in the London district.

93. The exact proportion of the rainfall absorbed by the different permeable and porous strata, and which is given out again in the form of springs, yet has to be determined. It varies according to the lithological character of the water-bearing strata. The general results are, however, known in many cases. Thus the annual flow of the Thames at Hampton and of the Seine at Paris, both draining areas composed partly of permeable and partly of impermeable strata, is equal to about one-third of the rainfall. In a district where the impermeable strata predominate, the total deliveries will be larger, but they will follow close upon the rainfall; whereas, as the permeable strata predominate, so will the rainfall be stored in the hills, and its delivery be spread over a greater length of time. The summer flow in a dry season consists almost entirely of the supplies derived from deep-seated springs. Mr. J. T. Harrison, to whose evidence we would refer for many interesting details on these points, estimates this generally in the Thames district to be equal to one-sixth of the rainfall.

94. The importance of such a condition of things for the supply of this large metropolis cannot be over-estimated. It ensures that permanence and regularity which are necessarily among the most important elements in a metropolitan water supply. With natural subterranean reservoirs extending over above 2,000 square miles, a storage reserve is provided comparatively independent of the seasons, and maintained by the ordinary operations of nature, while no filtration can equal that effected through masses of sand, sandstone, earthy limestones, or chalk, from 50 to 300 feet thick. The quantity of mineral matter taken up is in most cases moderate, while the really objectionable ingredient—the organic matter—is reduced to a minimum. However different the results obtained in

* Quart. Journ. Geol. Soc., vol. xvi. p. 63.

other cases, the two under-mentioned eminent chemists agree in their conclusions on this point, as will be seen by the following table, the quantities having reference in the first case to 100,000 parts, and in the second to a gallon of water:—

—	Dr. Frankland.			Prof. Wanklyn.
	Organic Carbon.	Organic Nitrogen.	Nitrogen as Nitrates and Nitrites.	Albuminoid Ammonia (representing the Organic Matter containing Nitrogen).
Caterham well (chalk) - - -	·020	·006	·027	0·000
Spring near Moor Park (lower greensand) -	·030	·010	·045	—
Cold Harbour (lower greensand) - -	—	—	—	0·000
Otter Spring (chalk) - - -	·026	·012	·422	—
Loch Katrine - - - -	·256	·008	·031	0·130
Welsh waters - - - -	·289	·004	·022	—
Cumberland Lakes - - - -	·211	·006	·009	—
Thames water at Hampton - - -	·260	·024	·192	0·134

At the same time the water is kept at a uniform low temperature and protected from light and air, conditions unfavorable to the existence of living organisms. Springs from such sources probably represent potable waters in their best state; and amongst the favourable specimens of such waters may be instanced many chalk springs, the water from the lower chalk at Caterham, and some of the springs of the Lower Greensands of Surrey.

It is satisfactory to know that there exists within easy reach of London a supply of the best and purest spring water which, in case of need, could readily be rendered available as an auxiliary source of water supply for the metropolis, in quantity sufficient at all events for drinking, if not for other purposes.

PART III.

ON THE PRESENT WATER SUPPLY OF THE METROPOLIS.

95. We now proceed to consider "the present water supply to the metropolis."*

We have accounts of the existence, at a very early date, of artificial works for the water supply of London, in the form of certain conduits, some of whose names still survive in *Conduit Street*, *Lambs Conduit*, and *White Conduit*, and the object of which was to bring for the use of the inhabitants the waters of local springs; but about the middle of the sixteenth century the metropolis had so increased in extent that these were no longer sufficient, and attention became directed to procuring supplies, by mechanical means, from the fine river running close to the city walls.

96. The first systematic attempt to supply London from the Thames was made by Peter Morrys, an ingenious Dutchman, who in 1581 obtained the consent of the corporation to erect a water-wheel under one of the arches of London Bridge; this, being turned by the tidal stream, worked forcing pumps, which impelled the water through the leaden or wooden pipes in the streets, and thence by branches into the houses. The *London Bridge Waterworks*, thus established, subsequently increased in magnitude, and kept up a considerable supply for two hundred years.

97. But as London extended, Morrys's mains and pumping power were, in that infant state of hydraulic science, insufficient to supply the higher and more remote parts of the town, and attention became redirected to sources inland. In 1606 an Act of Parliament was obtained to enable the corporation to bring a stream of clear pure water to the metropolis, from certain copious springs in the chalk at Chadwell and Amwell, near Ware; but the corporation, alarmed probably at the magnitude of the plan, hesitated to commence the works, and nothing was done until, in 1609, an enterprising citizen, Mr. Hugh Myddelton (afterwards Sir Hugh Myddelton, baronet) offered to execute them single-handed, on condition that the authority obtained from Parliament should be transferred to him. This offer was accepted, and he at once commenced the work; but through a complication of difficulties, and the refusal of the corporation to aid him (although he had brought his canal to within a few miles of London), he was compelled to appeal to King James I. for the means of completing his work. The King furnished the necessary grant of money on condition that half the property in the undertaking should be ceded to him, and in September 1613, the canal, then dignified with the name of the *New River*, was completed, conveying the pure Hertfordshire spring water into the reservoirs at Clerkenwell. Thus was introduced into the metropolis a true systematic "water supply by gravitation," after the manner of the ancients.

98. The New River and the London Bridge works, aided by the local springs, with many public pumps and shallow wells, kept the greater part of the metropolis well supplied with water for the whole of the seventeenth century; but as buildings began to extend westward new demands arose. Soon after the opening of the New River, the chalk springs had been supplemented by tapping the River Lee, near to them, but parts of London required water where the London Bridge and New River mains did not reach, and again the Thames was resorted to for an increased supply. In 1691 a company was formed, called the *York Buildings Waterworks Company*, for supplying a part of Westminster with water pumped from a point in the river near Charing Cross. These works flourished for some time, but were in 1818 leased to the New River Company, and in 1829 were abolished altogether.

In 1723 a more successful attempt was made in the establishment of the *Chelsea Waterworks* for supplying Westminster and the parts adjacent with water from the Thames at Chelsea Reach. The company first purchased some small works at Millbank, but afterwards removed to a site near the foot of the present Victoria railway bridge, where they erected a pumping establishment.

* The information in this part, where not obtainable from official documents, has been taken from Mathews's "Hydraulia" and Weale's "London in 1851," or gained by communication with the officers of the companies.