The Rev. J. C. CLUTTERBUCK said, there were many points to which he wished to direct special attention, both as regarded the nature and varied character of the water-shed, as well as to the question of the navigation and the mills. Some persons went so far as to say, that the navigation of the Thames must be discontinued, and the mills be removed, before any real improvement could be effected in the valley of the Thames. It was true that, as at present regulated, there was an antagonism in the interests of the mills and the navigation, and that by this rivalry damage was sometimes inflicted on the owners and occupiers of land, whilst the sanitary condition of the valley was affected. Now, he believed that, under proper regulation, both the navigation and the mills might be retained, not only without mutual injury, but also with benefit to the public. With respect to the sanitary condition of the valley, he begged to refer to the elaborate and valuable Memoir of Dr. Acland, on the Cholera at Oxford[1] and to the Report of Mr. T. Macdougall Smith, addressed to Mr. (afterwards Sir) W. Cubitt.[2] Referring to the geological rather than the engineering character of the Paper, he remarked that numerous failures in schemes for obtaining supplies of water had arisen from a want of sufficient knowledge of the geological condition of the strata whence water could be procured. It was now more than twenty years since he stated, that the aggregation of causes would produce some great effect upon the pumping under London. The bearing of agricultural drainage on water supply was a subject of growing importance, from the increase in the population of towns, and the large quantities of water now required by the inhabitants. The water-shed of the Upper Thames presented a great extent and every variety of agricultural land drainage. Though at first sight it might seem a contradiction in terms, yet he believed that winter evaporation was promoted by agricultural drainage. Evaporation depended on the condition of the atmosphere, and on that of the surface of the soil. There was little evaporation from the surface of water, but very much from a rough surface exposed to the air. This might be shown by a simple experiment. If two shallow vessels were filled with water, and into one a piece of brick, or some such substance, was introduced, then from this latter four or five times the amount of water would be evaporated in a given time, than from a surface of water alone; of course by the addition of the brick the surface would be increased, but not sufficiently so as of itself to account for the augmented

[1] "Memoir on the Cholera at Oxford in the Year 1854. By Henry Wentworth Acland, M.D., F.R.S.," &c. J. H. Parker, Oxford. London: J. Churchill, Burlington Street.

[2] "University and City of Oxford. Report of Sir William Cubitt upon the Sewerage and Water Supply." Amersham: W. Broadwater.

evaporation. Thus, on the falling of winter rain, there would be a greater absorption of water on the drained surface; consequently, winter floods would be diminished by agricultural drainage. He had applied the recorded readings of Dalton's rain-gauge in a novel manner, by presuming that the quantity of water which flowed from the surface, or was discharged as flood by land drainage, was represented by the water of super-saturation percolating the gauge. The interest felt in this subject, especially at Oxford, was very great. Heretofore it had only attracted attention after unusual and disastrous floods; but he trusted that this spasmodic action would give place to some well-devised and determined action, and it was with this view that he desired the subject to be thoroughly sifted, by those who were best able to cope with the various difficulties that it presented.

Mr. ALDERMAN TOWLE concurred in the opinion, that this subject was of immense importance to the inhabitants of the valley of the Thames. Having formed one of Mr. Pusey's Committee, consisting of six members, to which reference had been made in the Paper, having resided for many years at the lowest part of the Upper Thames, and having had the advantage of attending the practical discourses, delivered on the spot, by the late Dr. Buckland, he could claim to possess some acquaintance with the questions at issue. At Sandford, where all the streams met, there was a gorge, in form like the letter V, the rising ground on the east, which was in Sandford churchyard, approaching very close to that on the west at Bagley Wood. At this point an embankment had been thrown up, which was the only cause of the continuous floods round Oxford; for he contended, that no mill could cause a flood; it would simply divert the water from its course, throw it upon the neighbours, and soon after passing out of the river, it would flow in again. But in this case the mill produced a flood, because the valley, and not the river only, was dammed up. The highest fall in the Thames was upon the flat country, which here inclined towards Oxford. He looked upon this point as the grand mistake of the Thames Valley, and without it was altered, the drainage could not act, as all the disputes originated with the flood at this spot. This great evil arose from the lock at the entrance of the Sandford mill pond having been placed too high, in order, as it was supposed, to raise the high-water level. Before this alteration was made, barges of 160 tons could navigate this portion of the river, whereas now it was impossible for craft exceeding 30 tons to pass the same point. This was the gist of the whole question. It had been lost sight of by Engineers, in the general treatment of the Thames Valley, and had been got rid of in some way by the Thames Navigation Committee and other interested parties.

Mr. ALDERMAN RANDALL said, though he had no pretensions to scientific knowledge on this subject, he could bring the observation of many years to bear upon it. He was well acquainted with the peculiar features of the whole district of the Thames above Oxford, and could speak particularly as to the water being now brought down more quickly than formerly. Agricultural drainage had materially aided this, but he thought that larger operations had caused those sudden floods, with which the neighbourhood of Oxford had specially to contend. Above Oxford, there were some thousands of acres of meadow land, which formerly used to act as natural reservoirs, holding the water in suspension, as it were, and supplying the river by percolation through the summer. Across these meadow districts wide and deep channels had been cut, so that the water was no longer retained on the land, but was at once passed from the marshy grounds into the river; and any heavy rain-fall was, in like manner, conveyed more suddenly to the narrow part of the valley at Oxford, sometimes thus producing summer floods. At the large brewery of Messrs. Hall & Co., close to the old Castle Tower, at the back of which there were several low lying meadows, once belonging to the White Friars, there was formerly, as he was informed, considerable notice of a coming flood by the gradual rise of the river; whereas now the whole of the meadows were sometimes under water within a few hours. There could not be a more practical proof of the suddenness of the flow of water from the Upper Thames on to this district than was furnished by these facts, confirming as they did the opinion that the recently-made large cuttings, as at Aston Mead and at Standlake Common, across marshy districts, were instrumental in producing the evils described by Mr. Alderman Towle, as arising to the locality abutting on the narrow gorge of the river near Sandford. Besides this, however, it should be noticed, that it was at Oxford that the Cherwell flowed into the Thames, and the waters of that tributary were similarly swollen from the drainage of Otmoor Common. Prior to the systematic drainage of this extensive flat, it generally presented, through the winter months, the appearance of a large lake, from the hills, near Bicester, to the Beckley Hills, near Oxford; while now it was rare to witness such a flood after a heavy rain-fall. Even assuming that the natural autumnal fall had been to some extent taken up, by the lands being more thirsty than prior to the adoption of systematic drainage, the Cherwell, from the free influx of the surplus water through the deep channels intersecting the Otmoor district, would become more suddenly charged, and the mischief around Oxford would thus be aggravated, and the probability of flood be increased.

The Author had described the many sources of the perennial

waters of the Thames, as well as the causes specially producing flood water. These sources and causes appeared as existing largely above the gorge at Sandford, which held back the water upon Oxford in flood time, owing, as he believed, to the natural formation of the Valley of the Thames at that point, and not to any other cause. Much weight was to be attached to the remarks in the Paper, as to the changing deposit of gravel and soil in the bed of the river. He had himself witnessed a special illustration of the bad consequences of this below Sandford Mill. In 1862 he inspected, in company with one of the University Professors, the state of the river, then swollen by flood water, from Oxford to Abingdon. At the lower pound gate at Sandford, the water was nearly 3 feet above high-water mark. On the same reach, with no works of any sort to intercept the flow, and nothing but the old island at Nuneham legitimately to break the course of the stream, on proceeding to Abingdon, just above the pound gates, it was found to be only 5 inches above the high-water mark. On an after-inspection of the course of the river on this reach, the cause of this was soon discovered, as the manager at Mr. Norris's mill at Sandford had anticipated. The channel was materially affected in many places by such deposits as had been alluded to, but especially opposite Nuneham Park, where, at the fork of the river formed by the old Island at the cottages, within the last few years the deposit had formed in the centre of the stream a new island, now planted with trees. Under such a state of things, it must be evident, that there would be considerable difficulty in the escape of the water from the upper and narrower part of this reach, and the singular difference in the respective heights of the water at its two extremes was easily accounted for. Remedies, however, had been suggested for the relief of the Oxford district, and rough plans of them had been placed in influential hands. These were suggested by an inspection of the measures adopted at Abingdon, for the discharge of the waters there, from the reach just spoken of, where, by means of a paved towing-path at high-water mark, the swelling waters were passed on as soon as they reached that level. The late Mr. Treacher, for many years the surveyor of the Thames navigation, pointed out, at Sandford and at Iffley, spots exactly suited for the application of similar means of relief. It was right to mention that at Sandford, Mr. Norris, the owner of the mill and of the land at the required spot, expressed his readiness to help forward this or any other reasonable plan, if his interests were protected, and means were provided for keeping in repair the projected works. Mr. Norris also added the reasonable request, that if the water was brought to the mill tail, the channel should be opened to Abingdon to relieve it. The drawings for long lashers, like paved towing-paths, 150 feet each at high-water

level, both at Sandford and at Iffley, were placed in the hands of the Dean of Christchurch, to submit to the judgment of an eminent Engineer. He trusted that the efforts now being made would result in a well-devised measure, which, without prejudicing the landowners' interests, or injuriously affecting the navigation of the river, might improve the land throughout the whole of the valley, and benefit the sanitary condition of Oxford and its vicinity.

Mr. J. H. TAUNTON said, with regard to the early sources of the Thames in Gloucestershire, the springs at Thames Head, which had been spoken of as the principal feeder of the Thames and Severn Canal, rose at a level of about 330 feet above the sea (taking the Ordnance datum); and their volume was usually from 350 to 400 cubic feet per minute. He had never known them to afford less than 200 cubic feet per minute.

He did not understand whether the Author considered that these springs issued from the Oxford clay, or from the lower clays of the great oolite series.

Mr. CLUTTERBUCK said, the water at Thames Head issued from the oolite, which was overlapped to the south by the Oxford clay; thus it received no additional water after it passed the junction of these strata. In September 1862 no water flowed from the head, as he had stated in the Paper.

Mr. TAUNTON proceeded to remark that, in his opinion, the Oxford clay had nothing to do with the out-throw of the Thames Head springs. From borings made in the locality many years ago, he believed that these springs issued from a bed of blue clay, probably the fuller's-earth, 27 feet in thickness, at Thames Head, and which was under the great oolite. It was in consequence of that alone, that these great springs were brought to the ground. Below this point, there were the Ewen Springs, the average yield of which might be taken at 150 cubic feet per minute; so that the whole of these springs gave, on an average, fully 500 cubic feet per minute. The River Churn, the next feeder, rose in the Cotswold Hills, at Seven Springs, near Cubberley, about 6 miles from Gloucester. The stream there was inconsiderable, but before it had passed the lias bed, the volume was increased. Gaugings which he took, in the autumn of 1849, just below Colesbourn, showed that the flow there was 420 feet per minute. After passing Colesbourn, the flow was diminished, some of the water being lost in passing the inferior oolite. The principal source of the River Coln was at Syreford, near Andoversford, and it also received a supply from a great number of springs which proceeded from the oolite. Gaugings taken at Fairford Bridge, on 22nd March, 1854, showed its volume to be 4,700 cubic feet per minute. He had calculated the

drainage areas of these different gathering grounds, and found that of the Thames Head Springs and of Swill Brook to be 75 square miles, that of the Churn Valley was 64 square miles, and of the Coln 86 square miles, while that of the South Ampney Springs was 25 square miles, making a total area of 250 square miles. Now, a rainfall of 12 inches over that area would give a volume of upwards of 13,000 cubic feet per minute. It was stated, in the Paper, that at Wolvercot the summer flow was 8,120 cubic feet per minute, and the winter flow 17,224 cubic feet per minute, with a velocity in the former case of 58 feet per minute, and in the latter of 95 feet per minute. The mean of these quantities would be 12,672 cubic feet per minute, and assuming the drainage area at Wolvercot to be only 600 square miles, that result would be produced by 5 inches of rain, whereas the rainfall in that locality averaged about 30 inches a year. He therefore thought that the average flow of the river at Wolvercot must be much larger than had been stated, and that the sectional area of the river at that point must be greater than 140 square feet.

With regard to the navigation of the Thames, he thought there were other causes, than those generally assigned, for its present state. In reference to the remark attributed to the late Dr. Buckland, "that no lines of inland navigation could flourish, except they ran transversely to the lines of strata, as their variation ruled the products, and internal commerce of the country," he considered it empirical, and that the London clay traversing the greater part of the course had not much to do with the question, except so far as that it did not contain minerals. The interests on the Thames were distinct and separate. The right of the river belonged, in the first place, to the weir or millowner, and consequently the weir also. He had the right of pounding, and no boats could pass without he chose to pound, and he would not do so unless he was paid for it. At every weir there was a separate right. In addition there were the Thames Commissioners, who made the locks to pass the weirs. These different authorities must be made to accord before any real improvement could be effected; but there were so many weir and millowners' rights, and so many who took no interest in the navigation, that it was a difficult matter. With regard to the floods, the right of the weir or millowner extended to the fishing, and that right was most valuable in the early period of the flood. The eels began to pass just when the flood commenced to overspread the banks. It was at this time important to keep all the sluices down, except the one through which the eels were to pass. On some occasions, as the flood set in, as many as 4 cwt. of eels were caught. That was just the critical time when the flood should be let off; but the millowner had the right of pounding to what was called the old

'flash' mark, and that right he strictly preserved. He cared nothing for the flood, but he sought to catch as many eels as he could.

Mr. JOHN TAYLOR stated, that a survey of the River Churn, one of the principal tributaries of the Upper Thames, had been made under the direction of Mr. Simpson (Past President Inst. C.E.), in the dry period of the autumn of 1859. The gaugings of the volume of water, and other particulars then obtained, showed some extraordinary circumstances, with reference to the loss of water, by percolation, through the bed of the River and the Fish and Mill Ponds upon it. The flow from the Seven Wells, (the springs forming the source of the river in the Cotswold Hills) was ascertained to be 11 cubic feet per minute. At one-eighth of a mile below this point, the quantity had increased to 21 cubic feet per minute, and thence the increase continued, somewhat in proportion to the drainage area, as would be seen by the following Table:—

At $\frac{1}{4}$	mile	below	the springs	the flow was 31	cubic feet per minute.
$\frac{3}{4}$	"	"	"	61	"
1	"	"	"	73	"
2	"	"	"	105	"
$2\frac{1}{2}$	"	"	"	165	"
$4\frac{3}{4}$	"	"	"	312	"
$5\frac{1}{2}$	(estimated as the maximum)			320	"

At this point, however, the volume of the river, instead of increasing, began to diminish, for,

At $6\frac{1}{2}$	miles	from	the spring	the flow had decreased to	290 cubic feet per minute.
7	"	"	"	235	"
$7\frac{3}{8}$	"	"	"	179	"
$8\frac{1}{8}$	"	"	"	113	"
$8\frac{7}{8}$	"	"	"	45	"
$9\frac{3}{4}$	"	"	"	33	"
$12\frac{1}{2}$	"	"	"	30	"

and at $14\frac{1}{4}$ miles the quantity had actually become reduced to 10 cubic feet per minute, or less than the original flow of the Seven Wells. From thence to the junction of the river with the Thames at Cricklade, 22 miles from the source, the flow again gradually increased up to 110 cubic feet per minute. Thus, in a length of less than 8 miles of the course of this river, there was a measured loss of 300 cubic feet of water per minute, or 2,700,000 gallons per day. But even this was less than the actual loss, as, of course the stream would continue, under ordinary circumstances, to increase in proportion to the drainage ground, and allowing for this, the estimated flow at Cricklade ought to have been 450 cubic feet per minute, instead of being 110 cubic feet as gauged, thus showing a loss to the mills on the lower parts of the stream of 340 cubic feet per minute, or upwards of 3,000,000 gallons per day.

As to the geological character of the River Churn, the stream was derived, principally, from the drainage of a considerable area

of the inferior oolite, and was thrown out by a fault at Seven Wells; the upheaval of the impervious beds of the upper lias clay preventing percolation in the direction of the dip of the strata. The stream then took its course through a valley of denudation, where the upper strata had been swept away in some convulsion of nature, forming in parts a deep narrow ravine, surrounded by the Cotswold Hills, which were composed chiefly of the porous and fractured rocks of the oolite. It thence passed over the impervious beds of the upper lias clay for nearly 6 miles, from the source at Severn Wells to Maresden Farm; next over the porous beds and fractured freestone of the inferior oolite for $3\frac{1}{2}$ miles to a little below North Cerney Mill, by the Rendcomb fish-pond and the mill-ponds and courses of Rendcomb and North Cerney Mills; afterwards flowed over the impervious beds of clay known as fuller's-earth, continuing past Perrot's Brook and Trinity Mill to the mill-pond at Baunton, a distance of about $2\frac{1}{4}$ miles; and then it traversed the porous rubble freestone of the great oolite for 1 mile, by Stratton mill-pond. At this point commenced the tenacious clays of the forest marble formation, which, partly overlaid with the gravel and detritus of the oolite, passed under Cirencester, Barton, and New Mill Ponds to the head of Preston Mill; the only remaining porous strata being a short length at Preston and Seddington Mills, where the rubbly rock of the cornbrash formation outcropped in the bed of the stream. Thence the course of the river, from Seddington Mill to its confluence with the Thames at Cricklade, a distance of 7 miles, was entirely over the impervious beds of the Oxford clay. Such being the bed of the river, there was no doubt, the vast quantity of water which continually disappeared, percolated through the fissures and fractures of the rocky bed, and through the porous strata in the bottom of the mill and fish-ponds; and sinking below the impervious beds of fuller's-earth, never rose again in the valley of the Churn, but was completely lost to that river, and possibly even to the River Thames. Certain remedial works, chiefly such as puddling the bottoms of the ponds, were advised to be done, at a cost not exceeding £3,000, which would probably have prevented the loss of all this water; and it was estimated that this outlay would have resulted in a saving of nearly £1,400 a year in water-power.

Mr. S. C. HOMERSHAM said, it was now generally well understood, that rain falling upon different geological formation produced different results. Thus, upon chalk, the rain was immediately absorbed, even to the extent of 2 inches or 3 inches in depth in an hour, as sometimes happened over an area, say, of 100 square miles; whilst upon the primitive formations, it at once flowed off the ground, into the neighbouring valleys. He believed that

the effect of draining clay lands directly into rivers, or into ditches that communicated with rivers, was, by removing the rain more rapidly, to increase the severity of the floods of the district. There were, however, hundreds of square miles of country, which for the last seventy or eighty years had been drained in a different way. For instance, where there was chalk, or other absorbent strata covered by clay 16, 18, or more feet in thickness, the drainage was effected by sinking in suitable situations, what were technically called dumb wells, from the surface through the clay for a few feet into the chalk, then filling the dumb wells with broken flints or stones, and conveying the water through drain tiles in the usual manner from the clay land into them. The effect was, that the rain, instead of flowing through various surface channels into the rivers and causing floods, was absorbed into the body of the chalk, and escaped underground into the sea. Floods in districts thus drained were much rarer than they used to be.

Allusion had been made to the gauge used by Mr. Dickinson, still incorrectly called a Dalton Gauge. On a former occasion, Mr. Homersham had stated[1] that the two were not alike, and he had shown in what respect they differed. Dr. Dalton's gauge was made with a view to register both the proportion of the rain which penetrated the ground, and also that which flowed off the surface. Accordingly, there was an overflow pipe, with a bottle, or vessel, to catch the water that passed off without entering the ground, as well as a vessel to catch the water sinking through the earth. The sum of these two quantities, deducted from the total rain-fall, would leave as a remainder the quantity that was evaporated. Now Mr. Dickinson avowedly employed only one vessel, or bottle, and this collected the water which percolated through the soil, but it gave no record of that which flowed off the surface. The consequence was that, for this and other reasons, the records of these gauges could not be depended upon; and for himself he did not hesitate to say, that having had occasion to make himself fully acquainted with them he placed no reliance upon the records of these gauges. It had been said that Mr. Dickinson was in the habit of regulating his contracts, as to the amount of paper he could manufacture, by the indications afforded by these gauges. Now Mr. Homersham doubted that, for at all Mr. Dickinson's mills in Hertfordshire, steam power, as well as water power, was applied for driving the machinery; the former being greater than the latter. Besides, there was an inexhaustible supply of water, from small wells, with bore-holes sunk in the bottom of each, at all these mills, from which, in the driest seasons, more water could be obtained than was ever required for the manufacture of paper.

[1] *Vide* Minutes of Proceedings, Inst. C.E., vol. xiv., p. 82.

During the last twelve or fifteen years, numerous wells had been sunk into the chalk, for the purpose of obtaining water, without a single failure, so far as he was aware. At the present time the same thing was being done with the greatest success. Only a few years ago, the town of Hull was entirely supplied with water from the river: now it had sufficient for its whole supply from wells and bore-holes sunk into the chalk. Again, a large district of London was now supplied by the Kent Waterworks Company with from 4,000,000 to 5,000,000 gallons of water a day, obtained from wells sunk in the chalk, while for more than a century before, their whole supply had been taken from the River Ravensbourne. The wells not only yielded water abundantly, but the level of the water had not been lowered by the pumping. Therefore, he thought the Author was not justified in his views, as to the impolicy of sinking wells to procure large supplies of water from the chalk; and personally he had no confidence in any statements, with respect to the permanent lowering of the surface of the water in wells sunk in the chalk.

Mr. J. F. BATEMAN remarked that the facts and figures given in the Paper were not sufficiently numerous or minute to enable many deductions to be drawn from them. The area was not mentioned from which the water was collected, nor were there any particulars as to the quantity of water per acre, per minute, or during any other period of time. His acquaintance with the Thames was confined to the upper and lower ends; but of the main valley he had very little knowledge. He was, however, able to furnish some measurements of the flow of water in other streams in different parts of the country, showing the large amount of flood water that came off the land under certain circumstances in some districts, and the comparatively small amount which came from other districts under different circumstances. There was no doubt, that all the information that could be obtained, as to the amount of floods, the manner in which they rose, and the causes to which they were attributable, was valuable in an agricultural and engineering point of view. During the years 1833, 1856, and 1857, he had the means of ascertaining, with great accuracy, the quantity of water flowing off the ground, in a given time, by the River Medlock at Manchester. That river was a short stream, running through the city of Manchester, and draining only about 12,000 acres, principally of clay land. The maximum quantity of water passing off in those years was equal to a depth of 4 inches, 5 inches, and 6 inches respectively every twenty-four hours; that was, the volume of the floods when at their maximum was such, that those would have been the depths of water flowing from the ground had the floods continued at the same height for twenty-four hours consecutively. At the Manchester Waterworks, during the flood

of February, 1852, which might be remembered as the time when the Bilberry Reservoir, near Holmfirth, in Yorkshire, was carried away, the water which came down from a district of 15,400 acres, was measured either in reservoirs, or through discharge pipes and gauges. The flow, when at the highest, was from 3,600 to 4,000 cubic feet per second, or 25 feet per second for each 100 acres, or 15 cubic feet per acre per minute, being at the rate of between 6 inches and 7 inches in twenty-four hours; and the mean flow during the same period was 1,520 cubic feet, or $2\frac{4}{10}$ths inches per second. In 1856, the quantity of flood water flowing into the Woodhead Reservoir, of the Manchester Waterworks, from an area of 7,000 acres, was equal to 2,100 cubic feet per second for seven hours forty minutes, or a depth of $2\frac{1}{4}$ inches, being at the rate of 7 inches in twenty-four hours. This quantity was equal to 18 cubic feet per acre per minute. In 1849, during the early progress of the work, a flood occurred at Woodhead which, at its maximum, amounted to 50 cubic feet per second for every 100 acres, or 30 feet per acre per minute, being at the rate of 12 inches in twenty-four hours. He had also some further measurements of the flood of May, 1862, at the Woodhead Reservoir, from the same district of 7,000 acres. For a period of two hours and a half, the flow was equal to $22\frac{1}{2}$ cubic feet per minute per acre; for seven hours it amounted to $14\frac{8}{10}$ths cubic feet per minute per acre, and for thirteen hours to $9\frac{1}{3}$rd cubic feet per minute.

At the Glasgow Waterworks, in October, 1854, the flood from Loch Lubnaig, Loch Voil, and Loch Doine, (the water surface of the lochs being about $\frac{1}{34}$th of the total drainage area of 44,600 acres,) was equal to 328,000 cubic feet per minute, or a depth of 3 inches flowing off in twenty-four hours, and $7\frac{1}{2}$ cubic feet per acre per minute. On the same day the volume of the flood flowing out of Loch Venachar, from a drainage area of 45,800 acres, but where the surface of the lochs was $\frac{1}{11}$th of the whole, the flood only amounted to 150,000 cubic feet per minute, not one half of that which flowed from Loch Lubnaig, from about the same area and the same rain-fall. This showed the regulating effect of large lakes, or sheets of water. The quantity stored in and discharged from Loch Katrine in twenty-four hours was equal to nearly 4 inches, while in two days it was equal to 6 inches of rain over the whole drainage area. The surface of Loch Katrine formed $\frac{1}{8}$th of the whole drainage ground of 23,300 acres.

In the River Clyde at Carstairs, in the winter of 1856-57, from a drainage area of 190,000 acres, the flow of water was equal to 20,000 cubic feet per second, or 6 feet per acre per minute; and of that quantity only 9,000 feet passed down the river channel, the remainder sweeping over the flooded land.

From a Table of the measured maximum quantities of water

in various parts of the extensive valley of the Shannon, he would instance the measurement at Killaloe. Here the drainage was from a total acreage of 2,560,000, and the quantity of water in flood was 1,600,000 cubic feet per minute. The discharge of various large rivers into the basin of the Shannon, from actual measurement in flood, varied from 0·76 to 1·54 cubic foot per acre per minute, the latter being a maximum. That contrasted very strikingly with the quantities he had given from mountain districts in England and Scotland, where they amounted to 6, $7\frac{1}{2}$, $9\frac{1}{3}$, 15, 18, and in one case 30 cubic feet per acre per minute. He gave these measurements for the purpose of drawing attention to the great differences which existed, in order that one river might not be taken as a guide for calculations upon another, except when the circumstances were similar.

Mr. FREDERICK BRAITHWAITE remarked that, from the statements which had been made, it was evident a large quantity of the flood water which was supposed to fall into the Thames, did not reach the tidal part of the river below Teddington Lock. Of late years, in dry seasons, there had at times been so little water flowing over the lock, that the salt water had nearly reached as far up as Hammersmith. Moreover it was stated, that from ninety to one hundred million gallons of water per day were now being taken from the river above Teddington Lock for the supply of London; and as, by the main outfall intercepting sewers, the whole of that quantity, together with the rain falling on the area so drained, would be conveyed beyond the metropolis, to Barking Creek and to Erith, it was important to ascertain, what would be the probable effect of the abstraction of so large a body of fresh water from the tidal part of the river. It was manifest that it must lead to the intrusion of a still larger quantity of salt water. Dr. Letheby had recently stated,[1] that the mixture of a large proportion of salt water with the fresh water was likely to be attended with unhealthy results, as noxious exhalations would arise from the mud on the banks, in dry weather.

The Author had referred to the subject of evaporation, both from the earth and from a surface of water, stating that in the latter case the amount was very small; and citing in proof of this opinion, the case of two vessels both filled with water, but in one of which a brick was placed, and that the evaporation was much greater in the vessel containing the brick than in the other. Now, all evidence went to show, that the amount of evaporation from water was 30 inches per annum. He could readily understand, that if a porous substance was put into a vessel of water, the sur-

[1] *Vide* a letter in "The Times," March 16, 1863, p. 10, headed "The Water of the Thames."

face of evaporation was increased, and also the amount of capillary attraction which assisted the evaporation.

Some observations had been made, in which he did not concur, with regard to Mr. Dickinson's rain-gauge. He thought that the overflow pipe of the rain-gauge had nothing to do with evaporation; and that the absorption was dependent upon the nature of the soil. There were some descriptions of soil which would variously absorb from 20 per cent. up even to 60 per cent.; therefore it was unphilosophical to generalise, nor could it be done with any approach to accuracy.

Mr. R. B. GRANTHAM said, the map which had been prepared for the Salmon Fisheries Committee, by Colonel Sir Henry James R.E. (Assoc. Inst., C.E.), a copy of which he then presented to the Institution, gave some interesting details of the water-shed of most of the principal rivers in England, amongst the rest, of the Thames, and was a most important document for all who were interested in the drainage of the country. The areas of the catchment drainage of two hundred and four rivers and their length were enumerated, from which he had extracted the following particulars relating to a few of the principal rivers:—

	Area in Square Miles.	Length in Miles.
Thames	5,162	201¼
Ouse (Yorkshire)	4,207	59½
Trent	3,543	167½
Severn	4,437	178
Nen	1,055	99
Great Ouse (Cambridgeshire)	2,894	156¼
Mersey	1,706	68
Tyne	1,053	35
Witham	1,052	89
Medway	997	69
Humber	1,229	37
Wye (Herefordshire)	1,655	148

It would be extremely useful if this inquiry could be extended, so as to include the catchment basin of the minor rivers.

The Valley of the Upper Thames did not appear, from the description, to differ materially from the formation of the valleys of other rivers, except from its magnitude. It consisted of a series of large and flat areas, at places throttled by the hills, and by the undulations of the country closing upon and narrowing the valleys. It was at those places, he believed, where the gorges occurred, that the greatest improvements might be made, and to which the attention of Engineers should be directed, to draw off the floods. But the Paper, though interesting in a geological point of view, as showing Engineers the sources whence water was derived,

gave no suggestions as to the mode of treating the Valley of the Thames, so as to improve its drainage.

Mr. GRAVATT said, he should not have been induced to make any remark, had it not been stated, that the present condition of the Thames Navigation and Drainage rather implied a low state of Engineering skill in such matters. He had had to do with Navigations, Mills and Drainage for many years; amongst others with the Calder and Hebble navigation, and he was old enough to have actually constructed a Canal, called the Longport navigation. The Calder and Hebble works were originally laid out by Smeaton for a 3-feet navigation; and, as an instance of Smeaton's foresight, when the depth had to be increased to 5 feet, there was only one lock-cill that had to be altered, and that lock, Mr. Gravatt found, had been built by another Engineer, to avoid a local opposition. The real difficulties were not at all of an engineering character, but they arose from the supposed difference of interests, between Navigation Proprietors, Drainage Commissioners, and Millowners. Where these parties agreed, the Engineering difficulties almost vanished. As one instance out of many, already known to several Engineers, he mentioned that when the proprietors of the Calder and Hebble Navigation bought the Mills, there was no further difficulty. The Navigation proprietors, who had been before subject to continual lawsuits, completed their works, at a moderate expense, and the rents of the Mills actually increased. The power of half ruining a navigation, or of flooding large tracts of land, for the sake of a few hundredweights of eels, was a legal power possessed by many persons; but the difficulties that arose from such a source could not seriously be called engineering difficulties. He thought sufficient had been said to show, that the present state of the Upper Thames was not to be attributed to any fault of Engineers, or their works.

Mr. FREDERICK KING said, as a resident, for upwards of forty years, upon the banks of the Upper Thames, he had witnessed the most prosperous trade in the navigation, the many abuses practised upon the stream for the monopoly and misuse of the waters, and subsequently its decline and fall. For more than twenty-five years he had endeavoured to suggest remedies for the evils existing in this, the most fertile valley, and perhaps the most abused in England. He had been engaged as the valuer under several enclosures of meadow districts, between Oxford and Lechlade, subsequently followed in the same district by the late Mr. Woolley, one of the Enclosure Commissioners, and since by Mr. Bryan Wood. All had encountered the same difficulties, that whilst cuttings and drains could be made, no proper outfall could be obtained, for the system of economising the water in former days was such, that the whole valley was submerged, and the land a perfect swamp,—the habi-

tation of wild-fowls. This was considered, though erroneously, to be necessary by many, when the only means for the transport of coal, corn, timber, slate, stone and heavy goods was by navigable streams, and more recently by canals, and when water was almost the only motive power for grinding corn, and working the rude machinery of bygone days. He feared that the way in which Dr. Acland had taken up this subject was calculated still further to complicate it, by not keeping it separate from that of the disposition of the Sewage of Towns, a question which must have its issue first in London, when the main drainage works were completed.

The Paper was interesting, as it professed to show the source whence the water was derived which had to be dealt with. He believed that both in an agricultural and in a sanitary point of view, nothing more was required than the perfect drainage of the now water-logged valleys, so as to convert the swamps which now disgraced them into fertile vales, by which the health of the inhabitants of the numerous towns and villages situated on the course of all navigable rivers would also be improved. The plan formerly adopted, for securing the largest supply of water for navigation purposes, was to place a lock, or weir, immediately below a great outlet of land drainage, or of tributary streams running into the main river, by which, when the locks, or weirs were closed, instead of filling the river, (itself sufficient for all the purposes of navigation, if properly fed,) thousands of acres of rich land were unnecessarily submerged, or partially so. It was a fact that at the present time, not one boat passed annually down the Upper Thames from Lechlade to Oxford, and yet the water was still impounded. Even in hay-time, in dry summers, the water was dammed up to a depth of 3 inches to 6 inches amongst the hay, the herbage being water-plants, instead of nutritious grasses fit for animal sustenance. This occurred now, he believed twice a week, when the water was impounded for the purpose of sending down the unnecessary semi-weekly 'flashes.' If the river were made a perfect canal, and the land drainage was allowed to fall into the main stream immediately below a lock, mill, or weir, as the case might be, instead of immediately above it, this state of things would be remedied. Any increase in the tail water, tending to diminish the motive power, would be compensated by the head-water being raised in a corresponding degree, by the admission of the land drainage into the river at a higher level.

The observations in the Paper went to show that the great evil in the level of the Upper Thames was occasioned by the narrow gorge at Sandford, where the coralline, or coral rag, overlapped the Oxford clay. One of the consequences above Oxford of this great natural obstruction was that the levels of Wolvercot Mill,

King's Weir, and Wytham Mill Streams, had all been raised, within the time named, by the improper addition of new cills on the old ones, by which many acres of land had been flooded nearly a foot deep. This was only one of many similar abuses. Thus the damming up of Shire Lake Ditch at the top of Godstow, and of Swift's Ditch at the bottom of Godstow Liberty, had ruined Port Meadow, improved Binsey, and swamped Oxford. The treatment of all navigable valleys was a national question, affecting the production of food for cattle, and consequently of food for the people, and this could only be properly done by the application of Parliamentary Powers, the preliminaries of which in his opinion were, forming each valley into an elective drainage district, or districts, giving one-tenth of the proprietors of any area requiring a combined system of drainage, power to apply to the Enclosure Commissioners, to constitute such lands into a separate elective drainage district, with a saving clause as to the consent of existing Commissioners of Sewers, Town Councils, Local Boards of Health, or Improvement Commissioners. Upon receiving this Petition, the Commissioners should appoint an Inspector to make local inquiry as to the propriety of the boundaries of the areas proposed to be drained, &c. In the event of the proprietors of one-third of the land comprised within the area dissenting, within a given time, the Commissioners should dismiss the Petition. He suggested that the area to be dealt with was the alluvial strata of the whole valley, as laid down on the Geological Maps of the Ordnance Survey.

The Rev. J. C. CLUTTERBUCK said, in reply upon the discussion, that though he had had access to much information from landowners, he found it impossible to ascertain the extent of agricultural drainage, or to make any calculation of the drainage area of each tributary stream. It must be remembered that the whole area, 1,500 square miles, comprised every variety of soil, involving most complicated geological conditions. Thus, the water was thrown to the surface, in some districts, by the underlying lias clays, in others by the fuller's-earth, in another by the clay beds of the forest marble, and then from the extended surfaces of the Oxford, Kimmeridge, and gault clays. He had described the geological condition of districts drained by each tributary, and must refer to the Paper for all the information he could give. The accuracy of the gaugings had been questioned, the minimum flow at Wolvercot being deemed too small. Certain gaugings at other points were brought forward; but to show that these latter could not be relied on, it was only necessary to refer to the case of the Churn, a very considerable tributary, which decreased in its course from 320 cubic feet to 110 cubic feet per minute. It had also been stated that the Thames Head seldom yielded any water to the river. Averages of rain-fall afforded no guide

to the minimum flow of rivers, which could only be ascertained by actual observation. Personally he had great confidence in the gaugings at Wolvercot, as they were taken by a man of experience and an accurate observer. Mr. Treacher, the late surveyor of the Thames, had informed him that, in 1855, the perennial flow in the Thames was so much reduced, owing to the rain-fall in the previous eighteen months only amounting to the yearly average, that all the flood-gates at the Pangbourn Lock were opened at one time, a fact without example in his long experience. With regard to the capacity of the river for the discharge of flood-water, when the river at Clifton Hampden, between Abingdon and Wallingford, ran 'flash' high, the flood-gates at the lock being shut, the velocity was 134 feet, and the discharge 51,000 cubic feet per minute. In January, 1863, when the flood attained its height, on the flood-gates below being drawn, the velocity was increased to 265 feet, and the discharge to 182,000 cubic feet per minute, though the area occupied by the flood was only doubled. He believed that Mr. Bryan Wood's system of confining the flood by low banks would be generally adopted, in executing the so-much needed improvements of the Thames Valley.

With regard to the objections to the experiments on evaporation, experience would show, that the increase of winter evaporation from drained soils would tend to diminish winter floods. He believed that the amount of evaporation from a surface of water, or the wet surface of the soil, was over-estimated. In corroboration he could refer to the dew-ponds on the downs, which, when once filled, were never without water: he repeated his belief that the extension of agricultural drainage would tend to decrease floods. As to the remark that in Dalton's gauge no account was taken of the overflow from the surface of the soil, on looking to the daily records of that gauge, he observed that when rain commenced, only 1 inch out of $1\frac{1}{2}$ inch was recorded, showing that the $\frac{1}{2}$ inch went to replace the previous evaporation. If the rain continued, as in January, 1863, the whole of the next inch would percolate to the lower receptacle, and there would be no waste by overflow. As to what had been said about the water supply to be obtained from the chalk, it should be remembered that the London wells alone had been alluded to in the Paper; and he believed that the decrease in the level of the water in many of the wells of the large breweries in London confirmed his view. At the same time he could confidently affirm, that many towns depending for their supply of water from chalk wells might draw too heavily upon the quantity of water at command.

Mr. HAWKSHAW, President, in thanking the Author for his useful communication, which he regretted not to have heard read,

would only observe, that as far as he had considered the matter he thought it probable, that extensive agricultural drainage might have the effect of decreasing floods.

At this Meeting it was resolved unanimously:—

"That in consequence of the marriage of H.R.H. the Prince of Wales having been fixed for Tuesday, the 10th of March, there should not be any Meeting of the Institution on the evening of that day."

March 17, 1863.

JOHN HAWKSHAW, President,
in the Chair.

The discussion upon the Paper No. 1,074, on "The Perennial and Flood Waters of the Upper Thames," by the Rev. J. C. CLUTTERBUCK, occupied the whole evening to the exclusion of any other subject.