Mr. BIDDER,—President,—observed, that although the Paper treated of an unimportant river in the neighbourhood of London, it opened out questions of great social and scientific interest; the water supply, water rights, the pollution of rivers, and the remedies that ought to be applied, consistently with the improvements now taking place in social science, and with the drainage of the towns and the villages in the vicinity. He resided near the Wandle, and was the owner of the mill, on that portion of the stream, which passed through his land. There were circumstances connected with that river, interesting and important to the residents and owners of property in its vicinity. The town of Croydon was under the operation of the Health of Towns Act, and under the provisions of that Act, a well had been sunk, and water had been pumped from the Wandle for the consumption of the inhabitants, and also for the purposes of sewage. That proceeding had been contested at law; but it was finally decided by an appeal to the House of Lords, who held, that the possessor of the soil might sink a well, and pump from it to any extent, however much it might affect his neighbours. Now although that judgment seemed, at first sight, to be dictated by common sense, yet on reflection, it was doubtful whether it could be approved, especially when the owner of the well applied the water to other than his own wants. But the Croydon Board of Health were now extending the judgment in that sense, by intercepting the mouth of the Bourne, by a sewer which was carried at a lower level, to the vicinity of Croydon, upon the pretext of rendering the foundations of the lower part of Croydon, drier than heretofore. There was also the question of pollution, for the whole drainage of the town of Croydon was carried into the Wandle. After much contention on this subject, the authorities constructed a drain, partly open and partly covered, in the direction and close to the parish of Mitcham. Having found the fish in his own portion of the river, rapidly diminishing from this cause, he had taken legal proceedings, the result of which was, that the authorities undertook to remove any nuisances they might have created. There were various other pollutions from minor causes, of scarcely less importance; but they were only particularly obnoxious, at certain seasons of the year.

The flow of water in the Wandle was subject to peculiar vicissitudes, not alluded to in the Paper. During the greater part of the year 1858, the quantity of water flowing down that river, was not one-fourth of the present quantity, and in consequence, the mills were stopped, for not less than eight, out of every twelve hours. In addition, the Wandle had been, of late, over-run with a weed, possessing little buoyancy, and which collected great quantities of mud. It was supposed to have come, originally, from America, and it had fructified in this country to an extraordinary extent,

and interfered, in some measure, with the sanitary condition of the fish.

He hoped, that this discussion, although raised upon the condition of the Wandle, would take a wider range, as the questions which it involved, had an important bearing upon the past, the present, and, most certainly, the future of almost every river in England; and unless precautionary measures were taken, the condition of many rivers which, heretofore, had been ornaments to the estates, and sources of comfort to the residents in their vicinity, and who were the owners of the fish of those streams, would become deteriorated, and would occasion serious detriment to the surrounding property.

Water Supply and Land Drainage.[1]

Mr. Frederick Braithwaite said, he had been induced to prepare this Paper, embodying the results of a careful study and survey of the Wandle, in consequence of the recommendation of the President, in his Inaugural Address,[2] to investigate the condition of the rivers of England. The supply of water for the rivers had become an important question; for instead of that supply being inexhaustible, as had been sometimes asserted, there was an actual deficiency. The last year was an exception to the rule, for from September, 1859, to September, 1860, the rainfall exceeded by 11 inches, the average of the ten, or twelve previous years. In 1858, the excessive heat and the deficiency of water occasioned, in many rivers, the destruction of great quantities of fish, and at one period, the water ceased to flow. It was to be regretted, that the Wandle, which might, at little expense, be made a useful and powerful auxiliary to the water supply of London, should be allowed to remain in its present condition.

Mr. Braithwate, after alluding to Tables of the average monthly rainfall for the last twenty years, and of the daily rainfall for 1856, said, that the state of Mr. Dickinson's rain gauge, distinctly proved, that during the hotter months in the dry seasons, little water penetrated the ground, even to the depth of 3 feet, the depth of the rain gauge; it must be evident, therefore, that to calculate the supply of water to rivers, by averages, was a very unscientific mode of calculation. The actual amount could not be properly estimated, without taking into account the state of the weather, and not merely the quantity of rain, but also the time in which it fell. The available supply greatly depended, however, upon the absorbent

[1] The remarks made during this discussion, have been arranged under the following heads: 1st, Water Supply and Land Drainage; 2nd, Pollution of Rivers, Town Drainage, and Sewage; 3rd, Water Rights.

[2] *Vide* Minutes of Proceedings Inst. C.E., vol. xix. page 221.

powers of the soil. He had found, that a piece of chalk which, when dry, weighed 2 oz. 7 dwts. 7 grs., increased 13 grs. in weight, when saturated with water; at which rate, a cubic foot of chalk of the same density, would absorb nearly 4¼ inches of rainfall. Evaporation and absorption must also be carefully considered, in estimating the quantity of water supplied to rivers.

With regard to agricultural drainage, he thought that, generally speaking, sub-drainage was wanted, only where the excess of surface water was due to other causes than the rainfall, and in his opinion, the system was often carried out to too great an extent.

Mr. SIMPSON, (Past-President,) observed, that beyond Croydon, the geological character of the district traversed by the Wandle, was peculiar, and there were some remarkable circumstances connected with the watershed. He had been conversant, since the year 1815, with the flow of the Bourne. The gaugings had, evidently, been taken by a careful observer of the phenomena of that stream, and they were a record of its periodical variations, the cause of which had been correctly stated in the Paper. The flow was never exactly at the same period: when heavy rain had fallen at the latter part of one year, the Bourne might break out in the following January, or February. The President had remarked, that the Wandle was not an important river, but within a recent period, there was scarcely a stream of the same length, which presented a greater amount of manufacturing industry; there were thirty-five mills within a distance of nine miles, all fully employed. Circumstances had, of late years, altered the industrial character of the river; manufacturing trades in the vicinity of London had declined, and in many instances, steam engines, at present, performed the work in London and in some of the provincial towns, which was formerly effected by the water wheels. Still the Wandle was an important stream, for at certain seasons, it had a continuous large supply of water from the chalk. The Author's gaugings accorded closely with his own, although not taken at the points mentioned in the Paper, because his own attention had been confined to ascertaining the flow of the river. In 1858, at Garrett Mill, the total volume of the stream, for many months, did not exceed 11,200,000 gallons per day; and on several days he had no doubt the amount was less. The Author had recorded 83,469,060 gallons as the largest flow; yet at the same place, but at another time, 92,000,000 gallons per day, had been measured. Such an extraordinary fluctuation was not usually met with, in a stream issuing from the chalk. The Bourne never flowed for many months at a time, but a large quantity of water which produced fluctuation in the Wandle, came from the area feeding the lower part of the stream below Croydon, a large portion of which was clay land. The effect of this was,

however, equalised to some extent, by a number of large ponds, including the lake called Collyer's Water, in connection with the river.

From personal observation, without reference to gauging, it had appeared to him, that of late years, the lower parts of the stream had been subject to great fluctuations, and he attributed it, in some measure, to the extension of land drainage. In the Wandle valley, as well as in many other parts of the country, it was found, that the water from the rainfall ran quickly off the land through the drain tiles, into the brooks, and percolation was thus, to a great extent, prevented.

Sir JOHN RENNIE, (Past-President,) said, that the arterial drainage of large towns, and the extensive under-drainage of land, induced by the progress of civilisation, had materially affected the condition of the rivers throughout the country. The greater part of the rainfall was now discharged, almost as soon as it reached the ground, into the rivers and streams; floods, consequently, were more rapidly carried off, and in dry seasons there was great scarcity of water. Fifteen years ago, when he had the honour of occupying the Chair of the Institution, he pointed out the necessity of economising water during the winter, and the proper means of utilising it during the summer.[1] In rivers near the sea, unless means were provided for back discharge and for first carrying away the alluvial matter brought in with the tide, so as to preserve the equilibrium between the tidal and the fresh water, the former possessing a superior influence, would, eventually, deposit it in the bed of the stream. Many important questions had been raised by this Paper, and he hoped the attention of the Members would be directed towards the extensive field of inquiry it had initiated.

Mr. GIBBS said, that the Wandle, though a short river, presented many interesting features, mechanically and geologically. Mechanically, because some of the best mills in England were built upon it; there was one by Smeaton, and another by Rennie, which were models to be followed, even at the present day, being constructed upon true principles. It was interesting, geologically, because of the large volume of water drawn from the chalk hills, in so short a distance. This was owing to the upheaval of the chalk, and, consequently, of the London clay, between the Rivers Wandle and Cray, so that it was impossible for any great amount of water to escape from the chalk between Croydon and Carshalton. The Ravensbourne was a stream issuing from the chalk, in a large valley, with a very small quantity of spring water. The disturbance he had men-

[1] *Vide* "An Account of the Drainage of the Level of Ancholme, Lincolnshire;" Minutes of Proceedings Inst. C.E., vol. iv., p. 186.

tioned, accounted for the gradual depression of the springs, from Croydon towards the River Mole, which although it ran through the chalk, did not proceed from it. From London to Rochester and Chatham, no springs came out of the chalk, in sufficient copiousness to form a river; the chalk was intercepted by the Wealden clay, and the water passed through and between the chalk downs. Along this line of country, as there was no disturbing cause, the water issued from the chalk, in almost imperceptible streams; but between Croydon and the River Cray, there were disturbing causes, and the Wandle, in consequence, became a comparatively large stream. There was an impression, that what was called the Bourne, above Croydon, was a periodical river, which broke out about once in seven years, but it was, in reality, nothing more than the superfluous rainfall, when the rain had been very copious and long continued, which could not be absorbed by the gathering ground, and was, consequently, raised to a higher level. But when the power of absorption became superior to the amount of rainfall, the Bourne ceased to flow. Similar instances were not unfrequent; a stream occasionally broke out at West Wickham, between Croydon and the River Cray, when the chalk became incapable of absorbing the whole of the rainfall, and of transferring it to the springs.

Allusion had been made to the great absorbing powers of the chalk, but absorption by immersion, should not be confounded with absorption by capillary attraction; in the latter process, a less proportion of water was taken up by the chalk. The objection to averages of rainfall, in calculating the available quantity of water from drainage grounds, did not affect the question, for it was the minimum that was, generally, relied on. But with regard to the rainfall, it was important to bear in mind, that the quantity of water which might be expected, was much influenced by the state of the atmosphere before the rain fell; because, if the ground was exceedingly dry, and the sun was powerful, the rain would be nearly all evaporated, leaving scarcely any available. There had often been an erroneous impression, as to the proportion of the rainfall upon chalk, which was really available, and too much was generally calculated upon. The real quantity penetrating the chalk by gravity, after the water had sunk beyond the influence of the atmospheric temperature, had not been, in some cases, more than 5 inches, or 6 inches in the year, out of an amount of rainfall of 28 inches.

Mr. HAWKSLEY said, that the Paper had introduced so large a number of topics, that it was difficult to select those which were more immediately important, and bore most directly upon the particular conditions and circumstances of the River Wandle. The area of drainage of a river could, as a general rule, be

approximately determined; but the case of the Wandle was exceptional. Its actual drainage consisted only of a few thousand acres; but beyond that obviously visible and measurable area, there was a large tract of chalk country, which discharged its waters, not by streams, but chiefly by springs, flowing at a considerable distance from the point of rainfall, and under very unusual circumstances. Some of the springs were intermittent, not showing themselves more than once in five, or seven years, and then, perhaps, discharging as much as 20,000,000 gallons per day. The principal one was the River Bourne, which thus became the occasional head of the River Wandle; that river was now flowing at the rate of about 20,000,000 gallons per day. In considering, therefore, the conditions under which the Wandle was produced, it was necessary to take into account the rainfall, which was subject to great variations. In the neighbourhood of London, and in that particular district, it descended, in some years, as low as 16 inches, and in others, it rose to 33 inches, the average being about 23 inches.

The question had been raised both by the Paper and in the discussion, as to the amount of water which usually flowed off the ground and became contributory to rivers. It had frequently been asserted, that the rainfall might be divided into three equal portions, one of which was disposed of by evaporation, another by absorption, and the third by superficial flow. That statement was erroneous, for the amount of evaporation was very nearly a constant quantity. In the neighbourhood of London, it varied from about 15 inches, in some years, (14 inches was the minimum, and it was rarely lower than 15 inches,) to 18 inches, and as much as 19 inches; but the average evaporation in that and similar districts, might be taken at about 16 inches, or 17 inches. As the average fall of rain was about 23 inches, there would only be a residue of about 6 inches, or 7 inches, and it appeared, from the best information respecting the discharge of the Thames, a river produced from the drainage area of about 6,000 square miles, that such was the amount of discharge from the chalk area. At a period of maximum drought, as in 1850, when all the water which descended the river, proceeded from springs, the discharge was at the rate of about 2 inches per annum, during two, or three months. Under these circumstances, it was easy to account for the extraordinary changes that occurred in the volume of the River Wandle. That river, although deriving its chief supply from a chalky district, had fluctuated, by actual measurement, from a minimum of about 10,000,000 gallons, to a maximum of about 90,000,000 gallons: at periods of great rain, it must, of course, exceed that quantity. In mountainous districts, and near the heads of the streams, where he had been able to make observations over long

periods, he found the minimum to be about one-sixteenth of the average flow, and the height of floods to be more than sixteen times greater than the average flow, the ratio between the minimum and maximum quantities being about 1 to 300. In the Liverpool watershed, where the rainfall was chiefly upon rocky ground covered with clay, after elaborate gaugings during several years, the evaporation was found to vary from 10 inches to 14 inches per annum. The great bulk of the water was produced by the floods, and in the summer months, the yield from the springs was so small as, practically, to be of no value. A distinction should, therefore, be made, between a rocky precipitous district, and a chalk formation consisting mainly of flat table land; and in a pecuniary point of view, the difference was highly important. In the Wandle, the extremes were incomparably less than in the cases alluded to; in that district, the water was, therefore, proportionately more useful; the flow being more regular, it was more beneficial to the mill property, and more valuable for ornamental purposes.

In the Wandle district, an operation was now being carried on which had been found, in many parts of the kingdom, to be almost destructive of the value of water power. It was absolutely certain, that the effect of under-draining had been, in many cases, to diminish the flow of the rivers in dry weather, and to augment it in wet weather; thus increasing both the droughts and the floods. Valuable as was this system in many points of view, it was frequently carried to such an extent, that it had the effect of desiccating the soil, and even rendering it sterile. It was just as possible to carry off too much, as too little of the under-water; and it was well known amongst the agriculturists of the fen districts, whom he believed to be the best in the kingdom, that if water was drained below 30 inches, or 3 feet, the crops materially diminished in weight. The greatest possible differences of opinion, however, existed, as to the depth of drainage and the systems employed. Some professors always adopted the 4-feet system; others, the 6-feet system. Some always employed pipes of 1 inch, or 2 inches; others, drain tiles; and others, again, large stones. The necessary effect of any fixed system was, sometimes, to deteriorate much of the land, by removing from it water which was required for the growth of the crops, and at other times, to leave water which was redundant. In certain soils of Worcestershire and other counties, where there was a 'pan' of gravel underlying the productive soil, that 'pan' had been frequently tapped to such a depth, that the water was drawn through the land as through a sieve, and the soil became dry even a few days after rain; in seasons, therefore, of even moderate drought, the crops were scarcely able to grow.

Mr. HAWKSHAW, V.P., wished to point out the danger of too much generalisation on engineering subjects. It might happen,

under certain conditions and in certain localities, that the rainfall could be divided into three equal parts, of which one-third was evaporated, one-third was absorbed by vegetation, and one-third ran off the soil; but this division should not be established as a general rule. It had also been stated, that the drainage of the land necessarily increased the floods. It was obvious, that the effect of draining certain soils might be, to give them such a texture as would cause the rainfall to be first absorbed, and afterwards evaporated; so far, therefore, from causing floods, it would, in these cases, have the effect of preventing them.

Mr. HOMERSHAM remarked, that it had been dogmatically laid down, that in a dry year, only 6 inches, or less than one-third, or one-fourth of the total rainfall, sank into the drainage grounds of the Wandle and the Thames. The proportion would, however, depend, in a great measure, upon the quality of the ground. Thus a rainfall of 1 inch, in ten, or twelve hours, would nearly all run off a hill of clay, or primitive rock, almost as soon as it fell; this he had ascertained, both from experiments and from personal investigation. But on the steep chalk hills round London, some of which were at an elevation of 800 feet, or 900 feet above the level of the sea, although there might be a rainfall of 2 inches in an hour, as sometimes happened, the whole of it would sink into the ground. So also with the red sandstone formation, the water was absorbed almost as fast as it reached the earth. He had sunk into the gravel, or Woolwich pebble-bed, overlying the chalk, a well, 5 feet in diameter and 37 feet deep, and he had poured into it for many hours together, as much as 2,000 gallons of water per minute, yet he had never been able to cover the bottom of the well to the height of 1 inch, the water being absorbed at once. There were large districts of a similar absorbent character round London and elsewhere, and on such drainage areas, the whole of the water entered the ground immediately, especially during heavy rains; very little of this water was lost by evaporation, or was taken up by vegetation, which, in such situations, was, generally, of the most scanty description. On clay lands, especially when flat, a larger quantity of rain was taken up by vegetation and given off by evaporation, than on chalk hills.

It was stated in the Paper, that the quantity of water immediately below Waddon Mill, was 19,000,000 gallons per day; but Mr. Telford, who gauged the river, in 1833, at the same place, reported it to yield, in dry seasons, only 9,000,000 gallons per day. It was true, that in a wet year, the quantity would be increased, but Mr. Homersham did not consider 1853 to come under that category, and he thought, that the former quantity was largely in excess, when taken as a minimum. At, or near Hack Bridge, the Author had reported the gaugings at about 63,000,000 gallons

per day. Now Mr. Homersham had found, by actual measurement, that the drainage ground of that point was about 55¾ square miles, and to produce that quantity of water, a depth equal to 29 inches of rainfall per annum, must flow off the ground. In the course of the discussion, it had been said, that it was scarcely possible to define the drainage ground of the Wandle; from this he dissented, as in 1855, he had ascertained it to be, at the point before mentioned, about 56 square miles.

Mr. FENTON said, the Paper purported to contain a description of the Bourne, which accorded with the popular ideas upon the subject, but after a careful investigation, he was convinced those ideas were incorrect. The Bourne was not an intermittent spring, but it was constantly flowing underground, between the Godstone quarries and the Bourne culvert at Croydon. The original springs rose at the lower end of the three tramways which passed down the quarries, at about two miles from the Caterham Station. Even in 1858, an unusually dry season, the quantity of water at that point, was about 200 gallons per minute. The flow above ground varied with the rainfall; but the flow underground from the quarries and from other sources into the culvert, was 500 gallons per minute. The general idea was, that the Bourne originated in Marden Park; but the spring did not rise there, until the quarries were two-thirds full, containing nearly 15,000,000 gallons of water, when the other outlets being insufficient for the discharge, it burst out in the park. The Bourne had three channels, of which the first was underground from the quarries to Croydon. The second was the channel originating in the neighbourhood of the quarries, but only appearing above ground, four miles below them, at the fifteenth milestone from Cornhill, to the north of the Warlingham Station, on the Caterham Railway. It began to flow out at this point, in November last; it was then a small stream, passing in an open channel for three-quarters of a mile, and it then disappeared below Roke's Farm, near the fourteenth milestone. That stream was now flowing at the rate of 1,400 gallons per minute; and the quarries were now two-thirds full. The third stream commenced near Marden Park, about half a mile beyond the Warlingham Station, on the road to Birch Wood, and was now discharging 300 gallons per minute. That stream only commenced running, in the beginning of the present month of February; so far, therefore, from the Bourne springing up in Marden Park, it was only when the first and second channels were overcharged, that it burst out there. The combined waters from Marden Park and from the second channel, were now running below Riddlesdown, at the rate of 1,500 gallons per minute; but the flow from the mouth of the Bourne culvert, which also received the water from the vicinity of Mersham, was 3,500 gallons

per minute. The underground channels would thus appear to be discharging 2,000 gallons per minute. The under-stratum of gravel and chalk was so porous, that notwithstanding the discharge of 1,400 gallons per minute, at Roke's Farm, the water ran above ground at the present moment, to within a short distance of the Caterham Junction, where it entirely disappeared.

Mr. HAWKSLEY, in answer to a question from Mr. Rawlinson, said, his observations upon evaporation were not meant to apply, either to the surface area of the whole of England, or to that of a large lake. He had argued, that from a surface of rock, the rain was rapidly shot off, in the same way as from the roof of a house, and there was, comparatively, little evaporation; but that in chalk, sandstone, and free soil districts, a large quantity of water was first absorbed into the ground, and afterwards evaporated, exactly as it would be from sugar. In the northern parts of England, and in Scotland, the evaporation was less than in the south. In some parts of the north, the evaporation descended to 12 inches, or 13 inches, even upon soils of that description, whilst in exceptional parts of the kingdom, it ascended to 18 inches, or 20 inches. In the neighbourhood of London, the mean evaporation from the surface of the chalk was, on the average, about 16 inches, or 17 inches per annum, and from the surface of water, nearly 36 inches. In an exceptionally wet year, like 1860, more water descended into the earth than in a dry year, like 1859, and there was also less evaporation. In a dry summer there was, of course, very little water to be evaporated; but in medium years, with a great amount of rain falling lightly, and plenty of sunshine, there was a great amount of evaporation.

Mr. RAWLINSON had asked the question, because the amount of evaporation recorded by meteorologists, was from the surface of water, continuously and freely exposed, over which the power of the atmosphere was, necessarily, greater than over the drainage ground of the River Wandle. The amount of rainfall in the neighbourhood of London, varied, he believed, from a minimum of 16 inches in a dry year, to a maximum of 32 inches in a wet year, or as 1 to 2; and from all the information he had been able to collect, it appeared, that within a range of thirty, or forty years, a similar variation extended not only over this district, but over the greater part of the globe, in all countries, and in all climates. It was highly probable, that there was the same annual amount of sunshine, of heat and cold, and of evaporation and rainfall, over the whole surface of the globe, but it was unequally distributed. In tropical countries, the quantity of rain was considerably greater than in colder latitudes, and this was an important fact for the consideration of Engineers, in the construction of bridges, culverts, or waterworks. It had been stated, that the volume of water in

some of the streams and rivers of this country, had been found to vary in the proportion of 1 to 300: he had known instances, however, where the variation was as great as 1 to 500. But in tropical and semi-tropical countries, there was a much wider margin, as a dry ravine might become a destructive torrent, during thunder-storms and heavy rains; many inches of rain falling within a few hours.

He thought the question of land drainage might safely be left to the agriculturists, who would not be likely to expend large sums of money upon deep drainage, in order to injure the soil and render it unfit for profitable vegetation. The Duke of Northumberland had drained land to a considerable extent, upwards of 20,000 acres, and always at a depth of from 4 feet to 6 feet; and he said, "he thought he might live to be considered a shallow drainer." The experience of Mr. Rawlinson was in favour of deep drainage, and he thought, that so far from drains acting as so many culverts to carry off all the water from the land, they seemed to economise it.

Mr. JOHN EVANS said, that living in a chalk district of Hertfordshire, and being dependent upon chalk streams for the supply of motive power to numerous mills employed in the manufacture of paper, the firm with which he was connected, had endeavoured to ascertain the amount of rainfall and of percolation, through the soil of that district. In 1843, and again in 1850,[1] his late partner, Mr. Dickinson, had communicated to the Institution, the results of those experiments, and Mr. Evans thought it desirable to place the Institution in possession of a continuation of Mr. Dickinson's register of rainfall and percolation, up to the present time. In these Tables, (pp. 220-224,) the year was made to commence on the 1st of October and to terminate on the 30th of September, the first six months being taken as the winter half of the year, and the last six months as the summer half. It would be observed, that by far the greater amount of percolation, took place during the winter months, there being frequently none whatever during the summer, and the average summer percolation through the soil, during twenty-five years, being less than three-quarters of an inch. The maximum winter rainfall, = 20·27 inches, was in 1852-3; and the maximum percolation, = 17·98 inches, was in 1841-2. The minimum winter rainfall, = 8·58 inches, was in 1849-50; and the minimum percolation, = 0·9 inch, was in 1858-9. The maximum summer rainfall, 20·40 inches, was in 1860; and the minimum, 8·07 inches, in 1843. Though the annual average of rainfall of the last seven years and of the previous eighteen years was nearly the same, yet the proportions of the winter and summer rainfalls, were 13·86 to 12·79, in one of these periods, and 11·91 to 14·58, in the other; and the average winter percolation was reduced from 8·635 to 4·601.

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. ii., 1843, p. 160, and vol. ix., p. 158.

TABLES of RAINFALL and PERCOLATION through DALTON'S GAUGES, filled with Surface Soil and Chalk, at Nash Mills, Hertfordshire.

	1833-4		1834-5		1835-6		1836-7		1837-8		1838-9		1839-40		1840-1	
	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.
October .	2·55	..	·81	..	5·96	4·75	4·55	3·82	1·55	·02	2·68	·07	1·68	·09	1·50	..
November.	2·22	..	1·96	..	2·10	2·17	3·95	3·14	2·05	·18	3·55	2·91	4·40	4·70	4·25	2·57
December .	4·03	..	·84	..	·24	·48	2·21	1·82	1·70	1·62	1·58	1·84	3·02	3·75	·40	..
January .	3·32	..	1·20	..	2·40	2·32	2·40	2·10	·31	·04	1·40	1·04	3·95	3·05	1·50	..
February .	·75	..	2·62	..	2·04	2·04	2·85	2·92	2·65	·86	1·45	1·51	1·32	1·00	1·02	..
March . .	·75	..	3·48	..	3·65	2·51	·75	·01	1·55	2·73	1·92	1·22	·34	..	1·65	·53
	13·62	..	10·91	..	16·39	14·27	16·71	13·81	9·81	5·45	12·58	8·59	14·71	12·59	10·32	3·10
April . .	·60	..	1·67	..	2·57	1·74	1·32	..	1·35	..	1·65	·71	·34	..	1·85	..
May . .	1·50	..	2·05	..	·70	·03	·94	..	·84	..	1·22	·10	2·62	..	1·68	..
June . .	2·10	..	3·30	..	1·80	·01	1·86	..	2·85	..	3·31	·05	1·33	..	3·00	..
July . .	5·10	..	·80	..	2·29	·10	1·30	..	2·35	·09	4·36	·15	1·18	..	2·80	..
August .	2·47	..	·35	..	2·24	·15	3·00	·05	95	..	3·65	·09	1·90	..	3·62	..
September	1·50	..	3·82	..	2·60	·07	1·38	·05	2·47	·63	3·22	1·50	2·31	..	4·00	..
Summer .	13·27	..	11·99	..	12·20	2 10	9·80	·10	10·81	·12	17·41	2·60	9·68	..	16·95	..
Winter .	13·62	..	10·91	..	16·39	14·27	16·71	13·81	9·81	5·45	12·58	8·59	14·71	12·59	10·32	3·10
	26·89	..	22·90	..	28·59	16·37	26·51	13·91	20·62	5·57	29·99	11·19	24 39	12·59	27·27	3·10

Tables of Rainfall and Percolation through Dalton's Gauges—*continued.*

	1841-2		1842-3		1843-4		1844-5		1845-6		1846-7		1847-8		1848-9	
	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.
October .	4·40	5·99	1·41	·30	4·82	·91	4·38	1·13	1·65	..	6·36	3·98	2·59	..	4·50	2·58
November.	4·28	4·87	5·77	5·00	2·45	2·70	3·07	3·57	2·94	·30	1·47	·10	1·70	..	1·12	·47
December.	2·30	2·80	1·52	·84	·40	·30	·31	..	3·02	2·80	·90	..	3·49	2·38	2·92	2·68
January .	1·36	·60	1·46	1·25	1·90	·80	3·35	2·40	3·97	5·05	1·80	..	1·33	·81	1·80	..
February .	2·02	2·10	2·42	1·95	3·62	1·50	·70	..	1·28	·84	1·42	1·76	3·25	3·00	2·18	·40
March . .	2·20	1·62	·88	..	2·22	2·65	1·30	..	1·07	·02	·98	..	3·57	2·75	·97	·09
	16·56	17·98	13·46	9·34	15·41	8·86	13·11	7·10	13·93	9·01	12·93	5·84	15·84	8·94	13·49	6·22
April . .	·47	..	2·10	..	·33	..	1·45	..	2·52	·28	1·68	..	2·68	·70	2·00	..
May . .	1·85	..	5·00	·74	·47	..	2·25	..	1·59	..	2·15	..	·21	..	2·98	..
June . .	2·00	..	1·56	·25	1·18	..	1·60	..	·51	..	2·30	..	3·19	..	·46	..
July . .	1·93	..	2·09	..	1·95	..	2·30	..	1·90	..	1·91	..	2·42	..	2·79	..
August .	1·40	..	2·66	..	2·72	..	1·97	..	3·28	..	1·21	..	2·38	..	1·88	..
September	4·50	1·30	·63	..	1·42	..	2·00	..	1·70	..	2·06	..	2·12	..	3·80	..
Summer .	12·15	1·30	14·04	·99	8·07	..	11·57	..	11·50	·28	11·31	..	13·00	·70	13·91	..
Winter .	16·56	17·98	13·46	9·34	15·41	8·86	13·11	7·10	13·93	9·01	12·93	5·84	15·84	8·94	13·49	6·22
	28·71	19·28	27·50	10·33	23·48	8·86	24·68	7·10	25·43	9·29	24·24	5·84	28·84	9·64	27·40	6·22

Tables of Rainfall and Percolation through Dalton's Gauges—*continued.*

	1849-50		1850-1		1851-2		1852-3		1853-4			1854-5			1855-6		
	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.
October .	1·82	..	1·56	..	2·42	..	4·80	·80	3·60	1·65	1·82	2·23	..	..	5·47	..	3·00
November.	1·47	..	2·67	..	1·03	..	6·95	6·56	1·68	·57	·62	1·31	..	..	2·05	1·87	2·10
December.	2·50	1·03	1·66	1·39	·66	..	2·78	2·11	·65	·60	1·10	1·53	..	1·25	1·46	·92	1·12
January .	1·24	..	3·76	3·07	5·15	2·64	2·55	1·27	2·48	·95	·95	·79	..	..	2·97	2·28	2·40
February .	1·33	·41	·76	·85	1·15	1·02	1·44	..	·93	·45	·51	1·18	1·25	..	1·46	1·30	1·40
March . .	·22	..	4·30	3·18	·34	..	1·75	..	·32	..	..	2·28	1·20	2·20	1·07	·45	·45
	8·58	1·44	14·71	8·49	10·75	3·66	20·27	10·74	9·66	4·22	5·00	9·32	2·45	3·45	14·48	6·82	10·47
April . .	3·00	..	1·55	·04	1·13	..	2·60	..	·86	..	..	·40	·19	·22	3·10	·90	·90
May . .	1·67	..	·75	..	1·70	..	1·91	..	3·48	..	..	2·35	..	..	3·95	1·70	2·00
June . .	1·20	..	1·75	..	4·49	..	3·70	..	·97	..	..	1·76	..	·36	1·25	·19	·19
July . .	2·90	..	2·56	..	4·70	1·50	3·88	..	1·90	..	..	5·00	..	1·42	1·68	..	..
August .	1·14	..	2·00	..	4·08	..	3·00	..	1·75	..	..	1·43	..	·30	2·75	..	..
September	1·91	..	·64	..	3·87	..	1·70	·24	·51	..	..	1·72	..	..	2·13	..	..
Summer .	11·82	..	9·25	·04	19·97	1·50	16·79	·24	9·47	..	..	12·66	·19	2·30	14·86	2·79	3·09
Winter .	8·58	1·44	14·71	8·49	10·75	3·66	20·27	10·74	9·66	4·22	5·00	9·32	2·45	3·45	14·48	6·82	10·47
	20·40	1·44	23·96	8·53	30·72	5·16	37·06	10·98	19·13	4·22	5·00	21·98	2·64	5·75	29·34	9·61	13·56

Tables of Rainfall and Percolation through Dalton's Gauges—*continued.*

	1856-7			1857-8			1858-9			1859-60			1860		
	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.
October .	2·92	..	1 45	5·80	1·70	3·40	1·94	..	..	3·03	..	1·90	1·65	·62	·75
November.	1·30	..	1·05	2·06	1·35	1·35	·78	..	..	3·09	1·70	2 20	2·70	2·30	2·30
December.	2·05	·60	1·65	·47	·18	·18	2·03	..	·30	3·30	2·80	2·90	2·40	1·26	1·12
January .	3·60	2·80	2·74	·70	..	..	1·21	..	1·02	3·53	2·95	3·08			
February .	·21	·32	·30	1·60	1·82	1·61	1·91	·09	1·37	1·22	·90	1·10			
March . .	1·88	..	..	1·18	·59	·62	1·77	..	..	2·32	·92	1·26			
	11·96	3·72	7·19	11·81	5·64	7·16	9·64	·09	2·69	16·49	9·27	12·44			
April . .	2·35	1·11	1·32	2·46	·80	·84	2·62	..	1·04	1·32	·35	·54			
May . .	·83	..	..	2·33	..	..	2·04	..	·06	3·67	·24	1·22			
June . .	2·20	..	..	·65	..	..	3·70	..	1·02	6·19	2·44	4·00			
July . .	1·70	..	..	2·63	..	..	3·80	..	1·20	2·22	..	..			
August .	3·38	..	..	2·40	..	..	2·40	..	·35	4:44	..	2·08			
September	3·65	..	..	1·80	..	..	3·75	..	·55	2·65	·13	1·10			
Summer .	14·11	1·11	1·32	12·27	·80	·84	18·31	..	4·22	20·40	3·16	8·94			
Winter .	11·96	3·72	7·19	11·81	5·64	7·16	9·64	·09	2·69	16·49	9·27	12·44			
	26·07	4·83	8·51	24·08	6·44	8·00	27·95	·09	6·91	36·89	12·43	21·38			

Tables of Rainfall and Percolation through Dalton's Gauges—*continued.*

	Winter.		Summer.	
	Rain.	Soil.	Rain.	Soil.
1835—6	16·39	14·27	12·20	2·10
1836—7	16·71	13·81	9·80	·10
1837—8	9·81	5·45	10·81	·12
1838—9	12·58	8·59	17·41	2·60
1839-40	14·71	12·59	9·68	..
1840—1	10·32	3·10	16·95	..
1841—2	16·56	17·98	12·15	1·30
1842—3	13·46	9·34	14·04	·99
1843—4	15·41	8·86	8·07	..
1844—5	13·11	7·10	11·57	..
1845—6	13·93	9·01	11·50	·28
1846—7	12·93	5·84	11·31	..
1847—8	15·84	8·94	13·00	·70
1848—9	13·49	6·22	13·91	..
1849-50	8·58	1·44	11·82	..
1850—1	14·71	8·49	9·25	·04
1851—2	10·75	3·66	19·97	1·50
1852—3	20·27	10·74	16·79	·24
	249·56	155·43	230·23	9·97
Average of 18 Years.				
	13·864	8·635	12·790	·554
Annual Average.			26·654	9·186

	Winter.			Summer.		
	Rain.	Soil.	Chalk.	Rain.	Soil.	Chalk.
1853—4	9·66	4·22	5·00	9·47	..	..
1854—5	9·32	2·45	3·45	12·66	·19	2·30
1855—6	14·48	6·82	10·47	14·86	2·79	3·09
1856—7	11·96	3·72	7·19	14·11	1·11	1·32
1857—8	11·81	5·64	7·16	12·27	·80	·84
1858—9	9·64	·09	2·69	18·31	..	4·22
1859-60	16·49	9·27	12·44	20·40	3·16	8·94
	83·36	32·21	48·40	102·08	8·05	20·71
Average of 7 Years.						
	11·909	4·601	6·914	14·583	1·150	2·958
Annual Average . .				26·492	5·751	9·872
Average of 25 Years.						
	13·317	7·506	..	13·292	·721	
Annual Average . .				26·609	8·227	

There were various causes which affected percolation, notwithstanding that the amount of rainfall was nearly constant. If there was half an inch, or even three-quarters of an inch of rainfall on one day, succeeded by three, or four fine days, very little percolation took place, even in winter; but if 2 inches of rain fell for two consecutive days, the ground was so saturated, that even in summer, some of the water found its way into the ground. Although, therefore, by considering the amount of rain, and the manner in which it had fallen, an approximate idea might be formed of the quantity of water that had gone down to the springs; yet any notion of forming an average, based upon the rainfall, would be erroneous. During the last few years, an improved form of Dalton's gauge had been adopted. The gauges now consisted of two cast-iron cylinders, 18 inches in diameter, turned to a knife edge at the top, and sunk to a depth of 3 feet below the level of the ground. One of these cylinders was filled with the ordinary surface soil of the neighbourhood, and the other, with ordinary fragmentary chalk; both being covered with grass and the vegetation of the surrounding ground. Any rain that fell, was absorbed by the earth within the cylinders, and if it was afterwards carried off by evaporation, none of it, of course, reached the bottom of the cylinders; but if, on the contrary, any water sank to the depth of 3 feet from the surface, it was collected, and its amount was ascertained in the ordinary manner. It might be argued, that there were causes of error in these gaugings, and that they would not correctly show the absorption of rain, over any particular district of country. It might, for instance, be said, that land which was annually ploughed for the purposes of cultivation, would absorb more rain than land covered with turf; but then it would also part with the water more rapidly, and when the crop sprang up and was growing to maturity, the corn, or other vegetable produce, would absorb a great quantity of moisture. It had been found by experiment, that a blade of corn was able, under favourable circumstances, to absorb much more moisture than its share of the rain falling in any part of this country. Indeed, it would, generally, be able usefully to absorb a greater quantity than it could actually obtain, for it was found by these gauges, that owing to vegetation and evaporation, the percolation in summer was extremely small, compared with that in winter. He thought, that inasmuch as the gauges to which he referred, were covered with grass, the abstraction of moisture for the purposes of vegetation, taken as a whole, was nearly the same as that which took place over ordinary chalk districts. It might be objected, that the depth of 3 feet was scarcely sufficient to prevent the water from returning to the surface; but he thought that depth was quite enough for soil, and if it were not, the only error would be, that the

gauges would show a greater amount of percolation, than that which actually took place. It had been found, that the chalk with which one of the gauges was filled, was more absorbent than the soil in the other gauge. Those who lived in chalk districts, and had observed the effect of a shower of rain, could not fail to have noticed how rapidly it was absorbed into the ground. It was rare to see surface drainage in a chalk district; but though the absorption of the chalk was so rapid, he thought, that in these cases, the gauge might, possibly, be deficient, for the capillary attraction of chalk was such, that it always remained moist for a considerable height above the level of the water in the wells. On chalk downs, the vegetation generally remained green during the driest summers; this might, probably, be attributed, in part, to the water being drawn up from the inmost recesses of the chalk, by capillary attraction. The results obtained from these gauges had been confirmed by actual experience. In the manufacture of paper, large quantities of lime were used for boiling the materials, and chalk was burnt for that purpose. It was not dug from a pit in the ordinary manner, but a shaft was sunk, from which headings were driven, as in mining. When the gauges showed the water to have percolated into the earth, he had generally found, after the lapse of one, or two weeks, that it had also percolated into the chalk pit, a depth of 50 feet, or 60 feet below the surface; he could even hear it dripping. But though the gauges showed a certain amount of percolation, he did not maintain, that the flow of the streams in the country, in a given year, was immediately dependent upon the quantity thus absorbed; or in other words, that the volume of water in a stream, was in a direct ratio to the amount of percolation. It was evident, that the streams were the result of the water draining out of natural subterranean reservoirs, formed by the rain which had percolated through the chalk, and which was held up by the impervious strata below; it did not follow, that the whole of it quitted the reservoir in a single year, for he believed it contained enough to furnish a certain outflow for four, or five years, even if there was no rainfall. In point of fact, the water was held in a vessel from which there was a leakage, with a considerable head of water above it. The outflow would depend upon the amount of the head, but it might be a long time before the cistern above was emptied. The level of the water in the subterranean reservoir in the interstices of the chalk, varied in different years, and at different periods of the same year, according to the amount of percolation into the soil; wells sunk into the chalk, would vary as much as 60 feet, or 70 feet, in the head of water. The amount of variation depended, in a great measure, upon the nature of the chalk; in descending from the middle, to the lower chalk and chalk marl, it became less pervious to water. The

inclination of the surface of the subterranean store was thus dependent, not only on the amount of percolation, but also on the nature of the chalk. The inclination at which water would stand in the middle chalk, north of London, was, under ordinary circumstances, at least, 13 feet 6 inches to the mile, which was proved by the streams generally running at about that slope. It was evident, that if the water could pass through the chalk with that inclination, it would find its way by some underground passage, instead of by the streams. In its lower beds, the chalk was of a nature to increase the friction, and it would be found, that in the neighbourhood of Berkhempstead, the water stood at an inclination of about 19 feet 6 inches to the mile, and in some parts of Kent and elsewhere, at as much as 40 feet to the mile.

Allusion had been made in the Paper to the River Bourne, at Croydon, which had, for centuries, been regarded as possessing a somewhat mysterious character, but he thought the explanation of the phenomena which it presented, was very simple. He would assume, that under ordinary circumstances, the water that percolated into the chalk, passed through with an inclination of, say 15 feet, or 16 feet to the mile. In years of ordinary rainfall and percolation, the water would, therefore, find its way under ground in a valley, with a fall of 18 feet, or 20 feet to the mile, without showing itself upon the surface; but supposing there to be an excessive supply of water to the reservoir, the inclination of the surface of the reservoir became greater, and a stream would run upon the surface, where there was no stream before. In Hertfordshire, there was a similar Bourne, which was not more than two, or three miles in length. Some years ago, he had it levelled from the point where it joined the river, and the inclination which, as far as he remembered, was from 19 feet to 20 feet to the mile, proved to be within one foot of the calculation he had previously made. He had observed on former occasions, the inclination of the water along the valley of that Bourne, in ordinary years when the stream was not running, and he was thus enabled to judge of the increase of elevation necessary to make the stream visible on the surface. Owing to the excessive rains of last year, that stream had now begun to run.

Another point which had been alluded to in the discussion, was the effect of land drainage upon the streams. He had already remarked, that in purely chalk districts the soil was extremely absorbent, and consequently, no agricultural drainage was required; but in nearly the whole of the district round London, the chalk was intersected by valleys, cutting up what was once, high table-land. In valleys and on their slopes, the soil was light, but the tops of the hills were usually covered with a drift derived from the lower tertiary beds, or with spurs of the lower tertiary formation, and there the soil was of a loamy character, being frequently used for

brick making. The percolation of water through such soil was difficult, but still the beds were not impermeable. Those, however, were the only parts of a chalk district which required to be drained; and then, instead of carrying the water down to the rivers, dry, or dumb wells were sunk into the chalk, the absorbing power of which was so great, that it carried away all the water poured upon it, into the subterranean reservoir. In other places, the water flowing off clayey tracts overlying chalk, was absorbed in natural swallow-holes in the same manner.

In answer to a question by Mr. Homersham, Mr. Evans said, that the surface of the soil with which his gauges were filled, was slightly below the knife edge to which they were turned; and he had found the surface soil to be so absorbent, that in the heaviest rains, there was not the slightest overflow.

Mr. R. B. GRANTHAM observed, that he should confine his remarks to that portion of the subject with which he was most conversant, and on which he had, during the last session, presented a Paper to the Institution.[1] Sir John Rennie, (Past-President, Inst. C.E.,) with all the authority that attached to his great experience in the main drainage of Lincolnshire, had given an opinion, that pipe drainage was not suitable for that district of country, and that there were many instances in which deposit was brought down in great quantities to the river, by pipe drains, and land drains, rendering it necessary that they should be cleared. But Mr. Grantham maintained, that there was no deposit from pipe drainage; and that there was little, or none, from properly kept drains. Mr. Hawksley, (M. Inst. C.E.,) also, had complained, that particular depths were adopted without any reference to their suitability in each particular case, and that some preferred pipes 1 inch in diameter; others, pipes of 2 inches; and others, tile drains. Now Mr. Grantham believed, that Engineers had not yet given sufficient attention to the whole facts of the case. There were great varieties of practice, and it required considerable experience to know where this system of drainage might be adopted with the best advantage, and where it ought not to be carried out to too small, or to too great an extent. The depth of 4 feet had been established, upon the principle laid down by agriculturists and botanists, that even in stiff clays, the roots of plants would penetrate to that depth. Now if the water was kept at a certain level below 4 feet, the ground above would become more mellow, and warmer for the nourishment of the vegetation. In porous ground, such as sand and gravel, the drains might be placed wider apart, and be carried to greater depths. It might appear, that by putting pipes 4 feet deep into clay lands, scarcely any water would pass into them from above;

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xix., p. 53.

but the real object was, to prevent the cold water below, from rising to the roots of the plants. Pipes, 2 inches in diameter, were the best that could be employed, because part of the area of each pipe was occupied by water, and the other part by air, which was most essential to the nourishment of the plants, and the mellowing of the land, by keeping it at a warm and proper temperature. Valleys were, undoubtedly, occasionally flooded, in consequence of pipe drainage and of the clearing of agricultural land drains, but this was mainly attributable to the existing state of the law, which would not permit of a passage being made through an intervening property, in order to procure a proper outfall. It was well known, that mills, weirs, and other obstructions were causing much injury and harm in agricultural districts; a mill, not worth more than £50 a year, might occasion damage to many hundred acres of land. There were some few instances, however, in which drainage might be carried out to a large extent, and the mills be retained.

He believed a Bill would shortly be introduced into Parliament, with a view to remedy these evils, and the commission which it proposed to create, would be constituted upon the basis of the Inclosure Commission. Every locality would have its conservancy board, and regulate its own affairs, assessing themselves in any way they thought necessary, both for carrying out the requisite works, and for maintaining them.

Mr. BATEMAN was but slightly acquainted with the question of water supply in chalk districts. In the chalk hills round London, the absorption was so great, that there was very little flood water; the rivers were more equable and the springs more continuous, than was the case in other formations. In the hills of Yorkshire, Lancashire, and Derbyshire, which formed the 'backbone' of England, the yield of the springs in dry weather, was from one-half to about three-quarters of a cubic foot per second, for every thousand acres of contributing ground, whilst the flood drainage from the same area, amounted to 200, to 300, and even to 400 cubic feet per second. In the more impervious granite districts, and other primitive formations, there was almost a total absence of springs, and nearly the whole of the water passed off in floods. More information was required on this subject, upon which he had already contributed several Papers to the Literary and Philosophical Society of Manchester.[1]

Mr. BAILEY DENTON remarked, that he found the difficulties of under-drainage, increase rather than diminish. It was said, that it augmented both the drought and the floods; the latter effect could scarcely be doubted, but drought could only be increased by les-

[1] *Vide* "Memoirs of the Literary and Philosophical Society of Manchester;" Second Series, vol. vii., p. 157, *et seq.*, and p. 191, *et seq.*; vol. ix., p. 1, *et seq.*; and vol. x., p. 137, *et seq.*

sening the rainfall, which would, probably, result from diminishing the evaporation. The President, he believed, was of opinion, that under-drainage, on the contrary, promoted evaporation, rather than diminished it. Mr. Denton, however, had satisfied himself, both by experiment and by observation, that although there were not wanting many contradictory facts, that opinion could not be sustained. He had found that, supposing the evaporation from a water surface to be 33, the amount from a saturated surface would be 30, and from a drained surface, about 20. Capillary action might be promoted by drainage, in consequence of the soil down to the bottom of the drains, being reduced to a state of minute disintegration and comminution, thus creating channels of attraction, which brought the water upwards, from beneath the drains. He hoped it would not be inferred, that the water found its way into under-drains, by the upper part, or sides of the drains. Water could only enter from the bottom of the drains; as the soil below the drains must first be replenished by the rainfall before any could run out, and as the water must pass the drain to replenish the subterranean depths, it was evident, that the crust of 4 feet on the surface of drained land, was unimportant in considering the great question of water supply. It had been stated in books of authority, and he believed there was a prevalent opinion, that the amount of evaporation varied from 13 inches to 17 inches, giving a mean of 15 inches per annum. This assumption was contradicted by the fact, that in August, 1859, the evaporation exceeded the rainfall by 3 inches, whilst in the same month of 1860, the rainfall exceeded the evaporation by the same amount, thus making a difference of 6 inches, and showing the incorrectness of considering evaporation as a constant quantity, and the fallacy of quoting means and averages on water questions.

His views with regard to deep drainage were confirmed by the inhabitants of the fen districts who were, at the present moment, seeking a lower outfall, in order to increase the depth of their drainage. The opinion prevailed, that under-drainage led to the consolidation of the peat land of the fens.

Mr. G. R. STEPHENSON remarked, that in another district, there were complaints of the drainage having been already carried to too great a depth.

Mr. HAWKSLEY observed, that out of an average rainfall, near Watford, of $26\frac{1}{2}$ inches, only about $9\frac{1}{5}$ inches had been collected into Mr. Dickinson's gauge. Now he had previously stated, that the evaporation in that neighbourhood, had been ascertained to be about 17 inches, on the average, and that it varied from a minimum of 13 inches to a maximum of 18 inches, or 20 inches. Hence arose the inquiry in the Court of Chancery, as to the quantity of water flowing into the River Colne. Hitherto, it had been sup-

posed, that the water which went into the gauge, was simply that which would, under ordinary circumstances, have penetrated into the earth, and have reappeared in springs. But it was now stated, that the edge of the gauge was elevated above the surface of the surrounding soil, so that the $9\frac{1}{2}$ inches of water in the gauge, included both the flood water and the spring water. This explanation reconciled the results obtained by the gauge, with the actual observed yield of the Thames. By measurements made during a sufficient space of time, it had been ascertained, that the amount of rainfall which penetrated the surface, and reappeared as spring water, did not exceed, in very dry years, 5 inches per annum; and in dry summers after long drought, the quantity of water which flowed down the Thames, during the autumn, was only at the rate of about $2\frac{1}{2}$ inches per annum.

He still maintained, that subterranean drainage often had the effect of increasing the magnitude of floods. It had been urged, in opposition to this view, that as the ground became more subdivided, or comminuted by drainage, the rain was more equally distributed through the earth over the drains, and consequently, was more liable to be evaporated, than to flow off in floods, or to pass away by subterranean drainage. This might be perfectly true, under certain circumstances, but when considered under a different aspect, it would be seen, that the opposite result might follow. If this porous and comminuted ground was already perfectly saturated by a recent fall of rain, which was frequently the case in the autumnal months, the ground, being already overcharged, would refuse to absorb any further quantity, which would then run off either from the surface, or by the drains, and the floods would be augmented. That this was really the case was manifest; for recently, many bridges which had stood for ages without injury, had been washed away by floods, and it was an ascertained fact, that latterly, in nearly all districts, from some cause, or other, the floods had greatly increased in volume, and the flow in dry weather had as perceptibly diminished. All water millers concurred in opinion, that the extension of drainage had increased the severity both of the floods and of the droughts.

Mr. Frederick Braithwaite was gratified to observe the unanimity of feeling which prevailed, as to the necessity of procuring an adequate supply of uncontaminated water to the rivers. The laws of absorption and evaporation were in operation over the whole world, but under different circumstances which must be carefully taken into consideration; some were, for the most part, constant; others were fluctuating and variable. In any particular district, the surface of the ground and the nature of the soil were constant, but the extent of moisture in the ground was variable. Some soils absorbed as much as 90 per

cent. of moisture, whilst others did not imbibe one-half that quantity. The amount of rainfall was always variable, both with regard to the time and manner in which it fell. The hygrometric condition of the air was likewise subject to many variations; moisture and dryness could never coexist. It appeared from the Tables of Mr. Evans, (Assoc. Inst. C.E.,) that the rainfall, although it might be large, fell so lightly, that it was evaporated almost as rapidly as it was absorbed. The amount of the evaporation was greatly influenced by the velocity with which the air passed over the land. Thus, taking the evaporation over a given space, with a moderate breeze, as 2, it would be, with a gale of wind, 3, 4, and even 5. Under these circumstances, a diversity of opinion was to be expected, as to the actual amount of evaporation, but it had been distinctly proved, that the quantity of water which sank into the ground, was not so considerable as had been supposed.

Pollution of Rivers, Town Drainage and Sewage.

Mr. Simpson, (Past-President,) said, it could not be denied, that the Wandle was greatly polluted at the present time; and as the district became more populated, agricultural operations would be extended, and the land would be more highly manured; Collyer's Water and the other small streams would also contribute to the pollution of the lower part of the river. The time, therefore, had arrived, when the evil should be remedied, not only in this stream, but in the other rivers throughout the country. The Wandle was affected to a considerable extent, by the sewage of Croydon, and it had been recently discovered that the gas works of the town drained into the river. In addition to these sources of deterioration, there were others arising from the increase of population in the Wandle valley, the high manuring of the land, and the washing carried on at several of the mills, which frequently rendered the water turbid. He believed, however, that it was possible to exclude three-fourths of the polluted water, and to restore the stream to nearly its original purity.

Sir John Rennie, (Past-President,) remarked, that the amount of sewage was not constant, but it increased with the growth of the population; the drains were made more direct, and the velocity of the water enabled them to discharge the whole of their contents into the main streams. The latter were being gradually filled with sewage and alluvial matter, and unless proper means were adopted to keep them open, the outfalls would, eventually, be choked up; and during the summer, the nuisance arising from the offensive matter was greatly increased by the heat. The supply of water for domestic and other purposes was thus reduced, in consequence of the deleterious character of the matter falling into certain parts of the streams.

Mr. GIBBS observed, that the pollution of rivers became more apparent as the population increased, and as sanitary improvements were more systematically carried out. The more perfect the drainage, and the more copious the supply of water, the more difficult it became to preserve the purity of the streams. This was particularly exemplified at Croydon, where the sewers of the district were discharged into the river; and no change in the character of the Wandle, could take place, till the sewage was diverted from the river.

Mr. HAWKSLEY said, it was very important to consider the effects of urban drainage upon rivers. In the neighbourhood of populous cities, sewers must of course, be cleansed and drained, and the inhabitants must be provided with all those conveniences requisite for an improved state of civilisation; but he denied, that it was invariably necessary, in so doing, to injure the rivers by the introduction of the sewage. The River Wandle was an instance of a river being polluted, almost without necessity. In the valley of the Wandle was situated the now large town of Croydon, which, with its neighbourhood, contained not less than thirty thousand inhabitants. The municipal authorities of that town had constructed, properly enough, a net-work of sewers; but the sewage was, eventually, permitted to run into the river. It was said to be deodorised, but the process of disinfection which had been used was insufficient to accomplish the object. In this state, it was turned over the land for the purpose of irrigation, whence it was allowed to run into a stream communicating with the main river. The result was to create a stench, which could only be compared to that of the meadows near Edinburgh. Now there was no necessity, that this state of things should continue: if the local authorities expended the proper amount of money, there were several means by which foul water might be prevented from polluting the river. The works for that object, erected at Leicester, by Mr. Wicksteed, (M. Inst. C. E.,) although not commercially remunerative by the sale of the manure, effected the purification of the sewage water, which flowed perfectly clear into the river. When the undertaking passed into the hands of the municipal authorities, they diminished the quantity of deodorising material, and the water, consequently, was not so well purified now, as when the works were in the hands of the company. The expense, however, was not inordinate, as the experiment was made at an original cost of £40,000, and an annual outlay of £2,500, (since reduced about one-half,) which was an insignificant sum for a population of seventy thousand inhabitants.

There were two modes of employing sewage water with a view to its beneficial application; by allowing it to flow by gravitation over lands, situated on a low level, and by pumping it from tanks over large areas of elevated lands. But the first system

could not be applied usefully and economically, to the irrigation of land near large towns, because the sewage would have to travel a considerable distance in the urban sewers, and through prolonged outfalls, during which course the valuable fertilising matter became oxidised, and was therefore, almost, if not entirely, valueless for agricultural purposes. The attempt had always failed, near large towns; but near small towns, where the sewage water could be applied fresh, and whilst containing all the undecomposed manure, it became a valuable fertilising agent, when spread over the land. But precisely on account of its value it became a nuisance, unless previously deodorised. Experience had proved, that McDougal's fluid effectually accomplished this object, when applied in sufficient quantities; it, moreover, was cheap, as one gallon, which cost 8*d.*, would purify from 12,000 gallons to 15,000 gallons of sewage water, according to its strength. This fluid was the second product of distillation of gas tar, at a low temperature. In the first distillation naphtha was produced; in the second, a fluid which, being rendered alkaline by a little quicklime, possessed the deodorising power. This was the process pretended to be adopted at Croydon, but an insufficient quantity of the fluid was applied, as was manifest from the fact, that the matter from the sewage water deposited on the fields, emitted the most sickening odours. McDougal's fluid, though an invaluable deodoriser, was, however, inimical to fish and other animals living in water.

The second method of purifying the sewage was, by pumping it from tanks, over large elevated areas; but the cost of that system was so great as to prevent its application. It might, possibly, answer with a small quantity of water, but if it was requisite to pump millions of gallons daily, and to economise it in wet weather for use in dry weather, the arrangements necessary for giving commercial value to the water, would never be remunerative. It had been tried, among other places, at Rugby, the capital being found, partly by a private gentleman, and to a limited extent, by the town. But the result had been unsatisfactory, the value of the improvement to the land being, as nearly as possible, the sum expended in manipulation. The whole of the sewage was not used on the land, a considerable portion passing through strainers into the river. The pumping system could not, therefore, be recommended as a remedial agent at Croydon, where, he believed, it had been proposed by Mr. Shepherd.

Much misapprehension prevailed as to the increased value of land irrigated by sewage. An example had been cited near Edinburgh, in which land not worth £1 per acre had, from the application of the sewage, become worth £25 per acre. But it was the proximity of the land to the city, which had so much increased its value, and which had enabled the sewage to be made

available upon it; guano would have rendered it as fertile as the manure from the sewage. If the sewage could be put upon similar soil in the Highlands, it would not increase the value of the land one-tenth of that amount. He could mention other instances of land thus manured, fetching as much as £60 per acre, but it was the proximity to large towns, and not the sewage, which had so considerably increased its value, for any other proper agricultural stimulant, rightly applied, would produce the same results, without the nuisances which usually resulted from irrigation with sewage water.

The main question, however, was, what means could be taken to restore the Wandle, which was becoming daily more polluted, to nearly its pristine condition. A great number of manufactories were established on its banks, on which there were also many large and valuable properties, the owners of which were, generally, not interested in the adjacent mills, or manufactories. The rights of these proprietors ought and could be preserved, by instituting a proper conservancy for the purpose. He believed it could be effected by a combination of private individuals, and that there was no necessity for making that application to Parliament which had been proposed, under the name of conservancy, but the object of which was rather to destroy existing rights, than to maintain them.

Mr. HOMERSHAM said, that in the autumn of 1857, he had personally examined the system of deodorising the sewage, employed at Leicester, and from the returns furnished to him by Mr. E. L. Stephens, Engineer of the Borough, he had ascertained, that out of thirteen thousand houses, only seven hundred were connected with the sewers of the town, and that the fæcal matter from only that number of houses went into the reservoir, where the water was deodorised. The town was plentifully supplied with water both from the water company and from private wells, and the surface drainage of the streets was allowed to run into the sewers; it was not surprising, therefore, that when so small an amount of fæcal matter entered the deodorising tanks, the water should come out moderately clear. A large portion of the quicklime used to deodorise the sewage was, necessarily, converted into chalk, the water supplied by the water company, being of 16° of hardness, and containing much bicarbonate of lime. The greater part of the fæcal matter of the town, did not enter the sewers, but it was mixed with ashes at the various middens, and was conveyed away in carts. At Croydon, on the other hand, there was scarcely a house without one watercloset, and many with two, or three, all connected with the sewers. It was important, therefore, in instituting a comparison between the two towns, to bear in mind the different quality of the sewage matter.

Mr. FENTON thought, that justice had not been done to the

Croydon Board of Health, under whose direction he had carried out, without restriction, the present works, no expense having been spared in purifying the sewage water. The correctness of the principle adopted, that of applying McDougal's fluid, in the first instance, and then passing the water over the land was not denied, but it was asserted, that too little fluid was used. He had diminished the quantity of fluid, in consequence of the perceptible smell of tar at the outfall, when one gallon of fluid was applied to 20,000 gallons of sewage water. He had reduced the proportion of fluid by one-third, and even now, there were occasional complaints arising from the same cause. He should be glad to know, at what point the inspection had been made to which Mr. Hawksley had alluded. The Croydon Board was always ready to carry out any sanitary measures that could be proposed, and the expense had not been, and never would be, a matter of consideration with them. All were agreed, that sewage water could be purified, and that the rivers of this country ought not to be polluted by it.

In answer to inquiries by the President, Mr. Fenton said, that the sewage of Croydon was carried, at present, over about 60 acres of land, and that a very small proportion of fluid was used during the cold weather. He had found no smell at the outfall, and the water was quite pure. The quantity of fluid was not diminished from economical considerations, but on account of an intimation from some of the owners of the mills and fisheries on the stream, that they thought the tar was injurious to the fish. If it was thought desirable to use a larger quantity of fluid, he would undertake to say, that the Board would, at once, order it. He would not like to apply the sewage to the land, without first straining off the solid matter, and afterwards, in warm weather, deodorising the water; it would, otherwise, create a nuisance, which, in hot weather, would be unendurable.

Mr. RAWLINSON disputed the correctness of the remarks that had been made, concerning the irrigation of the Craigentenny meadows, near Edinburgh. The proprietors denied, that the extraordinary value of the land, which had risen from £15 even to as much as £45 per acre, was caused by its proximity to the city, but they asserted it to be due to the effects of the sewage placed upon it. A considerable portion, previous to the irrigation, consisted of sea sand, and on pulling up the grass, the sand was still to be seen, covered only with manure, about an inch in depth, attached to the roots. If the irrigation were discontinued during twelve months, the land would become worthless. As to the proximity of large populations giving value to the land, there was in the neighbourhood of Edinburgh, as also of London, and of most other large towns in Great Britain, grazing land of the richest

description, for which not more than £5, or £6 per acre could be obtained.

The composition of McDougal's fluid had not been correctly described; it contained a good deal of lime, and but very little carbolic acid. He believed, however, that during nine months of the year, it was not required. If the sewage was placed fresh upon the land, it would be disinfected, without the intervention of any deodorising mixture; it was the putridity that caused offensiveness, and putridity resulted from age. As a member of a commission appointed to inquire into the subject of the pollution of rivers, he had, in the course of his duty, examined nearly every stream in England that was polluted by sewage, and on which sewage works of any magnitude had been carried out. It was, undoubtedly, an evil that called for remedy, but he did not think, that it could be effected by such a conservancy of private individuals as had been proposed. He did not see how any national system of conservancy could be instituted, without the initiation of the government, or without centralisation in some form. It might consolidate powers, make them permissive, or hand them over to local authorities, as was generally the rule, but there must be a central official head. The Wandle was purity itself, compared with the rivers which flowed through the Lancashire and Yorkshire manufacturing towns, and which were foul from their sources to their estuaries. He contended, that the first consideration of a civilised community ought to be human life and health, for it was that, after all, which gave value to property. That object must be effected, even at the risk of private injury to individuals, by partially killing their fish, or partially damaging their ornamental grounds; but he firmly believed it could be accomplished, without the annoyances which had been so much complained of.

Mr. JOHN EVANS said, it had been suggested, that main drains should be constructed alongside the rivers, but it seemed to him, that if all the water that was now employed by the towns situated upon rivers, was permanently diverted from them, the supply would be so diminished, that the rivers themselves would become not only useless, but pestiferous. Then again, if the water was to be returned to the river, after it had been used for the various purposes of the town, it appeared there were very great, not to say insuperable, difficulties in restoring it in such a condition as not to be injurious to the river, and to the health of those residing near it.

The production and utilisation of sewage might be regarded as a manufacturing process. Sewage matter as originally produced, was, no doubt, a most valuable product for agricultural purposes; but if a manufactory were established to produce manures of various kinds, it would be thought absurd to dilute them with water to such an extent, so as to make them undergo fermenta-

tion, and thus render them comparatively useless. The question to be considered was, whether those matters which were produced in a solid form, could not be preserved in that form, so as to retain their value as fertilising agents. What seemed to be required was, some intermediate course between the old cesspools and the modern system of waterclosets and sewers. He could not point out a method by which this could be effected, but any one who could find a means of retaining the sewage matter for manure, and at the same time, of restoring the water to the rivers in nearly its original purity, must be regarded as a benefactor of mankind.

Mr. W. DRUMMOND, the Chairman of the Croydon Local Board of Health, observed, that there was a remarkable circumstance connected with the Wandle, celebrated as it was for its trout and for its beauty, that at the head of it, at its very urn, there should be a town containing, as it had been stated, thirty thousand inhabitants. That statement, however, was not strictly correct; the parish, indeed, contained that number, but in the town, there were only twenty thousand; and the locality inhabited by the others had its watershed elsewhere, and its drainage had nothing to do with the Wandle. When the Croydon Local Board of Health was established, ten years ago, and previously to that time, no effort had been made to keep impurities out of the river. The usual position for the privy of a cottage, was over one of the streams feeding the Wandle, and there were hundreds of these cottage conveniences. There were in the town, two large ponds, each about half an acre in extent, with copious springs in them; but these ponds served as two large cesspools for the sewage of the town, and they were choked with black mud, to a depth of from 2 feet to 5 feet. When the Board of Health undertook the drainage of Croydon, the river just below the town, was foul with deposits of offensive mud, on each side of the stream, which meandered through these banks of filth. It was the object of the Local Board, not merely to drain Croydon, but also to purify the Wandle, which was much esteemed as an ornamental and interesting feature of the neighbourhood. He mentioned this desire of the Board, because the labours of the Croydon Board of Health, had been unfavourably alluded to. They had been accused of devoting too much time to mere talk, but so little vanity did they possess on that score, that during the first five years of the Board's existence, the members had persisted in excluding from their meetings, the reporters of the public press. They had also been accused of parsimony in using too little disinfecting fluid with the sewage. The Board, however, laid no restriction in that respect on their surveyor, and they were disposed to spare no expense to prevent the pollution of the Wandle.

The problem which the Croydon Board had before them, was this: a population of twenty thousand being at the head of

a river, with no other outfall, or means of drainage, what was the best mode of dealing with the sewage? It was a problem now before the public, 'coram judice,' and which could scarcely be said to be yet solved. But the Croydon Board had laboured hard to solve, in practice, this very important problem, and they were, moreover, at all times, ready and anxious to receive the suggestions of scientific and of practical men; and he firmly believed the result to have been, that no other inland town was better drained, and the sewage disposed of, with less inconvenience to the neighbourhood. Formerly, there was no arrangement whatever, either for purifying the sewage, or for keeping it out of the river, which was the general dust-bin, sink, and sewer of the town. In fact, it was customary for the millers periodically to plough the bed of the river, in order to clear away the obstructing mud. At present, the sewage from four thousand houses was entirely intercepted. The whole, including the outpourings from a tan-yard, and from a street of butchers, was now received into glazed pipe sewers; it was there largely diluted with an abundant supply of water, and within an hour after any foul liquid was generated, it was carried, by these pipes, to a distance of two miles from the town. Not a particle remained to generate unwholesome gases among the inhabitants, and the river now, from the town to the first mill, ran sparkling and clear, and it was unpolluted by the population at its source. The sanitary condition of the town was greatly improved; the deaths were now only 16½ per 1,000 per annum, while the average for the previous ten years, was 20 per 1,000, and before the operations of the Board, it was 22 per 1,000. The sewage was conducted through fields, away from the river, till it came by gravitation, to a farm of 96 acres, belonging to the Board of Health, where it underwent three processes. First, it was strained through filters of gravel to remove the solid matter, about 20 tons per week, of rich manure being obtained, consisting almost entirely of night soil, not too much washed with water, to be deprived of its fertilising qualities. This met with a ready sale at one shilling per ton, the object being to get it promptly removed, rather than to make a profit by it; in three weeks, as much as 800 tons had been sold, for which £40 had been received. Having thus deprived it of all the solid matter, the sewage was then, in warm weather, mixed with as much as was necessary, or useful, of McDougal's fluid. On one occasion, so much of that fluid had been used, that the water at the outfall, after going over the farm, retained a perceptible odour of tar, of which the fluid was a distillation. Since then, a less quantity had been applied, and in the winter, none at all; yet there was no perceptible odour. He was satisfied, that the abominable smell, which had been so much complained of, did not proceed from the farm; it must have been at some spot

that had no connection with the drainage works. The sewage water was, subsequently, made to flow over and through the grass and land of the farm. The reason why this occasioned no offensive smell in the fields, and why so little disinfecting fluid was requisite, was, that the sewage was all recent and was much diluted. It was only an hour, or two hours old, and it was diluted with a quantity of water equal to 200 gallons per house per day. So long as the sewage was put fresh upon the land, it emitted no offensive odour; the odour only became repulsive and unwholesome, when it was allowed to stagnate till putrefaction set in. As the sewage reached its destination in about an hour, it did not require so much fluid as was supposed to be necessary; but a much larger amount would be required in dealing with the sewage of London, which had tarried in cesspools and loitered in its sluggish course, till it had begun to ferment. The result of sending the sewage over the grass land was, that the crops were largely increased, and that the water flowed off clear and pure, both in taste and smell. The Croydon Board, therefore, were doing all that could be done, in the present state of knowledge on this subject, and should not, therefore, be blamed, or disparaged. If any superior mode of dealing with the sewage of four thousand houses could be pointed out, he could promise, on the part of the Croydon Board, that it should, at any cost, be adopted.

Mr. Bailey Denton had, recently, an opportunity of examining the value of 'clear water.' He was called upon to decide, whether an order of the Court of Chancery had been duly carried out, in the case of Barnard *v.* Arkwright; and on that occasion, he had the assistance of Professor Voelcker, consulting chemist of the Royal Agricultural Society. The order of the Court was peremptory, that no pernicious water from the cleansing of certain dog kennels, and of the larders appurtenant thereto, should be allowed to flow into the stream at Harlow. Mr. Arkwright was the master of the Essex fox-hounds; and it appeared, that a practice existed of cleansing the dogs with some kind of arsenical preparation; that the dogs, moreover, were occasionally fed with the flesh of glandered horses, and that the water of the stream which received the drainage from the kennels, was impregnated to an injurious extent, by those two ingredients. On investigation he found, that Mr. Arkwright had constructed filter beds, and had adopted a variety of other contrivances, so that the water flowing from them, was perfectly clear. Professor Voelcker put some of this water into bottles for analysis, and when after two, or three days, it was uncorked, it emitted an insupportable odour.

Mr. Haly had been associated with several eminent Engineers, in inquiries which involved the whole subject of the pollution of rivers. In fulfilment of their duties, the Commissioners visited

nearly every place in England, at which attempts had been made to purify the sewage, and they had found, that at Croydon the question of sewage irrigation was still far from solution. To an unprofessional mind, there was little difference between sewage and any other manure, such, for instance, as guano. But there was no relevancy whatever between liquid sewage and guano in a solid state; nor between sewage as it issued from the sewers, churned and pounded up, and subjected to the action of water and of the atmosphere, and the liquid manure of the farmyard tanks. This point had been admirably argued, in the following extract from a Report signed by several distinguished Members of the Institution:—

"From the results of our own practice and experience in hydraulic engineering, and particularly in reference to the drainage of towns, and the utilisation of the products of sewage, we have long been aware of the important fact, that those organic matters which are commonly received from the domestic drains into the street sewers, and are there acted upon by water and air, undergo changes and decompositions, not necessarily of a putrefactive character, but in the course of which, they either become resolved into their original elements, or become combined into new forms, essentially different from those in which they originally existed. These changes are effected with great rapidity,—so much so, indeed, that it is rare to find in the waters discharged from the sewers of a large town, any of those fertilising agents it has been the object of so many endeavours to obtain; fertilising agents of a class which, if they could continue to exist and act in combination with flowing water, as they observantly exist under other circumstances, would engender nuisances of a character most prejudicial to health and intolerable to the senses."[1]

The contents of the sewers being thus shown not to possess a fertilising character, it was only left to consider, whether by any known process, they could be made to assume a commercial value. The processes hitherto tried, might be divided into two classes; the solid and the liquid. As the best possible illustration of the former, he would instance the sewage works at Leicester, where they had a Local Act in their favour. The works were situated in a town which, like Croydon, was extremely rich in its sewage products, which possessed the same advantage of being brought down fresh to the works. At Leicester, the sewage was not much diluted with water, but it was mixed with oily and fatty matters, from the woollen manufactures and the woolcombing so extensively carried on in that town. There were peculiar local advantages, therefore, for obtaining the sewage of

[1] *Vide* "Report of Messrs. Bidder and Hawksley to the Metropolitan Board of Works, upon the Main Drainage of the Metropolis." London, 1858. Page 66.

that important town, in a condition capable of being turned to profitable account. The local authorities, as at Croydon, were not seeking to make a profit; all they required was, that the river should be saved from pollution, by a system of deodorisation, and the separation of the solid from the liquid matters. In these respects, there could be no doubt, that the works at Leicester had been successful, and that the requirements of the Local Act had been carried out. The water was let off into the stream in a comparatively pure state, but the large quantities of débris which were obtained by the lime process, could not be disposed of. At Croydon, it appeared, that it found a sale at a shilling per ton, but at Leicester, there were, when he visited it, between 6,000 tons and 7,000 tons, in the shape of bricks, which no one would cart away for manure, and which were piled up round the works, polluting the atmosphere. In fact, a profit could not be realised by the manufacture of solid manure from sewage.

As an illustration of the liquid process, he would cite the works, established several years ago, at Stanley Green, under propitious circumstances, for they were favourably noticed in the Report of the General Board of Health, and they were even carried out under the auspices of that department of the Government. Their promoters first tried the solid process and failed. They then tried the liquid process, being placed in an advantageous position for the experiment, as the works were situated in a suburb of London, from which the drainage was obtained with comparatively small admixture. A large tank was provided, as at Croydon, from which the mixed fluid and solid matters were poured upon the market gardens in the vicinity. But the gardeners objected to its use, and the demand for liquid manure not proving equal to the supply, the works were closed.[1] Croydon afforded another illustration of the

[1] *Vide* "Report of Captain Galton and Mr. Simpson, on the Main Drainage of the Metropolis," Appendix XII., page 476. Minutes of Evidence given by Mr. G. E. Lane, late of the Stanley Bridge Sewage Works, 13 May, 1857.

"Mr. Lane stated, that the Metropolitan Sewage Manure Company's Works at Stanley Bridge, near Walham Green, with which he had been connected, were now suspended.

"Mr. Lane found the sewage, applied in a liquid state, very good for plants; when applied to the roots, it was good in every respect, but sometimes when applied from above, the leaves got covered with scum, and this was injurious to the plants.

"The reason the Company had suspended operations was, that the persons who used the liquid, failed to pay for the use of it, and the concern altogether was unprofitable.

"Mr. Lane said, that complaints were made to him of the works being a nuisance, but were never officially laid before the Company.

"Mr. Lane stated, that the pipes got so firmly charged with solid matter, (compressed manure,) that it was impossible to clear them, when taken up after the stoppage of the work, without the use of sledge hammers.

"The liquid sewage had been applied to a strip of grass land, with great success; the grass was, however, very rank and coarse.

["Mr. Lane

liquid process. When he visited it in 1858, there was a large space of ground over which the sewage had been poured, from which a powerful odour was emitted. At the period he referred to, there was a great accumulation of solid matter, which created an insufferable nuisance, for which he believed the promoters were indicted. Croydon had been, at one time, the seat of considerable disease, which was generally attributed by the medical profession, to the existence of these works. In the Report of the Earl of Essex and his brother Commissioners, in 1858,[1] it had been laid down, that malaria might be induced by open sewers conveying liquid manure, but that it would be prevented by passing the liquid through pipes and applying it to the land by the hose. Within the last two months, he had visited the works at Watford, from which the Earl of Essex obtained the liquid manure which he applied to his home farm at Cashiobury. At the Watford works, the sewage was accumulated in a tank at a low level, and it was then pumped through pipes for a distance of nearly two miles; but although it was applied to the land at Cashiobury, under the most advantageous circumstances, the undertaking was not commercially successful. The grass produced was of a rank character, and the works themselves were a nuisance to the neighbourhood.

He should now refer to the great case, invariably cited by those who favoured sewage works, that of the Craigentenny meadows, which had been subjected to the process of sewage irrigation, for sixty years. These meadows received their supply from the sewage running immediately out of Edinburgh, upon what was, formerly, waste land, and the plan had been, so far, commercially successful, that a very large amount was derived from the grass produced. This success, he believed, was to be accounted for; first, from the fact of the land being of no intrinsic value; secondly, from its peculiar position, which enabled it to be cultivated by a process which brought the soil to it, in its cheapest form; and thirdly, from its being possible to sell the grass to great advantage, in the city of Edinburgh, where milch cows, kept in stalls, were fed on the produce. Almost any waste land on which soil could be poured, would produce grass, and if that

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" Mr. Lane stated, that the operations at the works had been suspended some time, and all the pipes taken up.

" Upwards of £40,000 had been spent in the concern, and he considered it altogether a failure."

As to solid manure :—

" The manufacture of the manure for sewage with peat charcoal, sulphuric acid, &c., was so expensive that it could not be made profitable."

[1] This Report was signed by the Earl of Essex, H. Ker Seymer, (M.P. for Dorsetshire,) Robert Rawlinson, (Assoc. Inst. C.E.,) J. Thomas Way, J. B. Lawes, T. Southwood Smith, J. Simon, and Henry Austin. It is dated, " 13 Great George Street, Westminster, 26 March, 1858."

land was in the immediate vicinity of a large city like Edinburgh, such grass could, no doubt, be sold so as to realise a profit. He would, however, read a short extract from the Report of the Earl of Essex and his brother Commissioners, as to the effect of the system upon the health of the district:—

"There is one circumstance in the case of the Edinburgh meadows, which is invariably brought forward as an objection by the opponents of sewage manure, namely, that they give rise to constant complaints, not only from persons living in the immediate neighbourhood, but from inhabitants of some parts of Edinburgh itself, at a distance of two miles. There can be no doubt that, in their actual condition, they would be a source of nuisance, especially in hot weather; but we feel satisfied, that this evil is not a necessary concomitant of sewage application, even in the large quantities employed at Edinburgh, but that it arises from the existence of open ditches which convey the sewage, and on whose banks, solid, offensive matter is deposited and exposed to the air."[1]

This was precisely analogous to the state of things at Croydon. In both cases, it appeared that a nuisance was created, and it was alleged, that the system was injurious to health. If there was any doubt upon the subject, he would take the only remaining case of open liquid sewage irrigation that was said to be successful, that of the city of Milan, where the sewage of a large city was poured, under favourable circumstances, upon the meadows in its vicinity. Lord Essex's Commission sent a deputation to Milan, to inquire and report upon the sewage irrigation of the land around that city. Amongst others, the Commissioners examined Dr. Antonio Capelli, a leading physician of the city of Milan. The following was quoted from his evidence:—

"Have you observed any influence on the health of the inhabitants, from this use of the ground?—A most decided one.

"In what respect has it acted injuriously on health?—First, in producing every kind of ague; secondly, in producing the other forms of disease due to marsh miasma, such as neuralgia, rheumatism, chest inflammations, (pleuritis), &c.; thirdly, in sometimes producing pernicious remittent fever, which often kills in a few days.

"Are such diseases frequent?—Very frequent indeed.

"Is the health of infants and children more especially affected?—Yes, most especially, as is shown in the unusual prevalence amongst them, of scrofula and rachitis.

"You have stated that the condition of the houses has, in some

[1] *Vide* "Report of the Sewage of Towns Commission," page 15; signed as quoted in note, page 243.

degree, an unfavourable influence on the health of the inhabitants, from the want of proper means of disposing of the house refuse, from want of light and from dampness; do you suppose that these circumstances act by increasing the susceptibility to malaria, or in what other way?—If these conditions were entirely absent, if the houses were of the best kind, the people would be affected in the same manner, though, perhaps, in a less degree. These unfavourable circumstances do exert some influence in increasing their susceptibility generally; but those who live in the best houses in this neighbourhood, and who are comparatively rich, are by no means exempt from the influence of the malaria; on the contrary, they feel it sensibly.

"Then, is the result of your observation and experience, that the diseases you have named are produced generally, wherever irrigation is carried on close to human habitations?—Everywhere; it is so inevitably."[1]

He would now read the conclusions arrived at by the Commissioners, who had so laboriously investigated this subject. He would first quote the Report of the Government Referees appointed to consider the Main Drainage question, dated the 31st of July, 1857, and signed by Captain Douglas Galton, (Assoc. Inst. C.E.,) of the Board of Trade, Mr. James Simpson, (Past-President Inst. C.E.,) and Mr. Blackwell, (M. Inst. C.E.,) who were fortified by the Chemical Reports of Dr. Hofmann and Mr. Witt. Those Commissioners reported as follows:—

"That the so-called deodorisation of sewage does not remove the highly putrescible, soluble constituents from the liquid which passes off; and that consequently, the liquid, after deodorisation, must be disposed of in the same manner as ordinary sewage water.

"That we do not believe, that the deodorisation of London sewage could be carried on without creating a nuisance; and that no plan would be effectual with the increased volume arising from rain.

"That the value of the fertilising matter contained in London sewage is undoubtedly great; but that the large quantity of water with which it is diluted, precludes the possibility of separating more than about one-seventh part of this fertilising matter, by any known economical process.

"That a copious dilution of the sewage is necessary to health, and that therefore, the sacrifice entailed by the dilution must be endured."[2]

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[1] *Vide* "Report of the Sewage of Towns Commission. Dr. Capelli's Evidence." Pages 50, 51.

[2] *Vide* "Report of Messrs. Galton, Simpson, and Blackwell to the First Commissioner of Works." (Presented to the House of Commons, September, 1857.) Conclusions. Page 43.

That was the Report of the Government Referees. The Report of the Engineers appointed to consider the question by the Board of Works, fortified as it was by the Report of Dr. Letheby, was even more decisive. They reported thus:—

UTILISATION OF LIQUID SEWAGE.—"We have been compelled to consider this question, and being personally acquainted with most of the practical applications of town liquid, as at Edinburgh, Mansfield, Rugby, Croydon, and other places, come to the following conclusions:—

"Firstly. That the fertilising properties of the organic matters contained in town refuse, are, for the most part, destroyed by the long-continued action of water.

"Secondly. That the cost and difficulties attending the application of liquid sewage, in large quantities, are absolutely prohibitory of its use.

"Thirdly. That liquid sewage cannot, in general, be used with advantage in this climate, except in particular states of the weather, and in certain stages of the growth of the crops to which it is applied.

"Fourthly. That, commonly, the distribution of liquid sewage is accompanied by a noisome odour, and except in the case of its application to sandy, or rocky soils of considerable inclination, is liable to induce the worst forms of marsh malaria."[1]

Those were the conclusions for which he contended. He felt that nothing he could say, could add to their force, and he would, therefore, conclude by commending them to the attentive consideration of the Meeting. It was his earnest hope, that Civil Engineers would endeavour to prevent capitalists from embarking in sewage speculations which, whilst they began in delusion, must inevitably end in failure. For their own sakes, he urged, that it was most desirable, that this question should be treated on its real merits, for so long as the leading inhabitants of provincial towns supposed, that sewage works of some sort might, hereafter, be commercially productive, so long they would postpone effectual remedies for the improvement of their drainage. Finally, he committed the question to them in the most entire assurance, that it would be determined in the way that would be, at once, most beneficial to the public, and most honourable to the profession.

Mr. RAWLINSON, having been connected with the former Board of Health, could state, that no member of that Board had, in any way, patronised, either by becoming a shareholder, or otherwise, these irrigation works at Fulham. He had examined the works himself, and so far from approving of them, he stated his belief, that they could never prove commercially successful.

[1] *Vide* Report of Messrs. Bidder and Hawksley. Additional Observations. Note B. Page 145.

Mr. C. GREAVES was in a position to state, that the Metropolitan Board of Health had no connection with the Fulham works, either as directors, or proprietors. Those works were established, in 1846, by a company, who, at the outset, expended on them a capital of nearly £50,000, from which they had never received a single dividend. Not more than one hundred acres of land were watered at one time, nor was the system extended to more than 150 acres; and probably, the Company never received, altogether, more than £500 for rent. That project, therefore, ended in decided failure; but he did not necessarily infer, that the application of sewage manure was a failure, for there were many reasons why it should not have succeeded in the case in question. The Bill which constituted the Company, was strongly contested in Parliament, and when, after considerable expense, it was, eventually, obtained, it was found to contain many penalties and to confer but few privileges. It was, originally, intended to take the sewage from the Ranelagh and King's Scholars' Pond sewers, at Pimlico and at Knightsbridge; but difficulties arising about the purchase of land, the Company afterwards obtained an amended Act, enabling them to abandon a portion of the works. They then proceeded to construct the works at Stanley Bridge, and they began the operations upon a much more limited scale than they had, at first, proposed, abandoning their intention of pumping the sewage from Knightsbridge, as well as that of conveying it to Bagshot Heath. As carried out, the works consisted of the erection of a steam engine of 40 H.P., with a standpipe and complete apparatus, at the Counters' Creek sewer, the water of which was neither strong, nor of a fertilising nature, whence it was pumped upon the market gardens in Fulham Fields, which consisted of an area of between 800 and 1,000 acres. A main, 16 inches in diameter, was laid through the principal streets along the route, the size being reduced by branch pipes, as it approached Fulham. But the whole system was badly conceived from the commencement, and difficulties were encountered at every step. In the first place, the sewage water was not strong, and it had the appearance of being of less value than it really was; so that the gardeners had no great desire for it. The idea of pumping sewage, and delivering it at a distance, after the manner of a water company, through miles of pipes, was perfectly impracticable; the cost of working was so great, that the scheme could not be remunerative. After the works at the Counters' Creek sewer had been in operation for about twelve months, and after Mr. Greaves had undertaken the management of the engineering department, he obtained the permission of the Commissioners of Sewers to make a connecting sewer, so as to intercept the sewage from Knightsbridge, by shutting a pair of large gates in the Ranelagh sewer;

and the sewage from Paddington was thus forced through the Company's sewers and pipes to Stanley Bridge. From that time, the sewage was stronger, and was, probably, as rich as any that could be found; and the farmers did not complain of it. But there were other difficulties to contend with; the stench from the sewage was so strong and pernicious, that no one could remain in the engine house, for any length of time, except those who had long been accustomed to it; and it was not easy to obtain clean water for the condensers and for feeding the boilers. The grit, also, that came with the sewage, was a source of great inconvenience; it destroyed the valves of the pumps, with extraordinary rapidity, and when the pipes were afterwards taken up, the main, 16 inches in diameter, was found to be half filled with sand for the first half mile, and even beyond that distance, the pipes were choked to a considerable extent. Great difficulty was experienced in preventing the deposit of fine matter in the distribution pipes, and considerable pressure had to be applied to force the dirt through them, the farmers being often unwilling to receive it. Then again, the orifices for the distribution, for which ball valves were used, were tampered with, when the pressure was off. The destruction of hose pipes was also enormous: upon an average of twelvemonths, a hose lasted only seventy days; and in some cases, it did not last a month. Owing to the sewage being largely impregnated with salt, it was impossible to dry the hose, and the cost of that article alone, was more than the rent received from the farmers. The Company had been misled by some fancied analogy with the system employed at Edinburgh, which was a case widely different from that which they had undertaken. There, the sewage was brought down to the meadows with scarcely any cost, in a small channel, by gravitation, after the manner of ordinary meadow irrigation, and in some cases, it was distributed over the land in little trenches. By merely cutting a sod, the required quantity of liquor was obtained, and the supply was as easily cut off; the surplus, which was not wanted, escaping to the sea.

In answer to a question from the President, Mr. Greaves said, that it was the opinion of some of the market gardeners, that no benefit whatever was derived from the sewage; but there were no exact means of arriving at any definite conclusions on the subject. In many cases, the crop was, no doubt, benefited by the mere watering, without respect to the sewage. He remembered an instance, in which the water was applied for, to moisten the soil, which had become so hard, that the gardener could not pull his crop of radishes. But it was very evident, that the benefits were not sufficient to remunerate an extravagant outlay and an expensive system. In situations where the expenses would be less, or where any crop that might be forced, bore a fictitious, or unusual value,

he had little doubt, that the process of irrigation with sewage water, might be profitably worked.

Mr. HAWKSLEY admitted the correctness of the statement, that although the population of Croydon was thirty thousand, yet that part of it was outside the drainage of the Wandle. That, however, did not affect the point at issue, which was, that the Local Board of Health had constructed sewers, which had the effect, not only of receiving the drainage from the town, but of intercepting some of the springs, and of carrying off a large quantity of water, very nearly 2,000,000 gallons per day, which would, otherwise, have passed into the river in its pristine purity, and at a higher point than the outlet of the sewage. That water, mixed with the ordinary sewage of the town, was conveyed to the deodorising works, where the solid matter was roughly strained from it, and it was then delivered, by channels, over about 90 acres of land. The land over which this water was distributed, was very flat, and the edges of the channels which conveyed it were, in places, slightly raised by the earth. The upper portion of the soil was, to a certain extent, aluminous; but the lower portion consisted almost entirely of coarse chalk gravel. The result was, that the surface of the ground was flooded by means of the channels, only to a limited extent, and the larger portion of the water penetrated into the gravel, so that when the ground was trodden upon deeply, it oozed upwards, into the hole. The consequence was, that the vegetation was partially destroyed, and that the sheep put upon the land had become affected with foot rot, in numbers sufficient to demonstrate the unhealthiness of the ground. The water, moreover, was draining underground into the neighbouring property, where the hedgerows and the timber trees were already beginning to suffer. Having been into every field upon which the water was delivered, he could declare it to be an offensive nuisance; at any rate it was so last autumn, and he knew a gentleman who had been compelled, for that reason, to remove his family. As a specimen of irrigation and application of sewage manure, the result was as bad as could be imagined. It was difficult to ascertain exactly, all the facts of the case. It appeared, that the Board of Health originally turned this water, some years ago, upon the land, under the idea that it would improve it; but the occupiers were so convinced of the mischief which it occasioned, and of the nuisance it created, that some of them took legal proceedings to recover damages. Therefore, the Board thought it more expedient to take the land into their own hands, and consequently, it was impossible to calculate the commercial results, as the receipts were not known, nor the price paid for the land and for compensations.

There was no necessity for the existence of such a state of things, either at Croydon, or elsewhere. If the Boards of Health

would carefully examine the nature of the material with which they had to deal, they would soon come to the conclusion, that there was, in general, no pecuniary advantage to be derived from it as manure; and that their duty should be simply to deodorise it, in order to prevent its becoming a nuisance. The process of straining, adopted at Croydon, effected the separation from the sewage, of the bulky portions of the decomposing animal fibrine and albumen, and these gave forth that insufferable odour which prevailed at the works, when the deposited matter was thrown out of the tanks. The Birmingham sewage works had, for a similar reason, become a disgusting nuisance to the whole neighbourhood. If that matter, however, was deodorised, by mixing with it a sufficient quantity of lime, it would make a good dry manure for the land. The first operation, therefore, should be to precipitate from the sewage water, all that was possible, by the application of quicklime, or of some other equally effective agent. By this means the water would be rendered perfectly clear, although not more than one-fourth of the organic matter would be precipitated; but this was the portion which would, otherwise, most speedily run into offensive decomposition. But the lime process was insufficient for the treatment of the sewage, when used for irrigation purposes in the vicinity of towns, or residences; it was necessary to use an antiseptic, than which none was superior to McDougal's fluid; the water would then be rendered innocuous, and it might afterwards be allowed to pass into the river, unless the river happened to be valuable as a fishery, or was used for other purposes inconsistent with the employment of McDougal's fluid. Decomposition was produced, not only by offensive putrefaction, but also by eremacausis which did not create an unwholsome smell, and which was effected by the oxygen of the air and the water. The organic matter was largely decomposed by merely flowing down a sewer, if there was abundance of water through which it could become diffused; and the consequence was, that the sewage became valueless, having lost its fertilising properties. If the principles he had enunciated were recognised, the idea of making the sewage matter of towns commercially useful, would be altogether abandoned, and means would be at once taken, to prevent the further pollution of the rivers.

Water Rights.

Mr. Hawksley said, that he was not inclined to limit the right of a person to pump from a spring upon his land, as much water as he pleased. He regarded underground water in the same light as he looked upon game; that it might be taken by those upon whose property it was found. It was impossible to say positively, in the majority of cases, that the water drawn

by one person came from the land of another, and still less, that it was his property; in fact, the course of underground water could not, in general, be pursued to its origin. This view of the case might, possibly, be attended with hardship, in individual instances; a person might have established a business dependent on the use of the water, but even then he did not think, that if any other person sunk a well at a distance, and pumped his water from the same ground, there would be any legal cause of complaint. Having been concerned in conflicting cases of underground water, he believed it was impossible to adopt any other system of adjudicating upon such rights, than that which had been generally laid down by the Judges. As to water flowing over the surface, there had been some decisions, lately, of an exceptional character; such, for instance, that no one could begin to have a property in water until it ran in a continuously flowing stream. That principle had been laid down, in the case of Broadbent *v.* Ramsbottom.[1] Now in rocky, or clayey ground, although a stream of great importance might flow during several months of the year, and be valuable for manufacturing purposes, yet it might cease to flow during three months out of the twelve. The Bourne, which was the source of the River Wandle, would come under the same category, since it only flowed down a defined channel, once in a certain number of years. During that time, it was, of course, of considerable value to those through whose land it flowed; but it would result from that decision, that there could be no property in the water of the Bourne, till it reached the Wandle.

Mr. J. HORATIO LLOYD observed, that, wherever there was a defined stream in a defined course, although intermitted, there might be a property.

Mr. J. HAWKSHAW, V.P., deprecated the introduction of the law of water rights into the discussion, which should be confined to matters within the sphere of Civil Engineering. A large social question had been raised, and legal decisions impugned, with which the Institution was incompetent to deal, and which it ought not to entertain, to the neglect of the professional points of the subject.

Mr. JOHN EVANS thought, that taking into account the well-known natural laws which regulated the flow of water through chalk districts, there had been a grievous mistake in the legislation upon this subject, which was based upon the assumption, that the course of underground water was entirely unknown. The laws relating to the uses and rights of ownership of water flowing above ground, were clear and well defined. There was a certain limited use and ownership allowed, and any undue use, or abstraction of such

[1] *Vide* "The Weekly Reporter," February 9, 1856. In the Court of Exchequer, January 12, 1856.

water, could immediately be checked. Yet by a recent decision of the House of Lords, it was held, that provided the water flowing into a river by an underground course had not become visible, or reached the surface, it might be abstracted with impunity, even within a few yards of the river; so that it was held, in fact, to constitute an entirely different species of property. It appeared to him, that the property in water, whether upon the surface, or under it, ought to be regulated by the same social laws, in all cases where the same natural laws applied equally to both. The law ought to operate in the one case as in the other, and the maxim of law, "Sic utere tuo ut alienum non lædas,"—so to use your property as not to injure the rights of another,—should be carried out in both cases.

Mr. W. DRUMMOND said, that as he had assisted in conducting the somewhat celebrated case of Chasemore *v.* Richards,[1] or Chasemore *v.* The Croydon Local Board of Health, which had been taken from the Court of Exchequer to the House of Lords, and had now decided the vexed question of rights in underground water, it might be interesting to the Meeting to hear how the law now stood, according to this final decision. While the Croydon Board were spending £55,000 in their waterworks and drains, the law, (according to the reported cases,) was, that though an owner of land might not divert, or pump away water visibly running above ground, if by so doing, he worked an injury to a millowner, or other riparian proprietor,—yet he might pump and use, or divert, any amount of underground water, although by so doing, he might injure other proprietors. The course and direction of underground waters were considered too uncertain and too little known, to be the foundation of any rights in them. But the Croydon Board had no sooner dug their well, completed their works, made this large outlay, laid on the water to all the houses, and destroyed the old wells, than the case of Dickinson *v.* The Grand Junction Canal Company was decided, and appeared to reverse the law. The Canal Company had sunk a shaft in a chalk hill, and had pumped water to their upper level. Mr. Dickinson proved, that their pumping diminished his mill stream, and he obtained a decision in his favour. On this decision being known, Mr. Chasemore, the occupier of the first mill on the Wandle, ascertained by gauges, that the pumping of the Croydon Board from their deep chalk well, had lessened his mill power, and he brought an action against the Board for damages. If the Croydon Board had not reversed the decision in Dickinson *v.* The Grand Junction Canal Company, the grass would have grown in the streets of Croydon. The in-

[1] *Vide* "The Weekly Reporter," August 27, 1859. Vol. vii., p. 685. In the House of Lords, February 12, June 11, July 19 and 27, 1859. 7 House of Lords' Cases. Page 349.

habitants would never have re-opened their old impure wells, and they could not have compensated Mr. Chasemore, as all the other mill-owners lower down the river, could have claimed the same amount of compensation. They, therefore, resisted the action, and fortunately, but justly, they succeeded. An appeal was made from the Court of Exchequer to the Exchequer Chamber, but the latter confirmed the decision in favour of the Board. Finally, Mr. Chasemore appealed to the House of Lords. On the hearing, Lord Brougham said, that considering its bearing on mining and on a variety of engineering works, on private wells, on ponds, and on waters, it was one of the most important cases that had ever been brought before that tribunal. The Lords first took the opinion of the Judges, and afterwards delivered their decision, which was in favour of the Croydon Board. He believed no case had ever been studied with more thorough research, or had been more satisfactorily argued on both sides. The result of this decision of the House of Lords was, that water percolating under ground, like the air above ground, was unpropertied, and was not the subject of any prescriptive rights. Any owner of land might take as much as he liked from beneath his own land, and if he dried, or injured his neighbour's well, or mill stream, or pond, the neighbour had no remedy against him. He must sink a deeper well, or seek for water in other directions. Mr. Drummond differed completely from the opinion, that the decision was incorrect, or unjust, and that there were any hopes of a reversal. He was satisfied, and he believed the bar was satisfied, that this was a just decision, and that the question might now be considered, as irrevocably settled.

Mr. BAILEY DENTON observed, that the decision had already been reversed by Vice-Chancellor Stuart, in the case of Ennor *v.* Barwell.[1] The Vice-Chancellor, in delivering judgment, particularly referred to the cases of Chasemore *v.* Richards, and Broadbent *v.* Ramsbottom. The decisions on these cases were disregarded. It was held, that underground water was the property of the person whose land it would reach, by percolation and gravitation from a higher to a lower level. That decision, however, had not yet been confirmed by a higher court.

Mr. HAWKSLEY did not consider, that the recent decision of Vice-Chancellor Stuart had reversed the previous judgments, with regard to underground water rights. He had carefully read through the whole case, and in his opinion, it was confirmatory of the decisions of the Common Law and Equity Judges and of the House of Lords.

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[1] *Vide* "The Law Times Reports," October 20 and 27, 1860. In Vice-Chancellor Stuart's Court, June and July, 1860.

Mr. J. HORATIO LLOYD dissented from the opinion, that legal questions, especially those concerning water rights, were entirely foreign to engineering pursuits. Looking to the varied character of the duties which he might be called upon to discharge, and of the questions with which he had to deal, the Engineer should possess some knowledge, not only of chemistry, of geology, and of mineralogy, but also of the law which related to particular points of practice. Some of the questions relating to water rights had not, at present, been very satisfactorily determined. The law, indeed, might be considered, generally, as in a state of transition. The Judges were obliged to decide according to the peculiar circumstances of each case, as they often had no written law to guide them. In the course of the discussion, certain principles had been laid down, from which he dissented. He would, therefore, state in general terms, what he conceived to be the law with regard to water rights, so far as it might, or could affect the Engineer. The law, as it stood at present, dealt differently with the two questions of water above ground and water under ground. Where water was flowing in a defined channel upon the surface, its action and effect might be seen and appreciated, and the proprietor of the land through which it passed, had a right to use it for all reasonable purposes incident to his occupation of the land. That right, however, had this limit; the maxim of law must be observed, that a man must so use his own property as not to injure his neighbour's. Then came the question, what constituted such an abuse as would contravene this maxim? First, nothing must be done wilfully, wantonly, or negligently, the effect of which would be to take away, or lessen the benefit to which proprietors, or occupiers below, were entitled. Thus, in the case of millowners requiring water power, no person at a higher point of the stream, had a right to do any act which would either diminish the water power, or send forward the water in a different state from that in which it was ordinarily received; he had no right to divert, or to foul the water. Nevertheless, by long, 'users,' a right might be acquired, to do both, or either, as against the riparian proprietors below; the law presuming, from long enjoyment, or acquiescence, a grant, from all parties interested, of the privilege by the use of which they were affected. Twenty years' uninterrupted enjoyment was sufficient to confer this right but it must be strictly exercised according to the previous use; any excess would, of course, give a ground of action. These general points were easy and familiar to all lawyers; but the question, relating to underground water was more difficult. There were two ways in which water would find its way underground, from one spot to another; by percolation, or filtration, or by streams which, though not seen, might be traced in their effects. In the former of

these two cases, the courts had decided, that there was no right in such water, of which legal cognisance could be taken; and consequently, that although by digging a well in one's own ground, the neighbour's well was drained, there was no ground of action in that case. This frequently occurred, for example, with the wells of the large London breweries; but the Courts had decided, that they could not interfere, not because the abstraction of the water from another was not an injury and, ethically, a wrong, but because there existed no means of ascertaining and tracing out the fact, with anything like legal certainty. The water, in such cases, could not be identified. It could not be asserted, that the very water which, before the operation complained of, was in a particular well, was the same water which had found its way into another well, at some distance. Accordingly, the Courts declined to apply to a matter so obscure, the same rules which were applicable to visible and defined surface streams. Then came the further question now under consideration, and which would, probably, before long come formally, before the Courts. When water passed underground, as in the former case, not by percolation merely, but in a current traceable by physical means, so that the water flowing in such current could be itself identified, the question arose, whether in the absence of a prescriptive right, that water could be abstracted, or be contaminated, so as to deprive another of its beneficial use which he had previously enjoyed. His own opinion was, that it would be, eventually, determined, that the interference with such water, either by abstraction, or by fouling, was a wrong for which an action might be maintained.

Mr. BIDDER,—President,—observed, that he was personally interested in the condition of the Wandle, being the owner of a portion of that river, and unfortunately, whether from the operations of the Board of Health of Croydon, or from some other cause, he was suffering, in one part of his property, to the extent of £100 per annum, which would, probably, be increased to £200, or £300 per annum, if the nuisance was not abated. It had been urged, that local interests should not be allowed to stand in the way of the improvements necessary for the health of towns. Now he thought that was a gratuitous exhibition of humanity and benevolence, but too common in the present day. It was the main object of the Legislature and of the Courts of Law, to render justice to all parties, but they were, occasionally, misled by enterprising witnesses and ingenious advocates, to give decisions at variance with those principles of right, which it was their object to maintain. It was manifestly unjust, because a town had arisen upon the banks of a river, that the private property in its neighbourhood should be sacrificed, by the transformation of the river into a foul ditch, and

it was upon this ground that, at the opening of the discussion, he had given his opinion, that the question could not be satisfactorily discussed, without reference to the general principles of law which applied to these cases. Towns were arising in the vicinity of the banks of the Thames and other rivers, with populations rapidly increasing, and the streams were becoming polluted to a very serious extent; he thought, therefore, that the time had arrived, when the Legislature must direct their attention towards devising means for preserving the salubrity of the rivers, which formed so striking and beautiful a feature in the landscape scenery of England.

The River Wandle was an especial object of interest, as from its proximity to London, it had been suggested as one of the sources of water supply for the Metropolis. But it had been shown, that its flow was subject to great fluctuations. The minimum current that had been recorded, about 10,000,000 gallons per day, would only be sufficient for the supply of three hundred thousand inhabitants, or about one-tenth of the population of London. The variable amount of water in the Wandle, was not commensurate with the rainfall. The proportion of the rainfall flowing off by means of rivers, could not be determined by any system of averages, but only by a series of recorded observations, during many years, upon a particular soil in a particular district, and even then, these observations would not apply to any other case. Upon certain lands on the banks of the Wandle, he had noticed, that, between January, 1858, and September, 1859, although 23 inches of rain had fallen (at some periods, as much as 1 inch in two, or three hours,) none flowed off the surface of the land. Between September and November, 1859, there were 10 inches of rainfall, and not till then, did the water begin to pass through the sub-drains into the river. A rainfall of about 30 inches had thus been evaporated, or been absorbed by vegetation, upon drained land. That fact proved to his satisfaction, that one of the effects of sub-drainage was, by increasing the fertility of the land, to create a greater demand for moisture. This remark might not be applicable to other districts, because the supply to the rivers depended upon the varying nature of the soil, and upon the seasons. During a portion of the time over which his observations extended, it was a dry season, with plenty of sun, and there was a luxuriant vegetation, whereas last summer, one-half the quantity of rain would, probably, have been sufficient to supply a larger amount to the springs and rivers in the district to which he had alluded. He made these remarks, with the view of counteracting the tendency to draw averages, and to form diagrams applicable to the whole of the country.

He would premise his observations relative to land drainage, by remarking, that the opinions of Mr. Bailey Denton, (M. Inst.

C.E.,) carried considerable authority, on account of his great experience, and of his laborious investigation of the subject, upon which it was to be hoped he would present a Paper to the Institution. But the President was compelled to differ from him, on the question of deep drainage, as he was convinced, that if the moisture was kept 2 feet 6 inches below the crops, the most suitable depth would be found for all the purposes of vegetation. The late Mr. Tycho Wing had ascertained, by personal investigation, and by carefully-conducted experiments, extending over large areas and continued during many years, that vegetation suffered in dry seasons, when the permanent streams of water were below that depth, and also in wet seasons, if that depth was much exceeded. There were, no doubt, in certain cases, local considerations arising from the nature of the soil and from the existence of springs, which might render it desirable to drain to a greater depth, but he maintained, that it was not a sound principle to adopt a universal depth of 4 feet. The great expense of such a system of drainage was not in the cost of the pipes, but in the labour of excavating and filling up the trenches. For his own part, he would prefer constructing two miles of shallow drains, to one mile of deep drains, and he believed, that by so doing, he would not only save expense, but would also bring the land into better condition for vegetation.

The last point to which he would allude, was the question of outfall. There were many cases where a large area of land was deteriorated, in consequence of the outfall not being 12 inches, or 18 inches lower. This could, no doubt, be remedied, by interfering with private rights, which should always be made subservient to the general good; but at the same time, the law justly provided, that ample compensation should be given. In the north of England, a custom prevailed with regard to collieries, called 'way-leave,' and the same principle was applied to railway companies, who were compelled to compensate the owners, as well as the occupiers of property through which they were desirous of passing. If a man sought to use his neighbour's land for his own benefit, it was only just, that the advantages which might accrue to his estate, or to his mill, should be divided with the landowners through whom alone he could secure them. The authority of the Duke of Northumberland had been cited in favour of deep drainage, but however high might be the social position which he occupied, it gave no weight to his opinion upon practical questions of this nature.

In conclusion, he observed, that he had invited discussion upon many points not directly bearing upon the Paper; but he thought the Meeting would approve of the scope which he had given to it, on account of the importance of all the questions which it had

embraced:—land drainage, the value of town sewage, the management of sewers, the principles which should guide the future conduct of local boards of health, and the legislative measures necessary for preventing the further pollution of the rivers of England.

January 29, and February 5 and 12, 1861.

GEORGE PARKER BIDDER, President, in the Chair.

The discussion upon the Paper, No. 1,023, "On the River Wandle, its Springs, Tributaries, and Pollution," by Mr. Frederick Braithwaite, was continued throughout these evenings, to the exclusion of any other subject.

At the Meeting of February 5, the following Candidates were balloted for and duly elected:—JAMES NICHOLAS DOUGLASS, WILLIAM GILBERT GINTY, MICHAEL LANE, and PHILIP JOHN MESSENT, as Members; FREDERICK DALE BANISTER, ALEXANDER BREMNER, TELFORD FIELD, RICHARD HALL, JOHN KELK, WILLIAM WEBB MOORE, HUGH ADAMS SILVER, EDWARD HENRY THORMAN, and ALBERT AUGUSTUS WYNNE, as Associates.

At the Meeting of February 12, before proceeding with the discussion, the President directed attention to the Donations to the Library, which had been received during the present Session; particularly noticing the handsome edition of the very detailed account of the "Construction of the Great Victoria Bridge, in Canada," from the Author, Mr. James Hodges; the "Report on the Ganges Canal Works," in three volumes, with folio atlas of plates, from the Council of India, through the Author, Colonel Sir Proby Cautley, K.C.B.; a useful German periodical, entitled "Zeitschrift für Bauwesen," from the commencement in 1851, from Mr. W. W. Collins, (M. Inst. C.E.,) who had also presented a copy of Messrs. Tolhausen and Gardissal's "Technological Dictionary in the English, French, and German languages;" and the Official Descriptive and Illustrated Catalogue," with "Reports by the Juries," of the Exhibition of 1851, in six volumes, imperial 4to, from Mr. Andrew Cuthell, (Assoc. Inst. C. E.) The President, in proposing that the cordial thanks of the Meeting be given to the several donors, expressed the hope, that these excellent examples would not be lost upon the many new Members and Associates who had recently joined the Institution, and that it would be the constant aim of the Members of all classes, to maintain the Library in the highest possible efficiency.
