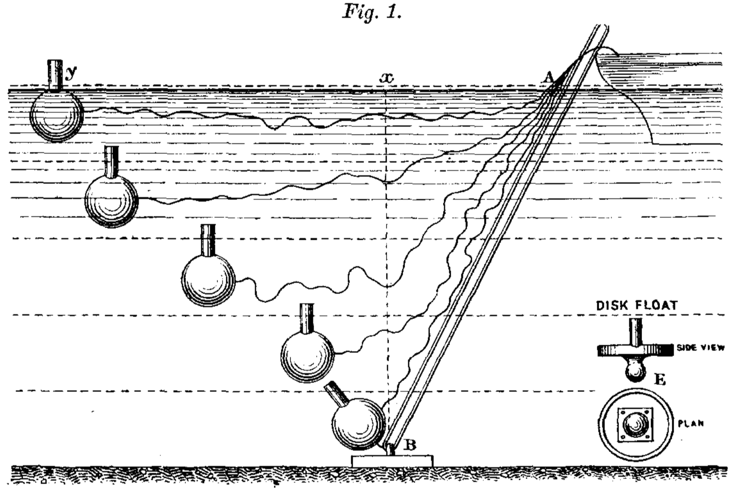
Discussion.

Mr. James Price, senior, said that the diagram, Plate 6, Fig. 2, required a good deal of study. At any date it was possible to see at once what effect had been produced by the quantity of rain falling over the whole area, and after what period of time it had been produced. The dotted line was not of much consequence; it was a line from which the Author had made the other calculations; from the opening of the sluices or from the flow of water, or from both, together with the rainfall, he had been able to ascertain the line which was really important—the net supply that came into the lake, which was what had to be dealt with in

Mr. Price, sen.

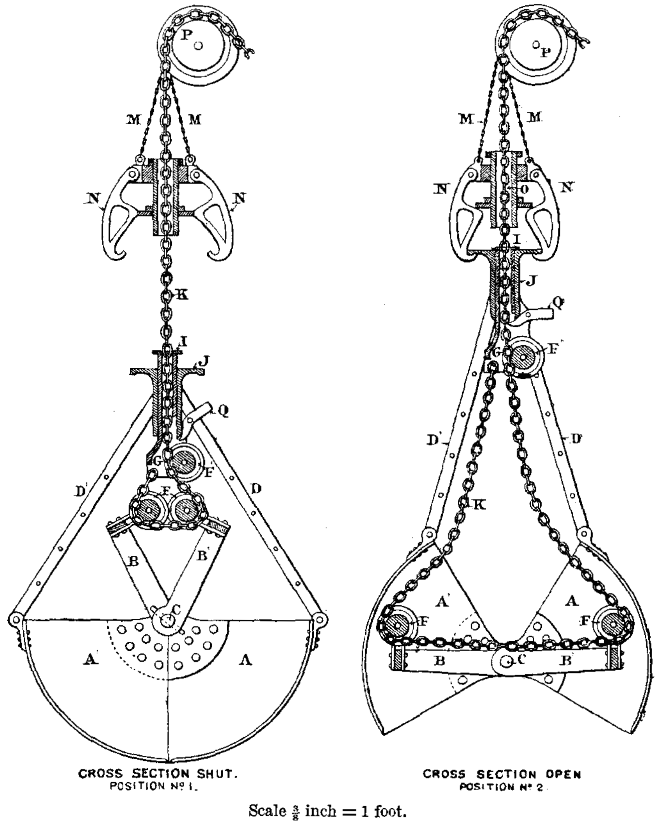
Fig. 1.



all drainage operations. If a line were drawn joining the lowest point of each of the dips it might be called the spring-water line, as it would not be affected by recent rains. With regard to the measurement of the flow of water, he believed no accurate nor reliable method of ascertaining the flow in a river existed. He had been trying a system that he thought would give the nearest approach to accuracy, having also the advantage that the experiment could be repeated many times under the same circumstances. No length of river was needed, one accurate section being sufficient. A ball, about 8 inches in diameter (*Fig. 1*), was weighted so that it would just float, and a boat was anchored a little above the position; the ball was attached by a slight thread to an endless

Mr. Price, sen. cord passing through a pulley attached to a heavy weight on the bottom of the channel. The ball having been drawn to the bottom, at an observed time the thread was broken, and the ball thereby released. There was a small period of time lost in the ball attaining uniform velocity; but after a very short distance (which he was trying to ascertain accurately) it did attain a

Figs. 2.

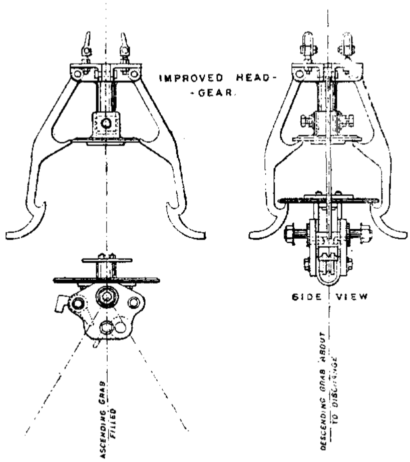


Scale $\frac{3}{8}$ inch = 1 foot.

uniform velocity of ascent. It was quite evident that the ball in ascending to the surface passed through each different stratum of water: the time of ascent gave the mean velocity of the current. Of course there were other methods by which the ball could be released from the bottom. A frame of light timber was allowed to float on the water moored to the boat by a string; this was

drawn up-stream or allowed to float down, so that it might mark Mr. Price, sen.
the place of appearance of the ball; thus the experiment could be repeated several times and the average distance taken. This was done through the whole cross section of the river. Owing to the absence of his son, he had not the advantage of his assistance in carrying out these experiments, but he hoped to complete them. The difficulty of measuring with weighted rods was well known. Even if they went close to the bottom they did not give the mean velocity. That method also required a long reach of uniform channel, and gave a great deal of trouble. But by his system a person could sit in a boat, cross the river from one side to the other, and get an accurate measurement of the mean velocity.

Figs. 3.



Scale $\frac{3}{8}$ inch = 1 foot.

Another form of float, namely a disk weighted underneath, was perhaps better than the ball, being more easily made, and acquiring its uniform velocity of ascent sooner than the ball. The grab had been used with great effect. It was different from any other (*Figs. 2* and *Figs. 3*). The whole inside of the grab was free. It was very useful for taking up large stones and boulders. There were only three pulleys, connected with levers which closed. The principle was a rather curious one. The grab had a considerable gripping force; it worked with a single chain. The most ingenious part of it was the arrangement whereby the grab when it came up was gripped by the claws. The sluices had worked effectively, they were working still, and had never given the

Mr. Price, sen. slightest trouble, nor cost anything for repair. The lake district was a remarkable one. He did not know any other consisting of so long a tableland. It formed a sheet of water 52 miles long with a fall of only 6 inches. He considered it unique in the British Isles. It was now a very fine navigation; but its commercial value was unascertained, as its use would depend on circumstances not connected with Lough Erne.

Sir John Coode. Sir JOHN COODE, President, said that two references were made in the Paper to the inclination of the ground-water. If the Author could give the rates of inclination through the different strata, it would materially add to the value of the Paper. It was very rarely that such observations had been made; there was a general deficiency of accurate data upon that point, and if Mr. Price or his son had any observations upon it, it would be very undesirable that they should be lost.

Mr. Stoney. Mr. F. G. M. STONEY wished to make a few remarks on some of the minor details in connection with the sluices. He hoped to write a Paper upon larger sluices, including those of Lough Erne, and would, therefore, not anticipate too much. The Author had stated that the sluices worked almost as easily down at the bottom of the water with a full head on as they did in air. Mr. Stoney wished to make an addition to that statement. He constructed a little wooden handle of only 6 inches radius; with this he was able to start and lift the sluice under the abnormal head of 16 feet, that was 1 foot 6 inches going over the top of the gate, and he could not detect the slightest difference in starting the sluice, with all that head, from the power required to move it in the air. There was a curious confirmation of that statement. He had spent a fortnight in calculating the comparative pitches of screws so as to arrive at a pitch that would allow the gates to creep down, and not to race. It seemed very easy, but it was not so. He considered himself somewhat fortunate in arriving at the results that had been obtained, because the sluices weighed 13 tons each, and there was no counterbalance. To begin with, he almost eliminated friction and resistance at the head of the screw, but could not get over the resistance in the nut. The nut was very long, and the pitch of necessity was considerable. Out of four sluices two crept down very slowly. One of them required the least occasional touch on the main spur-wheel after the pinion was withdrawn; in the case of the other, the man in charge occasionally put a hammer handle against it as it was inclined to race somewhat. As a matter of fact, the quality of the lubricating oil had more effect on the gear than all the water-pressure. The interesting engineering point about it was this. He had started the sluice to go down when a full flood was passing through; the sluice-door was open about 8 feet 6 inches or 9 feet, and there was a depth of 7 feet 6 inches or 8 feet of water passing through at high velocity. It was a wide river with a fairly sharp fall and a direct straight approach, and a head of 14 feet at the upper end, so that apart from the bottom-velocity there was a considerably increased surface-drop in the water approaching the sluice. The sluice commenced to go down slowly like clock-work. The wheels could be seen going round pretty fast, but without being close to the door its motion could not be noticed. The lower edge touched the water passing through, and was not retarded in the slightest degree, but went to the bottom without any diminution in velocity. He could not understand this for a long time; but, watching the sluices from day to day, he found out the cause. From actual experiments he had made on a large scale, he had no doubt the traction on the main rollers would not exceed some 250 to 300 lbs., and the door creeping down slowly with apparently no reserve of power would gradually have to overcome this traction, increasing from nothing at the top to a few hundred lbs. at the bottom. Close observation plainly showed a positive vertical movement of water down the skin of the gate, the friction of which, combined with a certain enlivening action of the flow, seemed to fully compensate for the increased traction, but inasmuch as this entire force was only some few hundred lbs., its effect was not perceptible on the lifting-gear, as the gate moved only $\frac{1}{24}$ inch for each turn of the handle, and the real work to be done was that of lifting the 13 tons of gate, the traction being practically nothing. Another proof of the skin action was that the last line of rivets on the bottom of the doors was 3 inches from the lower edge, and when the doors were open about 5 feet, with about 11 feet of water upon them, he had seen unbroken water for 50 feet below of dark, clear water, and the whole surface was streaked with marks, each mark corresponding to a rivet line, showing the quantity of water which made its way down by the skin of the gate. The Author was the first engineer in Great Britain who had had the courage to use things of that kind, which could not be tried experimentally. The Author had said to him, "we cannot open these big things as fast as we want; we must have a turbine." Mr. Stoney was afraid to use a turbine, because he knew that with a machine of that kind running at such a high velocity, with nothing apparently to control it, if there was a check anywhere, it would be smashed to bits. He therefore devised an automatic release. Upon one end Mr. Stoney.

Mr. Stoney. of the rocking-lever there was a cast-iron weight 5 inches in diameter and 7 inches long, which was quite sufficient to actuate one of the sluices. He made it light for the purpose of transmitting the least possible excess of power beyond what was actually required, so that if a serious check took place, the friction would not drive against any abnormal resistance. But apart from that, he depended from one end of the rocking-lever a small iron rod. When the gate came up it lifted this rod, eased off the weight, and so formed an automatic release. On the other hand, he dropped a long rod from the opposite end of the rocking-lever, having a stop at its lower end, which passed through the top member of the gate, and when the gate came within a few inches of the bottom, it pulled the lever and disengaged the weight as before. When the gate reached near the top or near the bottom, the turbine and shafting ran on, but no motion was conveyed to the gear, and the gate remained still. No accident had ever taken place, by overwinding. With regard to the coefficient of discharge, he thought if the Author had had sufficient water for testing the four sluices he would have obtained a better result. It would be seen from the section of the pier, that there was a very long sharp cut-water. If any one of the sluices was opened the water would not approach the sluice in straight lines. In the early days of working the sluices, he had a great fright in opening one sluice under a full head of water. The place was dry on the down-stream side of the sluices, and the water was about coming over the top. He put the turbine on and lifted the sluice as quickly as he could, and then he thought that the concrete bottom was swept out. A tremendous eddy was formed round the projecting nose of the cut-water. In that way the efficiency was reduced. He might be permitted to add that in putting the sluices up, he received a lesson in sluice-building. A land commissioner saw them, and was struck with their weakness. He saw that the skin was $\frac{1}{2}$ inch thick, and he spoke to Mr. Stoney on the subject. As a matter of fact the door was 7 feet thick. He said, "Are you not making the doors very weak?" Mr. Stoney replied, "I was informed that I had to hold up a head of 14 feet 6 inches of water against the sluices, and I think they will hold it." "But, my dear sir," said the commissioner, "you have 52 miles of water!" Evidently the commissioner was not familiar with the hydrostatic paradox.

Mr. Hassard. Mr. R. Hassard said that the history of the Lough Erne drainage was a rather curious one. The question of the construction of works for the relief of the periodically inundated lands bordering on Lough Erne, especially upon the upper lake, had been suggested from time to time and agitated during the last fifty years. The first feasible plan brought forward was a complete one; it was introduced in 1847 by Mr. Forsyth, who was for many years connected with the Board of Public Works in Ireland. His estimate for the works was £156,000, and it was very similar in all respects to the project as carried out by Mr. Price, except in the omission of a lock and weir, with a small fall of 2 feet between the lakes, which the Board of Public Works thought necessary at first for the maintenance of the navigation. But at that time the estimate was not thought reliable, owing to the cost of several works carried out by the Board of Works having been largely exceeded, although carried out under their own officers. The project accordingly dropped through, and was not revived for several years, when Mr. Porter, a gentleman resident in the locality, and a large landowner, considerably interested in the matter, re-commenced the agitation for the resuscitation of the project, and it was entirely owing to his energy and perseverance that it had been carried out. That was in 1873. Mr. Porter employed Mr. Lynam, well known in Ireland as an engineer, to make an estimate. The late Lord Erne employed Mr. James Barton, of Dundalk, also well known in Ireland, to investigate the matter. Mr. Lynam's estimate was £168,000, and Mr. Barton's £169,500. Mr. Lynam's connection with Mr. Porter shortly afterwards ceased, and the matter was placed in Mr. Hassard's hands, and he was asked to make an independent estimate, which he did, amounting to £172,000. It would be seen that the three estimates were approximate, within a few thousands, showing, he thought, the reliability and care with which they were framed. But a sum of £170,000 was thought more than the locality could bear, and the matter again dropped. About five years afterwards Mr. Porter, who was indefatigable, re-commenced his agitation. He wished Mr. Hassard to act for him, but after a short interval, he ceased to act, and Mr. Porter placed the matter in the hands of Mr. Price, who issued a pamphlet, in which he stated that a complete scheme of drainage could be carried out for £68,000. It was no doubt very gratifying to the landowners to be told that they could have carried out for that amount what preceding engineers had valued at £170,000, and that set the ball rolling again. Soon afterwards Mr. Hawksley, Past President, was instructed by the Board of Works in Ireland to hold an inquiry at Enniskillen, and he did so. At that time Mr. Price's estimate had reached £94,000, and Mr. Hawksley added another £10,000, making it £104,000. Mr. Price Mr. Hassard.

Mr. Hassard. had stated that the works had cost £180,000, but he had not explained the reason for the great difference. He had partially alluded to the large compensations paid to the Fishery Company. Mr. Hassard knew what the amount of those compensations was, having been employed by the Fishery Company. They amounted to very little more than it was well known in the first instance would have to be paid. As to the works themselves, it had no doubt occurred to many members to ask why the machinery and the appliances for controlling the water in the lakes were not placed at the outlet, instead of in a river about 4 miles distant. There was no engineering reason why the sluices should not have been situated at the outlet. The water was shallow, the foundations were excellent, and the sluices, or a combination of weir and sluices, might have been placed there without any difficulty; but the Board of Works had a very high estimate of the value of Lough Erne as an inland navigation, and thought that if the navigable channel were extended to 4 miles below, to a place called Belleek, such advantages would be conferred upon the locality that it should contribute towards the cost of construction, and placing the sluices at Belleek was made a peg on which to hang a contribution of £30,000 from the immediate locality. He thought that under such circumstances the Drainage Board was right in putting the sluices where they now were. With regard to the channel from the outlet of the lake down to Belleek, in the year 1873 he was called in, as he had been on several occasions since, by the Drainage Board to advise on various points that had cropped up from time to time. At that time he found that the dredger, by means of which it was intended that the channel, 4 miles in length, should be entirely excavated, was turning out only about 200 cubic yards per day. At that rate of progress, making allowance for the time that the dredger would be necessarily idle, from renewing the bucket-lips or the breaking down of the machinery, it would have taken fifteen years to complete the work, and the dredger was required in other parts as well as in that particular locality. It therefore occurred to him that the shape of the channel might be changed. The outlet of the lake was a broad, shallow stream; and if dams or stanks could be made and the dredging confined to the central portion of the channel, the two sides could be taken out by manual labour; and instead of the excavation proceeding only at one spot, the works might be prosecuted almost simultaneously over nearly the whole of the channel between the lake and Belleek. That process was adopted, and the greater part of the work was done by manual labour—

which was the means of giving a very large amount of employment in a locality where it was very much needed; the work being in the neighbourhood of one of those poor and congested districts of Ireland of which so much had lately been heard. The sluices no doubt acted admirably; but he thought it would have been wise, in the construction of the work, to have provided some means of isolating each sluice chamber, so that if any accident happened, either to the floor or to the sides of the work, the water could be excluded for a time to allow the necessary repairs to be effected. Mr. Stoney had said that he had lifted, by means of the turbine, one of those sluices rather rapidly, and that there was such a rush of water through the channel that he thought the floor of the chamber behind the sluice would have been blown out. Another thing that he thought might have been done with advantage was the lengthening of the piers somewhat upstream, making semi-circular instead of pointed ends. The water, as Mr. Stoney had stated, was much disturbed when one sluice was open and the adjoining one shut. He had himself seen, where the water was trying to get round the point of the cut-water, a whirlpool about 2 feet in diameter and 5 feet deep, down which a stick might have been put without touching the water. He also thought that the lengthening of the piers would have admitted of fender-girders being placed across the channel in front of the sluices, because it was manifest that a lumber boat or anything of that kind getting adrift in the lake above might, on going down at night, do serious damage to them if some protection of that kind was not adopted. In accordance with his advice, channels or grooves were made in the cut-waters, and beams of wood placed across. It would however have been better if iron had been used in the first instance. Mr. Hassard.

Mr. J. W. Barry thought that the members would admit the great importance of the subject of arterial drainage to engineers; and having had some special experience of the matter in Ireland during the last few years, he might, perhaps, offer a few remarks on the Paper. The importance of arterial drainage in Ireland was unusually great, owing to the remarkable configuration of the country. The general description of the land in Ireland was that of a slightly elevated plain extending over a great part of the country, which was surrounded by a rampart more or less continuous of limestone, of which material the plain itself was mainly composed. The result of that state of things was that most of the main rivers in Ireland had a remarkably flat course for many miles from their source, and a very precipitous course for the few Mr. Barry.

Mr. Barry. remaining miles that enabled them to reach the sea; and the problem which the engineer had to face in Ireland was to improve the flow of water over the long length of river course in the plain, and then allow it to discharge freely down the more precipitous and shorter course to the sea. That was really the key of almost all the large river improvements which had been so much talked of in Ireland. The importance of effective arterial drainage to the country consisted, mainly, in the agricultural pursuits which such a considerable proportion of the population pursued, making all matters affecting agriculture of far greater relative importance in Ireland than in England. He had found that much difference of opinion existed in many localities as to the value of excluding floods from land, or of letting them flow over the land at certain times of the year; and some persons had been disposed to assign a large amount of value to the fertilizing properties of the mud left by the floods. The Royal Commissioners of Irish Public Works came to the conclusion that although there was some value from the deposit in certain localities, yet, on the whole, the benefits of improving arterial drainage and diminishing floods were undoubted, not merely from an agricultural point of view, but from the points of view of the general health of the neighbourhood, and of the question of temperature alluded to by the Author. The manurial value of the mud left by the floods was very largely discounted by the fact that they induced a much coarser kind of grass to grow upon the flooded lands, and it was impossible to produce the best kind of grass for hay unless the floods were excluded. That, he believed, was now becoming, to a great extent, an accepted axiom in Ireland. These being the facts of the case, and arterial drainage being of such great value in Ireland, Government had, for many years, looked with a most favourable eye upon all schemes of improving arterial drainage, and had spent or assisted the expenditure of very large sums of money. In many cases that expenditure had been wholly contributed by the nation, but in others a large proportion of it had been found by the landowners and others interested in the various localities. Government also, in times of scarcity, had spent large funds which were raised for the relief of distress on the laudable enterprise of improving arterial drainage, while at the same time feeding the starving population. Some of those works were done under pressure of time arising from the necessity of finding work quickly for people. Mistakes had consequently been made in Ireland, and some of the works that had been undertaken had proved very expensive having regard to the results which were attained. But he thought that, on the whole, it might be said with great certainty that the action of Government in Ireland, in the matter of arterial drainage, had been decidedly beneficial, and that very important works, which had resulted in great good, could never have been undertaken unless Government had taken *the position of not only finding money, but also supervising* the works. The Rivers Bann, Shannon, Suck, and Lough Erne were all examples of large works which had been helped by Government, and which, although not entirely successful, had produced valuable results for the country at large. Last year Government was prepared to spend from £300,000 to £400,000 in improving the drainage of the Shannon, the Bann, and the Barrow; but unfortunately, owing to circumstances over which the Government could not perhaps exercise much control, the Bills never arrived at maturity, and those works which were urgently required were consequently still in abeyance; he hoped that when the time was more opportune the money would be forthcoming, and the works would be undertaken. One matter referred to in the Paper was of considerable importance as affecting one of the rivers which the Government proposed to deal with, namely the Barrow; he referred to the question of embanking the river, as compared with dredging or deepening it for the whole of its course through a flat plain until it reached the more precipitous part below Carlow. In Ireland up to the present time, with perhaps two exceptions, he thought the usual practice had been to deepen rivers, and in doing so, owing to the existence of such an expanse of limestone forming their beds, vast sums of money had been spent, which could have been avoided if a more liberal use had been made of embankments such as were seen in the Fens of England, and of which examples existed in the north of Ireland. The notion which he heard expressed in Ireland was that, if a river was embanked, the people were so careless by nature that they would allow the embankments to go to destruction or decay, and would not maintain them with the care which was necessary for works of this kind. For himself, he did not believe that the works would be neglected. Certainly the rivers he had seen in Ireland that had been embanked were as well maintained as any rivers in England. There could be little doubt that a system of embanking, in the case of the River Barrow, would result in much economy in regard to the first cost, and, as far as he could see, without loss of efficiency in the carrying power of the river. A combination of deepening and embanking seemed to be a most advantageous thing in Ireland, as he had no doubt that it was **Mr. Barry.**

Mr. Barry. elsewhere. The best system consisted in taking advantage of the configuration of the land, in applying embankments in places where excavations would be abnormally expensive, and in applying excavation exclusively where it could be done with a reasonable amount of cheapness. A matter which had been found very important in Ireland was the necessity of some new legislation with regard to all matters of river regulation. Numerous Acts of Parliament had been passed, but the present condition of the law was chaotic, and required, in his judgment, most material alteration and consolidation. Such was the condition of the law in Ireland, where some attempt had been made to deal with the subject from a general point of view, but it was still more the case in England. He thought that no one, who had anything to do with the subject of arterial drainage in England, could come to any other conclusion, than that some more drastic and general mode of dealing with all the conflicting interests, which were evoked by any scheme for arterial drainage, was urgently needed for the regulation of the chief river courses of the country. No one could travel through the flat parts of England, in rainy weather, without feeling ashamed that he lived under a system of laws which allowed of such vast areas of land being left to be flooded whenever the weather became moderately severe. The time ought not to be far distant when floods should be brought under proper regulation. With reference to Lough Erne itself, he had the pleasure of seeing a great deal of what had been carried out, and apart from any question of cost, which had been discussed by Mr. Hassard, he thought the work was of national importance, and was a very creditable undertaking. In the Lough Erne scheme would be found the old antagonism between navigation, fisheries, and arterial drainage. There could be no question that the works on Lough Erne had been materially increased in cost and difficulty by the necessity, or the assumed necessity, for dealing very tenderly with navigation interests. The result of the investigations of the Royal Commissioners in Ireland, had been to convince them that the value of navigation facilities had been generally much over-rated, and he could not help thinking that, in the work which they had under consideration, if the question of navigation had been altogether set aside, no one would have been much the worse, but many people would have been considerably the richer. The cost of the works had also been largely increased by financial and legal difficulties, and he could understand that large additions to the original estimates were not unreasonable if those circumstances were allowed for. Still, even with the large cost incurred, the works were not altogether unsatisfactory in a financial point of view, and from an engineering point of view he thought they were exceedingly creditable. He much regretted that he had not had time to visit the sluices, as he should have been glad to see those important works; but he saw other sluices in Ireland of the same description, not, however, of the same size, and had come to the conclusion that they were the most desirable mode of dealing with flood-water. The sluices at Belleek seemed to him rather peculiar with regard to the form of the piers, and he could quite understand what Mr. Hassard had stated, namely, that large whirlpools and eddies were caused by the very short cut-waters which formed the approach to the sluices and by the swelling outwards of the piers behind the sluices. The great advantage of these handy and easily-worked sluices was that relief could be given to the river quickly, and at a time when that relief was of the greatest value. He was much struck with the investigation which the Author had made into the amount of water which would be given off into the river course at different times of rainfall, and under different conditions of soil. Such investigations were of the greatest value, and it was to be regretted that more accurate records were not kept in all parts of the country of the effect of heavy rains, or even ordinary rains, falling upon different soils on different declivities. It was extremely difficult to arrive at any sound conclusions on these points when the necessity arose for designing works of arterial drainage; and any conclusions based upon a short investigation were likely to lead either to extravagance on the one side or to undue parsimony on the other. If some general means could be adopted of recording such matters, they would be of the highest value to engineers and to the whole community. He had nothing to add but to express his congratulation to Mr. Price on the conclusion of his arduous work, and to say that he thought the Paper was one of those which afforded valuable records on a matter which it did not fall to the lot of many persons to be able to investigate with the advantages which the Author had possessed. Mr. Barry.

Mr. R. W. Peregrine Birch enquired whether, and if so, to what extent, the commercial results had justified the expenditure of £8 12*s.* 6*d.* per acre, and also whether the Author had any health returns bearing on the subject. He had no doubt, as Mr. Barry had stated, that the health of the district had been much improved by the reduction of the water-level. It would be well if the annual rainfall was stated in the Paper, and if, for the benefit of Mr. Birch.

Mr. Birch. members not familiar with the local conditions, a cross section or two of the valley were also appended, so that they might be able to estimate the extent of the soakage from which the 3,000 or 4,000 acres had been saved. He was glad to hear the Author's statement that the improvement of the drainage had mitigated the floods. He believed that that was not a generally-accepted view. Floods in rivers were constantly attributed to improved drainage. He had himself always believed that the tendency of improved drainage must be to reduce floods, and he knew from records he possessed that the floods in the Thames had not been higher of late years than they were seventy years ago. The flood in the Thames in 1821 was at least a foot higher than that in 1877—the biggest flood of late years; and the floods of 1823 and 1852 were also higher than that of 1877, although not so high as that of 1821. He had no doubt that more suffering was now caused by floods because a large extent of low land had been built upon during the last twenty or thirty years, which fifty years ago was simply meadows. Referring to the storage of water available for summer flow, he thought the Author had made a mistake in his statement that: "Taking the area of the catchment-basin as 25 times that of the lakes, and the absorbing power of the ground as 10 per cent. of its volume, the water stored in the pores of the ground, per foot of depth, is 2·5 times the storage of the lakes for the same depth. Then taking the average level of the district as 50 feet above the lakes, the storage in the ground is 125 times that contained in 1 foot of the lake." That required some little explanation. It could only be true if by the level of the district the Author meant the sub-soil water-level of the district, and it was only true if he knew that there was no impervious bed rising above the level of the lake. The mistake would be seen when he pointed out that 10 per cent. of 50 feet meant 60 inches, whereas only 30 or 40 inches of rain fell upon the watershed during the whole twelve months.

Mr. Vernon-Harcourt. Mr. L. F. Vernon-Harcourt said it was about ten years since he had advocated before the Institution the importance of introducing movable weirs for combining drainage and navigation,[1] and he had also had the opportunity of visiting the sluices at Belleek. It was well known by people who had lived, like himself, in Ireland, and also by people who had visited the country, that it was a remarkably wet country, with large tracts of lakes, besides the very indented shores of the west coast. Therefore it might be

[1] Minutes of Proceedings Inst. C.E., vol. lx. p. 24.

Mr. Vernon-Harcourt.

expected that considerable difficulties would be found in the drainage of flat districts there. Moreover, in many parts there were large areas of bogland, which were excavated to some depth for obtaining peat for fuel, so that large quantities of low-lying land had water standing on them in the centre of Ireland. With regard to what Mr. Birch had said about the extension of arterial drainage diminishing instead of increasing the floods, the Paper showed that that was not the view held by the Author, because he considered that it was all the more necessary to have these drainage works on account of the extension of arterial drainage. With regard to the Lough Erne district itself, it was remarkable that there was a very good fall at Belleek and below. The river below Belleek was more like a mountain stream than a stream near the sea, whereas above there was a long tract of flat land; and therefore it was possible to get a remarkably good fall at the outlet below the lakes. Mr. Price also had the advantage of the large water area of the Lough Erne district for a reservoir for the floods. He thought, looking at the plan of the land surrounding Lough Erne, that, but for the navigation, it would have been desirable to lower the level much more than had been done, because there were considerable tracts surrounding the lake which seemed to be only a kind of marshland; and it would appear desirable to lower that level and gain more land for the purpose of agriculture if that land was of any value agriculturally. Drainage works had been carried out, with great advantage both to agriculture and health, at the lakes Fucino and Copais. The Author had mentioned that Mr. Price, senior, had been to see the various movable weirs in France and other places, and he quite agreed that weirs of that kind, which were very suitable for navigable rivers, would not have been suitable at Belleek, because they were simply required to be raised and lowered at certain periods of the year, and did not adapt themselves so readily to the exact adjustment of the discharge as sluice-gates. The sluice-gates themselves, with a head of 14 feet 6 inches of water against them, could be raised with great ease by turning with one hand the handle of the sluice-gate gear; and it simply required time to raise the gates. The other sluice-gates, of similar type, which had been erected in Ireland on the Suck Drainage, at Ballinasloe, were rather different. He had had the opportunity of inspecting them. They were counterbalanced, and therefore they were moved much more quickly, and rose much more readily; but they were not such large gates as those at Belleek. Similar gates might now be seen in course of erection on the Manchester

Mr. Vernon-Harcourt. Ship-Canal Works, across the River Weaver and higher up. The Author had mentioned that a current meter was not used for measuring the discharge. He had himself found that a current meter, if there was not too sluggish a stream, was very suitable for measuring the discharge of streams, and it seemed a pity that that method of measuring had not been tried as well as others. With regard to the diagrams, he agreed fully with Mr. Barry that records of the hydrology of the district were very valuable. They showed the amount of the supply, and the water flowing into Lough Erne; they also showed the rainfall at each period; and in that way it could be judged how far the rainfall affected the supply in the different months of the year. It also showed what was very well known, but it was interesting to see it reproduced in the diagram, that in the summer months, July, August, and September, the rainfall had comparatively little effect upon the discharge of the streams. In some years the rainfall, if it occurred in July and August, seemed to have no effect upon the supply, showing that the whole of the rainfall, even though it amounted to a fair quantity, was taken off by evaporation and percolation. Apparently, from the Author's diagrams, the greatest rainfall from 1885 to 1888 occurred in the month of July, and it was followed only by a very moderate flood. In some cases the rainfall and the flooding apparently coincided; and in other cases, which was the more natural order, the flood followed the rainfall. He thought that diagrams were most valuable for the purpose of judging exactly how the rainfall affected the discharge of rivers. The Author had suggested that the whole river basin should be rated. That would be a most useful piece of legislation, if it could be carried out, for the purpose of the drainage of a district; because the great difficulty in all those matters in England, as well as in Ireland, was to obtain sufficient money for carrying out works for improving the flooded districts. If a rate was only imposed upon the flooded area, that area was comparatively so small that it was impossible, especially at the present time of agricultural depression, to do sufficient work to remedy the evil. But the improvement, which was effected by the removal of floods from the lower districts, really did improve the sanitary condition of the upper districts; and therefore it would seem fair that a rate of some kind, though smaller, should be imposed upon the whole catchment basin, as suggested by the Author. He had further suggested that reservoirs should be made for preventing floods. That would seem inexpedient, especially in the case of Ireland, where the Author complained of too much water, and also where land was well cultivated. There was a difficulty in getting proper places for forming such reservoirs at a moderate cost. It was very well in a case where there was a large natural reservoir like Lough Erne to utilize; but the forming of reservoirs for that purpose was another question. The Author also suggested that, in Ireland, too large a fall had been generally given for the drains. That must be due to the large fall that was obtainable towards the sea coast. It was quite the contrary in the Fen Districts in England, where only a fall of about 4 inches per mile could be obtained; and most probably the reason why so much fall had been given was that it was cheaper to utilize a large fall, and so to reduce the cross section of channel required for a given discharge. The Author had suggested the use of embankments instead of enlarged channels. There was no doubt that a moderate use of embankments might be advantageous, especially where small embankments would provide against the flooding of a small quantity of land. The only objection to embankments seemed to him to be that their use might lead to the neglect of the channel itself, and thus sometimes lead to serious floods from the breaking of those embankments. Mr. Vernon-Harcourt.

Mr. G. J. SYMONS said he was glad to find that Mr. Barry approved of the Paper with regard to its engineering portion. He was sorry, however, to differ from Mr. Barry, and also from Mr. Vernon-Harcourt, as to the value of the diagrams. He yielded to none in the desire for information of that kind, but he should endeavour to show that the diagram as it stood was not such a one as ought to be brought before the Institution in the year 1890. He thought it very strange that a Paper on the drainage of a district should not contain a map of the watershed. It was true that the details of Lough Erne itself were given, but there was no information as to the watershed beyond a rough statement of the total area. He was sufficiently acquainted with the watershed to know that it had a very different rainfall in different parts. The Author stated that "For several years two rain-gauges have been kept as the standards of the Erne district, one at Florence-Court, on the high ground south of Enniskillen, the other at Colebrook, about 8 miles north-east of Enniskillen." He might state as a matter of history that one of these gauges was established in 1844, and was therefore not put up in connection with the Lough Erne Drainage Works. The Author had taken these two records, but there were four stations within the watershed, and two others on the immediate confines which threw considerable light on the rainfall on the watershed. Mr. Symons.

Mr. Symons. The two stations that he had chosen gave for the years 1885–1888 an average of 45·5 inches and 38·9 inches respectively, so that taking those two stations, the average of the Lough Erne watershed was 42 inches. But the station at Florence-Court was immediately under the hills on the western side, and the rainfall there was 6½ inches more than at any other station in the watershed. The consequence was that by adopting those two instead of all four, or all six, the Author had an average quantity to deal with of 42 inches instead of 37 inches, which was probably much nearer

—	Edgworthstown, Currygrane.		Lawderdale, co. Leitrim.		Belturbet, Red Hills.		Rockcorry, Monaghan.		Enniskillen, Florence Court		Brookeboro', Colebrook Park.	
	Feet	Ins.	Feet	Ins.	Feet	Ins.	Feet	Ins.	Feet	Ins.	Feet	Ins.
Diameter of gauge .	0	5	0	5	0	5	0	5	0	8	0	0
Height above ground	1	0	1	0	0	9	1	0	1	9	1	0
Altitude above O D .	265	0	275	0	208	0	290	0	250	0	279	0
	Inches.		Inches.		Inches.		Inches.		Inches.		Inches.	
1885	29·29		36·61		29·77		29·48		50·54		38·40	
1886	41·25		44·89		39·96		39·23		48·48		45·08	
1887	26·00		33·16		24·50		22·09		35·29		31·46	
1888	36·96		41·31		66·15		(33·50) ?		47·79		40·69	
Means	33·38		38·99		32·59		(31·33) ?		45·52		38·91	

Mean of two stations quoted by Mr. Price . . . . 42·22

Mean of four stations in the watershed . . . . . . 37·09

Mean of six stations in or near the watershed 36·79

the truth. Having an extra large rainfall, and then having measured the outflow from the ground, the Author had put down the difference between those two quantities as loss. He had been much puzzled at that, because in one part of the Paper the Author referred to the loss as 0·15 inch per day. He had stated, "Thus the summer flow of a river is made up of the yield from the springs, and the excess rainfall over 0·15 inch per day, which seems to be the amount of rain taken up by vegetation and evaporation during the summer months." The 0·15 inch daily would give 18 inches loss in the four summer months alone, whereas it was well known in England that the loss, at the very outside, might be put at 15 or 16 inches for the whole year. In

Mr. Symons. the present instance, however, it might be seen where the Author had got his large amount of loss. He had miscalculated the rainfall to begin with, and therefore a large estimated loss was the only way to make the quantities balance. One error was apt to lead to another. The diagram itself, was rather puzzling; he could not make out whether the rainfall was supposed to be given for days or weeks, or for variable periods. It was represented by a gently flowing curve. The proper way of showing rainfall on a diagram of that sort would be by what was known as the organ-pipe arrangement, vertical columns the lengths of which were proportionate to the quantity of rain falling each day. There were also some other puzzling things about the diagram. Ireland was well known to be wet, but the diagram represented only ten days without rain in 1885, thirteen in 1886, five in 1887, and twenty-five in 1888. It was well known that often for a week together, if not for a fortnight, there was no rain at all, and during that time the line ought to run along at zero, which it did not. If the Author had given the numerical values from which the diagrams were constructed, the members would have been in a much better position. At p. 84 there was apparently a little slip; the Author had stated that the evaporation was least in February, and greatest in August. He presumed that the Author meant the amount of loss. Of course the term loss as understood by engineers contained other things besides evaporation, but with regard to evaporation itself he did not quite see why it should be at a different period in Ireland from what it was in England, and certainly the maximum evaporation in England was in June and July, and not in August, while the minimum was almost always in December and January, and not in February, unless the smaller number of days in that month had something to do with the result. The Author had referred to the useful applications that might be made of diagrams of that sort, as to which there could be no doubt. The suggestion that had been thrown out, that something might be done towards collecting data of that kind was of the highest importance, and if the Institution could see its way to do something of the sort it would prove of the greatest value. But first-rate observations would be necessary. It would be convenient to those who were only on the outskirts of engineering if the same expressions were always used. The Author, in referring to the yield of the springs, gave the number of cubic feet per acre per minute, whereas in England it was usual to give it per cubic foot per second per thousand acres; it would be very convenient if a uniform method were adopted. The question of

Mr. Symons. the influence of drainage on the floods, and the relative heights of floods, as compared with those of past years, was far too large a question to discuss in connection with the present Paper; but it was only right to point out that the Author appeared to contradict himself. He referred on the first page to "the increase of flood-water, owing to the reduction of absorption, resulting from the diminution of timber since the year 1847." That seemed to imply an increase in the flood-water; that there was not so much undergrowth and so on, to hold water like a sponge; but further on he stated "this has the effect of reducing the maxima points of flood supply," so that it was not quite clear whether he thought that the floods were greater or less than they were originally. To sum up, he should be thankful if something could be done towards giving statistics of the nature of the Author's diagram, but statistics of an unexceptionable value.

Mr. Wells. Mr. L. B. Wells said that his experience did not extend to Ireland; he was chiefly interested in the question of sluices, and had seen the Belleek sluices erected in the maker's yard. Acting upon a report by Mr. Leader Williams which was approved by Sir John Hawkshaw, their Consulting Engineer, the Weaver Trustees determined some years ago to improve the navigation by diminishing the number of ponds below Northwich by one-half, thus necessitating the alteration of the water-level in many of them. One of his first duties upon becoming their Engineer in 1877 was to advise the Trustees as to the best method of raising the surface of a pond 4 feet 9 inches, some 6 inches higher than the pond above it. Of late years, the people, in the Weaver Valley especially, were alive to their own interests, and if there were floods endeavoured to get damages from the Trustees. He felt the juncture was a critical one, and that he could not recommend a fixed weir such as existed on the navigation, with small side sluices to let off the water when repairs were necessary. He therefore advised that the water should be penned up entirely by sluices, and placed himself in communication with Mr. Stoney. When Mr. Stoney had spoken during the discussion of the courage of his countryman, Mr. Price, he had forgotten the Englishman who had been quite ready, years before, to adopt his sluices, and in fact recommended them. The question between them was one of cost. He was satisfied that the sluices would work, and that they were thoroughly sound in principle. He was however left to his own resources, and determined that at any rate he would not have surface sliding over surface, but would lessen friction in some way, and to do that he introduced four rollers.

The sluices were made somewhat on the principle of those described. There was a plate girder near the bottom, and another 4 feet from the top. At the back he put four rollers, which travelled on a planed surface of iron attached to the pier. The sheathing of the sluices was of timber. The rollers worked in a recess as in the Belleek sluices, and a stop-water, in principle the same but different in detail, was adopted. He had great difficulty in getting assent to sluices being used in lieu of the old type of weir, and thus breaking through the practice on the Weaver. His report was referred to Sir John Hawkshaw, who confirmed the proposal of having a movable instead of a fixed weir, and eight sluices of 15 feet span and 13 feet deep, about half the size of the sluices at Belleek. There was a depth of 4 feet of water on the lower side. The lift was 13 feet. This provided for a drainage area of about 530 square miles, and was calculated to run off 0·50 inch of rainfall in twenty-four hours. It had been found sufficient, and the effect in conjunction with the removal of two fixed weirs, and other alterations in the way of deepening and widening the navigation at certain places, had proved most beneficial in the valley. To go back to the year 1850, there was a flood at Northwich of 12 feet on the navigation gauge; in 1863, of 10 feet 2 inches, and in 1872 there were floods of 8 feet and 9 feet 3 inches on the same gauge. In 1879 there was a flood of 7 feet 9 inches, and in 1880 of 7 feet 2 inches. Since the construction of the sluices at Dutton 4 feet had been the maximum flood, and that happened four years ago. It was necessary to be especially careful at Northwich. The town, as was notorious, sank owing to the subjacent rock-salt melting; it had subsided several feet in a few years, and boats were used in the streets during floods. Finding the sluices at Dutton acted so well, he applied them when improving the upper navigation between Northwich and Winsford, wherever he had the opportunity. There were now sixteen places on the Weaver in which the spare sluice provided could be fitted if it should be required. No spare sluice, however, had been needed, and everything had worked satisfactorily. Having eight sluices at Dutton, he constructed a treble geared travelling crab, by which one man could raise a sluice slowly, and this could be done with speed by several men on the other purchases. Where there were fewer sluices, a screw with rack and pinion had been used, and had answered the purpose well. The men in charge were in telephonic communication with each other, and with the Engineer's office, to which telegrams were sent from the head waters of the Weaver and Dane whenever the rainfall was Mr. Wells.

Mr. Wells. excessive. He quite agreed with what Mr. Barry had said with regard to the large amount of land flooded without any very extraordinary excess of rainfall, and he hoped that when the next cycle of wet weather came the British public would be educated as to the advantage of having movable weirs in the place of short fixed weirs which they now put up with, although grumbling very much when their lands were damaged. By removing obstructions and improving the river channels generally great benefits would ensue; this had been proved in the Weaver valley.

Mr. Tripp. Mr. W. B. TRIPP said that in gauging with current-meters under Mr. Deacon, he had found one practical difficulty in that when a flood was rising all the little streams washed off the ground small matters such as straws and twigs, which tended to interfere with the revolutions of the meter. But immediately a flood had gained its height and began to fall—it seemed never to be quite stationary—the water became comparatively clearer and the difficulty of using a current-meter was then very much decreased.

Mr. Hawkshaw. Mr. J. CLARKE HAWKSHAW could corroborate what Mr. Barry had said with regard to the prevalence of the idea that floods were to some extent beneficial. That idea was held, not only by farmers in Ireland, but by some in England. In 1878, Sir John Hawkshaw was asked by the Thames Valley Drainage Commissioners to report on the best means of dealing with the upper 60 miles of the River Thames; and his instructions were that the works should not be designed to get rid of the floods altogether. They believed that floods to a certain extent were beneficial, and that the works should be designed for the purpose of mitigating them. The great difficulty in designing drainage works for the prevention or mitigation of floods was to settle the amount of rainfall over the drainage area which the new or the improved channels should be calculated to carry away. In some districts that was more difficult than in others. In the Upper Thames it was especially difficult, because of the great variety in the character of the soil. Part of the drainage area consisted of clays, but a great part of very permeable rock, such as oolite and chalk. In the Lough Erne district works were provided to carry away 0·25 inch of rain in twenty-four hours; in the works Sir John Hawkshaw proposed for the Thames Valley Drainage they were designed to carry away 0·12 inch. Of course those works were not designed to get rid of the floods altogether, but only to mitigate them. In some of the tributaries a larger amount was provided for, namely 0·20 and 0·25 inch. The works proposed in the report had not been carried out entirely; but certain parts of the river had been dealt with in the manner suggested; and, so far, it might be said that the amount provided for, 0·12 inch, appeared to be sufficient for the purpose of getting rid of the floods which did most damage. Mr. Hawkshaw.

Mr. W. Berrell desired to supplement the statement of Mr. Hawkshaw with reference to the works of the Thames Valley Drainage. He had mentioned that the provision for 0·12 inch of rainfall in the Thames Valley against 0·24 and 0·25 inch in the Lough Erne district offered a great contrast. The drainage areas were very nearly equal. From what he knew of the district of Lough Erne probably the greater quantity of water to be carried away in the short time was due, not so much to the heavier rainfall, as to the greater steepness of the tributaries rising in the limestone hills surrounding Lough Erne, bringing down water into the lake with great rapidity and causing a very sudden rise in the level of the water in the lake; whereas the same amount of rain falling in the Thames Valley would not raise the level of the water to the same extent. The works Mr. Hawkshaw had referred to had in a great degree been carried out, especially below Oxford; and since 1886, when the greater part of those works were completed, very little of that land had been under water, and that for only a few days, which, he believed, farmers thought did no injury to the crops; they rather liked the land to be warped, as they termed it, to get the slight sediment on the grass, which did not injure it. If that water, however, remained for any length of time, it killed the finer kinds of grass, and the quality of hay became deteriorated. The weirs that had been put up in the Thames Valley drainage-district were not so large as those constructed at Belleek, but they might be called deep-sill weirs; they had, many of them, a depth of 9 feet of water running over the sill below the summer water-level. He noticed that the sluices though 14 feet 6 inches deep, were only raised 9 feet. He presumed that the depth of water running over that sill in flood time was only 9 feet; so that the actual capacity of the sluices built in the Thames per foot of width was equal to the sluices designed for the Lough Erne drainage. Whilst on that subject, he might remark that considerable difficulty had been found, with large sluices designed like those at Belleek, owing to the accumulation of twigs, boughs, and trees, and drift that came down with the surface-water. It would be seen that, as the water rose, the sluices had to be lifted from the bottom, the lip of the sluices being submerged, a large quantity of rubbish accumulated on the upper side, which had to be cleared away. It was a great convenience to have a small upper sluice to lift off just sufficient Mr. Berrell.

Mr. Berrell. to carry the rubbish through in some part of the weir; but where there was a weir of the full width of the river, with the whole of the water pouring under the sluice, there would be very great inconvenience in times of flood from the amount of rubbish accumulating above it. With reference to the amount of water which passed through the weirs, he should like to examine the gaugings which had been taken, for, from what he could ascertain, the formulas, which had been based on smaller weirs, greatly underrated the amount of water passing through such sluices. The obstruction of the new weirs constructed on the Thames, with frames about 6 inches wide, and spaces of 6 feet between them, was so slight that the water, instead of surging through, seemed to pass through as a steady current, with very high velocity; and it was some long distance below, where the water of high velocity met the more sluggish water, that the broken water occurred.

Mr. Topley. Mr. W. Topley said that one point of interest was the geological nature of the basin under consideration. The matter was important, because the Paper was so good, even making allowance for the apposite criticisms of Mr. Symons, that it was likely to be taken as a standard reference for some time by engineers; and it was therefore the more important to have precise knowledge of the data submitted. The Paper had referred to the district in question being a limestone area; and comparison was made with other districts, the object of the Author evidently being to take that as a typical limestone area, and to compare it with others not so circumstanced. There were one or two criticisms upon that statement which might be read within the lines of the Paper itself. The Author had stated that "the Erne drainage basin consists almost entirely of calp limestone (except at the north-west where a little gneiss and granite crop up); the rock is fairly absorbent, being a mixture of solid limestone with shaley beds;" and he added, "a glacier deposit of blue boulder-clay overlies the limestone." Everyone knew that, in a question of this kind, if a deposit of clay overlay limestone, it was of very little consequence which rock might lie some feet below. What the engineers had to consider, in a drainage area, was the surface soil, because upon that depended the way in which the rain would run off. He had examined the maps of the Geological Survey, and had found that a very large portion of the district was composed of boulder-clay. The Author had referred to this in speaking of the manner in which the excavations had been made. There was only one place in which rock-cutting was mentioned, namely, Belleek; everywhere else the cuttings were through clay; that referred to low-

Mr. Topley.

lying land near the lakes, but it was equally true if applied to the higher area surrounding the lakes, over which the water flowed. The limestone was not entirely limestone. Even disregarding the boulder-clay, it would be a mistake to speak of it as a limestone area in the sense of the centre of Derbyshire, which was a typical limestone area. There was a considerable amount of shale even within the limestone beds; and in the beds above them, forming the course of the watershed, there was a large amount of sandstone. Mr. Symons had referred to the desirability of having a map, showing the actual line of the watershed; and he would suggest that if that were done, it would be desirable to show the nature of the soil, which could easily be done by means of the published Geological Survey maps. He should be happy to supply the information (Plate 6, Fig. 5).

Mr. Price, sen.

Mr. JAMES PRICE, senior, in reply to the discussion, on behalf of his son, who was abroad, observed that Mr. Hassard made light of the expenses incurred by the claims of the owners of the Ballyshannon Fishery Company, and said that it was very little more than might have been expected; but it turned out to be ten times as much as had been contemplated; at least, no considerable sum did appear in the estimates of the engineers who had previously considered the question. The Drainage Board paid over £10,000 in compensation and costs for an eel-weir at Belleek, though a better one was constructed in its place, and offered to the owners, who refused to take it as a substituted work; and when the Board fished the weir at a large profit, in order to prove its value, it was restrained from doing so by a decision of the Irish Master of the Rolls, whereby the owners of the fishery got large compensation, and at the same time caught the eels in their weirs lower down; such a result was certainly unexpected. Another reason for the excessive cost was the rate of wages, which rose 25 per cent. from the time of making the estimate till the works commenced; this delay was caused by circumstances not within the control of the Board. In addition to the above causes, the plans had to be prepared from surveys and borings made by other engineers, which showed about one-third of the quantity of rock that had to be excavated, and there was neither time nor money to prepare new borings. Mr. Porter, the promoter, having already spent out of his own pocket many thousands of pounds, and long years having been occupied in the several attempts to accomplish this work, was not prepared to delay the matter further; to have made new borings would have been most tedious and expensive, the bottom of the river being paved, as described, with boulders.

Mr. Price, sen. The position of the sluices, at a distance below the head of the lake, was not determined on with a view to the navigation of these 3 miles of river; the only navigation considered was that in the upper waters; but they were placed at Belleek in consequence of the rapid fall at that place, which took the water away at once without any backwater, so that the sluices were only half as large as they should have been if placed at the head of the lake. If they had been constructed in the position suggested by Mr. Hassard, almost the whole water-power of the pottery-works would have been destroyed, involving enormous compensation, as the wheels gave at present 130 HP., and there was enough water for 200 HP. all the year round. The performances of the dredger had very much improved since Mr. Hassard's inspections; it would now excavate up to 400 cubic yards per day; the smaller output at the earlier stages of the work was due to the surface pavement of boulders. It was always intended, as the specifications would show, that most of the cuttings should be made in the dry by means of stanks, or that the contractor should procure more dredgery plant, as he might prefer. The section suggested by Mr. Hassard had been adopted in two or three places with advantage, and Mr. Price was indebted to him not only for this suggestion, but for his careful measurements and favourable report on the works, and his recommendation to the Board as to a settlement with the contractor for a portion of the works. As Mr. Price, senior, and the Author of the Paper were, in fact, agents to carry out two-thirds of the work, it was necessary that an independent engineer should be employed to measure the work and advise the Board. The remarks of Mr. J. W. Barry were very encouraging, coming from one of the Royal Commissioners on Irish Public Works. However, on the subject of navigation, there was a tendency on his part—shared by others—to underrate the inland navigation in Ireland. No doubt it had not as yet proved of very great consequence; but as Lough Erne, with its unbroken sheet of water 52 miles in length, joined the Shannon navigation from Limerick with that of Lough Neagh and the Lagan terminating in Belfast, it would be a gross error, having regard to what might be in the future, so to lower Lough Erne as to close this great water highway. Besides, a large number of resident proprietors had their demesnes on the margins of the lakes, no doubt attracted there by the beauty of the scenery, and by facilities for yachting, who would never have given their consents to the scheme were the lake to have been lowered even by 2 feet; and it was a proposal to reduce the summer level of the lower lake by 2 feet, as embodied in almost all the previous schemes, that prevented those projects obtaining the necessary assents of two-thirds of the proprietors. Moreover, were the lakes run down to their very lowest, on account of the quickly-shelving margins, only an insignificant area of land would have been laid dry, which would consist principally of stony shores, and these must have been flooded in all except very dry seasons to gain sufficient head to drive the water through the channels from the lower lake to Belleek, unless these channels were enlarged and thereby the expense of the drainage doubled; so that, on the whole, the maintenance of the navigation—which was used by the country-people—was a matter not only of prudence but almost of necessity. The commercial advantages had been shown to be at least double the annual charge upon the loan, which would itself be paid off in thirty-five years. The Author did not assert that a depth of 60 inches of rainfall was run off every summer from its storage in the ground, but that such a quantity was stored there, and would form a reserve in case of a succession of dry years. As Mr. Vernon-Harcourt had himself resided in Ireland, and seen the sluices, his general approval was much appreciated. The Author stated that "thorough drainage" increased the floods, but arterial drainage did not do so necessarily. On neither of these points could any general rule be laid down, as everything depended on local circumstances. For instance, in the case of a long river with a great many tributaries coming in together, when the catchment area had an expansive head, if all these tributaries were improved simultaneously, the floods would be greatly increased, as the large area of flooded lands, which allowed the waters to escape over them, both mitigated and delayed the floods before the drainage took place. On the other hand, in the case of a river with uniform width of catchment, and tributaries coming in like the branches of a fir-tree, by draining some of the lower tributaries, the floods from them would have passed away generally (not always) before the flood from the upper tributaries could arrive; in this case, arterial drainage diminishes floods, besides the diminution from the cause assigned by the Author. There was hardly any catchment-area where suitable sites for forming artificial lakes could not be selected, as they might be on the worst land adjoining the main river, or any of its tributaries, no matter where, so as it took up a portion of the flood. The criticisms of Mr. Symons were very fair; neither his son nor he could give the time to arrive at the high degree of accuracy in the investigation that he desired.

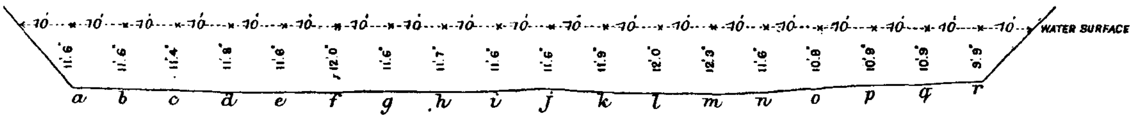
Mr. Price, sen.

Mr. Price, sen. They were indebted to him for the returns of rainfall, as both the gauges from which they took the rainfalls were, he believed, under his direction. Still, there was so much hill district unprovided with gauges in the Lough Erne catchment area, that to have taken an average of three lowland and one hill gauge would have given too small a rainfall. After careful consideration they concluded that the mean of the two gauges, at Florence-Court and Colebrook, represented the average rainfall. It was quite natural that the loss from evaporation in Ireland should have its periods of maximum and minimum different from what it was in England; thus, in Ireland the lowland meadows were still uncut and very luxuriant in August, and held the water as a sponge, exposed to evaporation; in fact, the light showers hardly reached the ground. Mr. Symons objected to a flowing line, in Fig. 2, representing the supply from rain, which was not exactly the rainfall; but the flow of yesterday was merged into the flow of to-day, and continued after the rain had ceased. Figs. 3 and 4, which were only intended to represent May and June, 1888, seemed to agree with Fig. 2. The diagrams showed what took place during these years, whatever conclusions might be derived from them, and they certainly represented actual phenomena. As to Mr. Wells' remarks, Mr. Price fully believed that he, as an Englishman, would have had the courage to use Mr. Stoney's sluices, had he the same unfettered choice and opportunity. It was not clear whether he only used wheels to mitigate friction, or suspended live rollers, of which it may be stated that they almost annihilated that force opposed to motion. With reference to Mr. W. Berrell's assumption as to there being only 9 feet depth of water when all the sluices were fully open, he believed there would not be so much as 9 feet; probably during a high flood, with all the sluices open, there would be only 7 or 8 feet in depth passing under the sluices, which would all stand clear of the water. As yet it had not been customary to pass off a full flood as quickly as possible, as the current interfered with the dredging operations above the sluices, so that the exact depth was still undefined. The fact of this small depth of water when passing full floods arose from the free fall below the sluices, which greatly increased the velocity through them. There had been no trouble with rubbish accumulating behind the sluices, as they were opened in succession, no one sluice being left too long shut; and the slightest opening allowed the rubbish to pass. Mr. Topley's remarks on the geological features of the district were of the greatest importance; the district around Lough Erne had a considerable variety of formation. He subjoined a

Table of experiments on measurement of discharge by ascending floats:— Mr. Price, sen.

EXPERIMENTS on MEASUREMENT of DISCHARGE by ASCENDING FLOATS.

Fig. 4.



Scale 35 Feet = 1 Inch.

This section was at a place a short distance (150 yards) above the sluices; the water was disturbed in its natural flow by the proximity of the sluices; it would be most difficult to measure the discharge by any other method than the above. Two sluices were raised 4 feet each. Head of water over centre of orifice = 10 feet.

Position on cross section.	Distance $x\ y$.	Time of Ascent.	Corrected mean velocity (V.)	Discharge depth × 10 × velocity (V.)	Surface velocity.	Position on cross section.	Distance $x\ y$.	Time of Ascent.	Corrected mean velocity (V.)	Dischargedepth × 10 × velocity (V.)	Surface velocity.
	Feet.	Seconds.	Feet per minute.	Cubic feet per minute.	Feet per minute.		Feet.	Seconds.	Feet per minute.	Cubic feet per minute.	Feet per minute.
a	22	13½	103	11,850	97	*j*	27	12	145	17,040	120
b	22	11¾	120	13,800	116	*k*	28	12¼	146	17,520	120
c	25	11¼	143	16,210	127	*l*	28	12¾	140	17,150	120
d	25	10½	154	17,960	127	*m*	29	13	143	16,440	113
e	27	11½	152	18,240	120	*n*	30	14½	131	14,080	104
f	26	11½	146	16,790	120	*o*	29	14¾	124	13,330	85
g	26	11½	146	16,940	127	*p*	22	14¼	111	11,930	78
h	26	11½	146	16,790	120	*q*	18	16	70	7,520	74
i	26	11¼	146	16,790	136	*r*	6	16	23	2,240	53
						Total discharge in cubic feet per minute . .				263,560	

Mr. Price, sen. The corrected velocity was found by deducting one second from the time of ascent (being time occupied in float assuming a uniform velocity), and deducting from $x\ y$ the distance passed through in one second at velocity of bottom stratum, *Fig. 1* (p. 95); a bottom velocity was assumed, if not quite correct, the error was inappreciable, or the bottom velocity could be measured. The surface velocity was less than the mean velocity on account of the draught of the sluices disturbing the regular flow. In order to compare this discharge with what the sluices were discharging at the same time, the following calculations had been made. The apertures through which the water passed at the sluices $= 2\ (29 \times 4) = 232$ square feet, one portion of this water might be taken as approaching the sluices with a velocity of 146 feet per minute, and flowing through rectangular apertures, having the bottom continuous with that of the reservoir above it, and each side with smooth curved channels leading up to the sluice; the border under such conditions was 37 feet in length, and to this a coefficient of 0·96 might be applied; the rest of the border being the top (29 feet) would be in the condition of water flowing through an orifice in a thin plate, to this he applied the coefficient of 0·62, therefore the average for the whole aperture was $\frac{37 \times 0 \cdot 96 + 29 \times 0 \cdot 62}{66}$ $= 0 \cdot 81$, $66 =$ whole border. Thus one portion of the water had a theoretical velocity

$V = 481 \cdot 8 \sqrt{H}$	= 1,523 feet per minute.
Velocity of approach	146
Total velocity	1,669

Which multiplied by section 232 square feet and divided by 2, being half the water with a coefficient 0·81, gave as discharge of water arriving in the line of sluices $\frac{232}{2} \times 1{,}669 \times 0 \cdot 81 = 156{,}819$ cubic feet per minute. The other portion of the water lost its velocity entirely by coming up against the two sluices that were shut, and then it had to pass round the sharp points of the cut-waters, so as to arrive at the sluices; therefore, the theoretical velocity should be multiplied by a coefficient of 0·62, thus:—

Discharge $= \frac{232}{2} \times 1{,}523 \times 0 \cdot 62 =$	109,534	cubic feet per minute,	
Adding formerly calculated discharge	156,819	,,	,,
Total	266,353		

Which very nearly agreed with the discharge calculated by the ascending-float method, namely 263,560. This agreement in the results proved that the ascending-float method was accurate, even in disturbed water, and would be probably more so in regularly-flowing water. It also proved that the coefficients were approximately correct. From the above considerations it was manifest that these coefficients varied according to each particular position of the sluices. As either one, two, three, or four might be partially or entirely open, an interesting series of experiments might be made to determine the discharges under all possible conditions. The above observations with the ascending-float were made by Mr. Samuel Armstrong, Clerk of the Works at Belleek, who now had charge of the opening and shutting of the sluices.

[CORRESPONDENCE.