

Mr. Preston, furnished with iron gates and gearing for enabling the supply to be regulated in the channel. Mr. Fitzmaurice had misunderstood the duty anticipated from the canal, which was never likely to reach the 3,000,000 acres mentioned by him. The canal had been designed to irrigate 1,100,000 annually, and had already done 2,000,000; but it was unlikely it would ever exceed 2,500,000 acres. Mr. Whiting's suggestion that every cultivator should use the water simultaneously was impracticable; it was correct for the distribution of the water from the Government distributaries to the village watercourses, and was the practice actually in vogue; but the distribution of the water to the fields from the village watercourses, which was done in the manner described in the Paper, could not be done as Mr. Whiting suggested, as the volume of water would be too small. Such a channel might discharge 2 cubic feet per second, and be kept running for 10 days for the use of one hundred cultivators; it would be quite useless to give every cultivator 0·02 cubic foot for the whole 10 days; it would never reach the fields, and the whole volume would be lost in meandering about innumerable field-channels. Instead of this, the cultivator was given a larger volume for a shorter period, which rushed quickly on to his holding in a single channel; and when he had had his turn the same volume was given to the next irrigator.

Correspondence.

Mr. Arnott. Mr. M. H. ARNOTT thought a brief description of irrigation in Orissa might be of interest. The irrigation system there was altogether settled and scarcely any considerable addition was possible. There were three Divisions which comprised the irrigation portion of the Public Works Circle, and he would describe the working of the division of which he had been in charge, that of the other two divisions being similar. The canals from which the distributaries took off were as a rule used for both navigation and irrigation. One of them, however, the Machgang, in the division described, was used purely for irrigation, the locks at the head of each reach except the first never having been constructed. The head-sluice of the system was served from the Mahanadi River, which was entirely rain-fed, so that the supply was dependent on the rainfall over the catchment-area. As rice constituted fifteen-sixteenths of the crops irrigated by the canals, the scanty discharge available in the cold- and hot-weather months offered no practical

difficulties, as when the demand for irrigation occurred in the rainy season there was always an ample supply available in the river. Irrigation commenced on the 15th June, and leaseholders were entitled to a supply until the 15th November. The only engineering work ever undertaken was the construction of village channels, known as "Minors." They were generally made on a petition presented by the inhabitants of one or more villages ("mouzas" in the vernacular), who complained that their area was not commanded by the canal or distributary, and said that if a minor were constructed they would all make a long lease. Sometimes they were so anxious for the construction of the channel that they offered, if Government would make it, to give the land on which it was to be built, free of cost; that was to say, Government would not be put to the expense of its acquisition. In all such cases it might be taken for granted that the undertaking would prove profitable to Government, as the villagers would be sure to bring their land under lease. Even where the land was not offered free, it would turn out profitable in nine cases out of ten, as the villagers would nearly always be sure to lease, although they might not see their way to relinquish the land free, generally on account of conflicting interests in the village or villages. After a petition was received, flying levels were taken, in order to see whether the area was commandable; if so, a longitudinal section and land plan were prepared by a subordinate and sent in to the Executive Engineer's office, for the preparation of the detailed estimate after the grading of the bed on the longitudinal section had been effected. The fall varied between 6 inches and 1 foot per mile, according to the level of the country; generally it was 6 inches per mile. In grading the bed the desideratum was to obtain a head of 6 inches over the highest fields, then irrigation all over the area was assured. This, however, was not always possible, as of course the bed might have to be lowered or raised, in order to equalize cutting and embankment. However, if 6 inches could be obtained it meant not only that the irrigation would be perfect, but that water would be conserved, as it would never be necessary to put that amount over the high fields for any length of time, if ever; as a rule 3 inches or 2 inches was sufficient. For the outlets the formula $v = 5\sqrt{h}$ was used, and as regards the masonry works, they were all arranged in types varying according to the head over them: *e.g.*, with a small head there would be no wing-walls, and country-made pipes would be used; with a large head there would be wing-walls, shutters, and pottery-burnt pipes. The channel was

Mr. Arnott.

designed by Bazin's formula, $v = C d \sqrt{\frac{R}{s}}$. The bed-width was supposed never to be less than 2 feet, height of bank above full-supply level 1 foot to $1\frac{1}{2}$ foot, in and out slopes 1 to 1, and width of crest 1 foot, 2 feet, etc., according to the size of the channel. All local drainages were taken across by siphons, consisting of 12-inch pipes with concrete above and below when the catchment-area was small, and ordinary brick siphons when the area was larger. In submitting projects a note had always to be made as to the financial results that might be expected. Although the land in the irrigable area was flat as a whole, when the fields of an individual village came to be considered, it was found that some of them were high, others low, others did not require water except at times of drought, and some were suited in every way for irrigation. Also that certain areas, with fields such as those described, were separated by well-defined drainage-depressions, or by high ridges, and such areas were known among the engineers working the Orissa canals as "Blocks." One block thus differed from another in that it could be irrigated only by its own system of outlets, and by no outlets of another block. When the system now in vogue on the Orissa canals had been started in 1892, the plan had been to divide all the area commanded by the canals in each division into these blocks. Having done this, the next thing was to see that each village in a block was given a lease for such a number of years that it lapsed concurrently with the rest of the area. The object of this was obvious; for if all the areas in a block lapsed together and did not renew, the outlets serving the block could be closed at once, and misuse of canal water be prevented. If villages near the distributary applied for leases in a block they might be accepted, as the outlets could be reduced in size to meet the reduced area; when the areas farther away from the distributary or minor applied for leases, the diaphragm could be removed from the outlets. Thus leases were never taken indiscriminately, as to do so would vitiate the whole principle on which the blocks were worked. All the outlets were worked at a duty of 80 at the outlet, or of 65 at the head sluice of the distributary or minor; and the area was supposed to receive a continuous supply for 15 days. The assessment was carried out entirely by the engineering staff, and the collection by a special Deputy Collector who was in charge of what was known as the Revenue Division, his immediate superior, as in the case of the Executive Engineers, being the Superintending Engineer. One of the Deputy Collector's subordinates, known as

the "Zilladar," was attached to each Revenue Sub-division, and it was his duty to assist in both assessment and collection. The method of assessment was the following. On an application for a lease being received by the Sub-Divisional Officer, he attached it to the authorized investigation form and sent it to the Sectional Officer for report as to the suitability of the area for a lease, etc.; after the latter's enquiry, he returned it to the Sub-Divisional Officer with the form filled up, and with a tracing of the map on the scale of 4 inches to the mile, showing on it the outlets from which the area would be irrigated, or, in the case of a new lease, their positions, the distributary, and the villages bounding the village referred to in the application. The form showed roughly the area of the fields that were to be assessed at a full rate, or at a reduced rate, or not at all, owing to their being so high as to be unirrigable, or so low as never to require water. This information was obtained by personal enquiry on the ground, with the help of the Settlement Survey maps 32 inches to the mile, and the Settlement "Khasrah," which, as stated in Mr. Preston's Paper, was a form having columns for the owner, occupancy, area, etc. Were these Khasrahs not in existence the work would be heavier than it was, as would be readily seen from what followed. On receiving the investigation form from the Sectional Officer, the Sub-Divisional Officer forwarded it to the Divisional Officer (who was the Executive Engineer) with the former's recommendation of the lease or otherwise; if recommended, he stated the number of years for which the lease should be sanctioned, the time depending on the considerations which regulated the block system noted above. After the Divisional Officer had returned the papers, duly sanctioning the lease, to the Sub-Divisional Officer, the latter forwarded them with the settlement Khasrah to the Zilladar for the preparation of the irrigation Khasrah. The numbers and areas of the fully irrigable fields were taken from the Settlement Khasrah by surveyors known as "Amins," and also those to be assessed at a reduced rate; the low-lying fields and high lands were excluded. When the Amin had finished his work, the Khasrah was returned by the Zilladar to the Sub-Divisional Officer for check, and after this had been done the Sub-Divisional Officer sent it back to the Zilladar approved, and with orders to prepare the Demand Statement or "Khationi," showing the number of fields belonging to each man and the total area to be assessed at a full or reduced rate, with the total amount payable by each lessee, and a column for his signature or thumb impression. It was at this point that delays took place, as the villagers often contended that some of

Mr. Arnott. their fields had been wrongly assessed, some being too high and others fit only for irrigation at a reduced rate; and before they would sign, their objections had to be removed. In case the Zilladar failed to do this, he returned the Khasrah to the Sub-Divisional Officer with an "objection list," and the latter had to make personal enquiries again with the help of his Sectional Officers. The full rate for a term of years was 1 rupee 12 annas (2s. 4d.) per acre, and the reduced rate for land only requiring water in seasons of drought was 8 annas (8d.) per acre. Should the differences between the Sub-Divisional Officer and the villagers not be reconciled, and the irrigation of the area be an undoubted fact, it was assessed at a season-lease rate of 3 rupees 12 annas (5s. 0d.) against the men who had signed what was known as a "Provisional Lease," binding themselves to be jointly and severally responsible for the water-rate. The reason for using a provisional lease was that the Uriya cultivator would never apply for water when his lease lapsed until he was absolutely compelled to through the rain holding off and his rice being on the point of withering, and then there was not time to complete the lease. To enable him, therefore, to get water quickly, and so save his crop, water was supplied if the villagers, or a portion of them, signed for 75 per cent. of the area applied for. It was very seldom that the assessment had to be effected on the provisional lease, as if a few recalcitrant men would not sign the Khationi, pressure was brought to bear upon them by their co-villagers, who did not relish having to pay 3 rupees 12 annas per acre instead of 1 rupee 8 annas. After all differences had been reconciled and the Khationi signed, the Zilladar returned it to the Sub-Divisional Officer, who prepared the Permit which was sent to the Divisional Officer for signature with the Khationi and the 32-inch map, showing on it the classification of the fields in different colours. After signing the Permit and Khationi, the Divisional Officer transmitted them to the Deputy Collector, whereupon the latter realized the water-rates due. Season-leases for 1 year were practically unknown, as the rate was so much higher, and villagers invariably applied for a long-term lease extending over a period of 7 to 10 years; of course leases were granted for shorter periods, in order to make them lapse simultaneously on the principle already mentioned. The granting of long-term leases saved a vast amount of trouble, as, once the lease was completed, complaints were as a rule comparatively few; and if careful classification in the first instance was insisted on, they were reduced to a minimum. In the case, however, of a new lease coming in, and the classification taking place in the dry

weather, when it was almost impossible to distinguish whether a field was irrigable, or high, or so low as to be assessed at a reduced rate, fields might be assessed at 1 rupee 12 annas: such mistakes were rectified during the next irrigation season. The system of long-term leases practically extinguished complaints of non-irrigation, for with the canal, distributaries and minors running full, a case of non-irrigation would show laxity of inspection on the part of the staff. The system of putting the assessment under the entire control of the engineers had been found to work very well. Before 1892 the engineers had simply turned on the tap, so to speak, the assessment having been done by a Revenue Superintendent under the Collector of the district; and the friction between the Engineers and Superintendent had been serious. Complaints of over-assessment from the villagers had also been numerous, as the land had been assessed yearly on the areas irrigated, which, as could easily be realized, would lead to harassment of the villagers by the subordinates employed. Also this led to the chance of areas irrigated being let off for a consideration, so that altogether the villagers had not known what their position was; and when nothing was settled in a system of irrigation it was fatal to its advancement and popularity. He entirely agreed with Mr. Preston's remarks that it was more advantageous to have the assessment under the control of the engineers.

With reference to the granting of leases referred to on p. 158, it appeared that a great deal of labour was yearly employed in the assessment of the area irrigated; for if, for instance, a part of a field only was irrigated, it had to be measured, and this might occur twice in a year, if two crops were sown on the same field. There might be some reason for this laborious process, but otherwise, in starting a system of irrigation on Government land which was absolutely dependent on water for the production of crops, and which had formerly been a desert, it surely would have been possible to introduce an irrigation-tax on the whole irrigable area of each settler's holding, which he would have to pay whether he irrigated the whole of his holding or not in any year. The crop-producing power of the land on the whole irrigable area of the scheme must originally be the same, so that each settler would start fairly in that respect, and his improvement of the land would depend on his own individual effort and his skill as a cultivator. The introduction of such a tax would practically eliminate four out of the five of grounds of complaint enumerated on p. 158. The fifth was always liable to occur through wrong information being given

Mr. Arnott, to the recording officer, frequently wilfully, for purposes of avoiding assessment.

Mr. Joyner. Mr. R. B. JOYNER remarked that the works described in Mr. Benson's interesting Paper were of a peculiar nature, and appeared to be more for the purposes of reclamation than for irrigation; but the circumstances were complicated, and it was not easy to follow the exact objects aimed at throughout, owing partly to the smallness of the plan and the lack of levels. The Author appeared to have devoted much care, thought and attention, to the design and work. It was evident that a weir for reclaiming land from the sea could not irrigate the land it reclaimed, nor in fact any other, unless the water was lifted. The principles aimed at seemed to be, to keep the salt water from overflowing and soaking into the lower lands, substituting fresh silt-laden water, and so warping up the low lands and keeping a more uniform level of fresh water within easy reach of the cultivable land-surface. He would like to know if this was so? Taking 60 square miles of land as practically gained from the sea, the total cost of all the works came to only 7s. 4d. per acre, which was remarkably low. In addition, there was fresh water available for lift-irrigation all the year, except in the monsoon when presumably it was not much wanted. It was possible that the depression of the Rann, or the raising of the shore, had been caused by the notable earthquake in 1819, which was said to have been responsible for the larger portion of the great Rann of Cutch. The Author stated that the water-way of the weir provided for only an insignificant part of the flood-discharge; and some explanation was needed as to where the flood went. It was not easy to make out from the illustrations the precise action of the weir-shutters. Presumably they were and could be fixed up only when the river was practically empty, the minimum discharge being perhaps run through the lock-gates; but if this was so there would appear to be occasionally some risk of not catching the right time for fixing them. If the guides were fixed in the hot weather, could the shutters be fixed when the river-floods had started? It would seem likely that the shutters would leak considerably, and, if so, it would be interesting to know the extent of the leakage. A form of weir-shutter which was cheap, easily opened and shut by ordinary labour, and effective in point of water-tightness, was a desideratum. It was possible that the Author would find it necessary to run a curtain-wall across the river-bed in the lower parts on the down-stream side, parallel to the weir, in order to protect it from scour. Judging from these works and from the collecting-tanks constructed or proposed, it was evident that the Native

States concerned were keenly alive to the value of irrigation and Mr. Joyner. land-improvement, and so set a good example to the Chief Government, which frequently found difficulty in providing funds for works, even when they would be of great and undoubted benefit. A general statement of the total expenditure and the total results of such works as that described in Mr. Benson's Paper should always be kept up and be available for reference. The most carefully-prepared designs and the most thoughtfully executed works were of no real value to the engineer unless they showed good financial results.

Mr. Preston's Paper was highly interesting and instructive at a time when the important subject of irrigation was again attracting attention, not only in India, but in South Africa, where some Indian engineers were being appointed to advise the Government as to suitable irrigation projects for those colonies. The Author was to be congratulated upon the lucid and able manner in which he had described this most satisfactory outcome of over 30 years' experience of Indian irrigation engineers. Irrigation was not at all the simple operation which those who had not experienced its numerous great difficulties would think, especially in hot dry climates with variable supplies of water, and that water heavily charged with silt. The Chenab Canal was an excellent example, showing what could be done by the engineer in actually adding to the British possessions nearly 5,000 square miles of fertile territory, capable of producing, independently of rainfall, crops sufficient to maintain several million people; or which, if grown with wheat, would supply three-fourths of the total imports of that grain into the United Kingdom. The project was also a striking example of the value of systematic administration by officers of scientific training. The Author need not have apologized in any way for showing the value of the engineer outside, perhaps, his own particular line. It had been said that the future of the world was the engineer's—meaning that the complicated problems of advanced civilization and the inventions on which the world's progress would now so much more depend, must be dealt with by those possessing scientific training, instead of being, as hitherto, left more or less in the hands of those whose youth had been almost entirely wasted in learning languages dead 2,000 years ago. The magnitude of the work could scarcely be properly appreciated from the Author's modest description. Some idea of it might be formed by imagining a large river, over 280 feet wide and nearly 11 feet deep—exactly reversing nature, running at over $2\frac{1}{2}$ miles per hour backwards, as it were, from its mouth up all its branches and up all the little brooks and ditches till the water was

Mr. Joyner. finally run over every square foot of an area as large as the entire counties of Kent, Surrey and Sussex and most of Hampshire, every drop of water under full control, and every acre marked and numbered like the pages of a book! Yet this was only one of the many large irrigation projects so successfully carried out by English engineers in India, and almost entirely unknown to the general public. Coming to details, it would have been interesting if the nature of the soil had been described. Presumably it was the light-coloured silty soil deposited by the river in the course of ages; but if so, it was probably very sandy in parts. In that case, how was the great absorption prevented and how were the canals and distributaries kept from being choked by drift sand? In Sind, lower down, sand often caused much trouble, and the results of experience in avoiding this would have been welcome. The average rainfall for the past 11 years was said to be 11·81 inches, but during that time the land had been gradually brought under cultivation. It was to be hoped that records existed of the area for previous years, as the effect of the irrigation of large tracts of desert on the rainfall should be watched, and such opportunities as the Chenab scheme did not often present themselves. It was most probable that the rainfall over the Rechna Doab would be more than doubled, as the cool, moist, south-west monsoon winds passing over the great Rajputana desert became heated, expanded, and were enabled to retain their moisture, but when they met lands cooled by irrigation the moisture would condense and fall. Should the rainfall be increased, the people would become less dependent upon irrigation, and the duty per cubic foot per second would increase; this would point to the advisability of Government protecting itself by a land-rent, as well as a water-tax. It is not clear that this was arranged. Nothing was said in the Paper about regulators, either at the intake at the weir, or at the heads of the branches and distributaries; yet the Author wrote as if every drop was under control and the banks were only 1 foot to 3 feet above full-supply level, which seems a perilously small margin, considering how cattle going to drink, traffic, windstorms and thunderstorms quickly wore banks down. There must be regulators, and some description of them would have added much to the value of the Paper. In rivers heavily charged with silt, the successful working of regulators was a matter of great difficulty, as directly they were partly or wholly closed, silt was at once deposited, owing to the lessening of the velocity. Under some head of water silt frequently became too consolidated to be carried off by merely opening the gates. The question of silt was one of the great difficulties in designing and

working an irrigation system from rivers which played about Mr. Joyner. alluvial plains. In the lower parts of the Indus, into which the Chenab ran, in strong currents in the flood season $\frac{1}{10}$ part by weight of the water—and often more—was found to be silt; half of this was pure sand, which, being heavy, required a strong current to carry it, and was, of course, useless for fertilizing. The great object was to have such a current as would carry the fertilizing silt and not the sand; but then the latter accumulated, most probably at the head regulator, and arrangements were required there for carrying it off successfully. Details as to how this was arranged for—if the silt contained sand—would be of value. Another difficulty, which was not mentioned in the Paper, was to maintain everywhere the velocity which at all seasons would carry this silt and yet not scour the bed and banks. He had found in Sind that slightly less than 3 feet per second would be right; but a large canal designed to meet the heavy demand for water in the “khariph” season running full, would at other times be only half full, and consequently there would be a much decreased velocity, leading to accumulation of silt. This was sometimes very serious, and was not only expensive to remove but hindered the flow of water, to the great detriment of the crops. The Author mentioned that silt has to be removed at different seasons of the year. If there was plenty of water all the year round, the difficulty could be overcome—as he had proposed in Sind for a project very similar to but still larger than the Chenab—by running the canals and distributaries full the whole year and designing drainage-channels in the lowest levels, gradually increasing in size as the canals decreased, down which the surplus water escaped when not wanted for irrigation. By this means constant velocity was maintained, and a full head for command of all lands was given; while a fairly even head was maintained for the measurement modules. To show the cost of silt-clearance, in one engineer's district in Sind about 72 million cubic feet of silt had to be cleared every year from the ancient tortuous inundation canals; which was equal to the labour of digging annually a canal 350 miles long, 15 feet wide at the top and 5 feet deep. The Author did not mention any difficulty about the stability of the river at the canal-head; perhaps it was secure. The sudden shifting of the river-channel was often a great difficulty in irrigation systems in soft alluvial plains. He had known the Indus suddenly shift its position 6 to 8 miles in a year, leaving, of course, its canal-heads behind; and what was more astonishing, he had steamed in a launch over 20 to 30 feet of water and 2 years later had ridden over

Mr. Joyner. the very same spot with the tamarisk bushes as high as his head ! It was curious to find that the discharges of the canals increased with use ; unfortunately his experience had mainly been the reverse, namely, that newly-made canals discharged more than they ever did afterwards, on account of growth of weeds, washing of banks from storms, etc., as well as uneven wear due to differences of material and silt-deposits. It looked as if the Chenab canals had really scoured their sides and beds. The question of "Reh" (efflorescence of salt) was an important one, not directly alluded to in the Paper ; but it was seen that the risk of this destructive efflorescence was appreciated, by the care taken to avoid excessive irrigation where subsoil springs were high. If the Chenab scheme was to be a guide for the construction of other projects, it would have been well to lay stress on the great loss which too often occurred from over-irrigation in low districts from "Reh." But the important question of over-irrigation led to the troublesome question—troublesome in India, at least—of rates and manner of irrigating and delivering water. The system now generally adopted was a crop-and-season rate per acre, as in the Chenab project ; but for many reasons it was unsatisfactory, even with such careful marking out of plots as had been done in that case. It led to fraud and speculation by the petty officials in combination with the cultivators, and to much expense in measuring and checking. It was a complicated system, as different crops required such different quantities of water, and the water as a rule differed so much in value, according to the time of year. It would be much better and simpler in all ways to sell the water by measurement. Those who had been used to lifting water by the "mot," or the "Persian wheel," or by hand, were very keen in their knowledge of quantities of running water and its value, and others soon become so. Modules might be fixed under lock and key to deliver under all circumstances certain fixed amounts of water, according to agreement, for a certain season : which would lead to great economy of water and would obviate all risk of "reh," the great cost of measuring crop areas, the irritating speculation, and the difficulty of checking the same. It would no doubt be said that a module for delivering, under all conditions of varying head and silt, a certain fixed quantity of water, had never yet been designed ; but it could not be an impossible task, and he alluded to it in the hope of drawing attention to an urgent want. Again, nothing was mentioned about manure. This might not directly be an engineering question, yet it vitally affected the financial position of many irrigation works. It might be that in the Chenab

a sufficiency of silt was got on to the surface of the fields; or the Mr. Joyner. settlers might be using virgin soil, and so did not suffer from the want of artificial fertilization. But Indian cultivators always insisted that irrigation necessitated the use of manure much more than did rainfall. The question of "fallows" was an engineering one, as allowance had to be made in estimating quantities of water for certain areas; this was not mentioned either, possibly for the same reasons. Notwithstanding the high percentage of return shown on the outlay of the splendid work described in Mr. Preston's Paper, it should be noted that the Government had obtained fertile land under command of perennial water at a cost of under 13s. per acre; and the return included apparently no rent for the land nor any sums for its occupancy. The work reflected the highest credit on all concerned in its conception and completion, and they deserved the fullest praise from the engineering profession.

Mr. G. H. LIST remarked that Mr. Preston's excellent Paper Mr. List. should go a long way towards correcting the prevailing ignorance of the work of the Indian Irrigation Department, and to disclose the magnitude of the work done, the importance of its effect on the body politic of India, and last, but not least, the quiet, untiring, self-sacrificing work of the Engineers of this famous Department. Some time ago an interesting series of articles had appeared in the London Press on Irrigation in Egypt and its progress to date. He had been sorry to see no mention in them of the Indian Engineers who had brought Egyptian Irrigation to its present high position. To the Indian Irrigation Department belonged the entire credit; and that department might well be proud of the members of their body who had repeated in Egypt what had been done in India. With regard to the railway mentioned in the Paper, it was now clearly seen that a railway should go hand in hand with a new canal such as the Chenab, in what was practically a desert. The line mentioned should have been made 3 years before it actually was constructed, and in the Jech Doab Canal scheme, now in hand, this mistake had not been repeated. Not only was the railway useful in getting labour, material, and supplies through, during construction of the canal; it was badly needed the moment irrigation began to bring in settlers and take away the produce raised. The line referred to in the Paper had been sanctioned only after repeated application and much opposition. It had had to be made as cheaply as possible, and not to cost more than Rs.30,000 (£2,000) per mile. The formation had been constructed by the canal engineers, because they had had full control of labour and material, and it had been judged

Mr. List. inexpedient to have two agencies at work. Girders and permanent way were of second-hand material, from renewals on the main line. The only bridges were those over canals and distributaries; all other water-ways were "Irish bridges" or "dips" heavily laid with rip-rap. The length constructed was only about 90 miles, as the first 8 miles had been built some years earlier for taking material to the great Khanki weir. The line had been completed and opened for traffic in 12 months' time, and it had very soon been found that a serious mistake had been made in using second-hand permanent way. The line had simply been unable to carry the traffic offered to it, and it had been impossible to use powerful engines, or higher speeds than 15 miles per hour. Renewals in steel had had to be put in hand at once, much more siding-accommodation to be given, and extra stations to be opened for crossing trains. The extension to Multan had been built more substantially and laid with steel rails; and this line, which, when first sanctioned, had been intended to be worked almost as a steam-tram line, at a speed of 12 miles per hour, was now carrying a heavier traffic than many expensively-built trunk lines costing three times as much. This mistake was not being repeated in the line now under construction alongside the Jhelum Canal. One of the most pleasant of his experiences in India had been his association with the Author and other irrigation officers, in connection with the construction of this line, the original branch to the Khanki weir, and the supply of rip-rap from the railway quarries; more especially with Mr. Preston in settling the alignment and sending in the preliminary estimates for the Jhelum Canal line. He had thus been able to see and understand the immensity of the labour involved in maturing such an irrigation scheme as the Paper described, getting "behind the veil," as it were, in a manner that few outside the Irrigation Department ever did. He could have wished his career only beginning, and to be a canal engineer. There were still some grand projects to be developed. He knew them well from a railway point of view, and how depressing the districts were to travel through in the hot weather. Between Lahore and Multan stretched a tract 100 miles by 50 miles, still waiting for water from a weir across the Sutlej, near Ferozepur; and the great Sind-Sagar Desert, between the Indus and the Jhelum, a tract nearly 200 miles by 80 miles, awaited water from the big weir projected across the Indus at Kalabagh, where it debouched from the hills. With control of the sea, and possession of these grand wheat-lands of the Punjab, there need be no fear of failure of food-

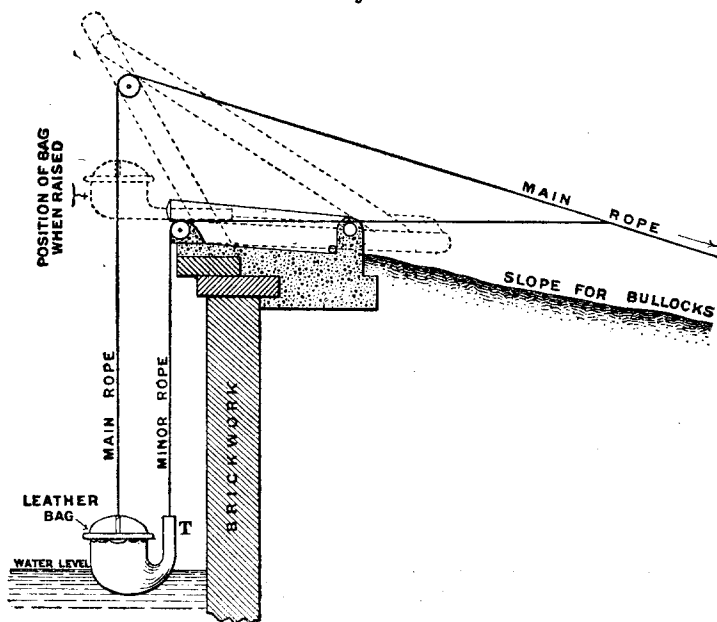
supply in England in time of war. Truly, the Irrigation Department of India was an Imperial Department in more senses than one.

Mr. PLAYFORD REYNOLDS remarked that, having been ordered by Mr. Reynolds, Government, about the year 1895, while Superintending Engineer of the Northern Division, Bombay, to report on the project devised by Mr. Benson—which he had been able to do favourably—he was in a position to offer some remarks on that gentleman's interesting description of the works. On the occasion of his visit the Gosa Bara bund or dam had been completed, and tidal waters had then been excluded from the Mokul Rann, a “Rann” being a low-lying plain, often a marsh, liable to submersion by the tides. He had found it an easy matter to free soil from the salts that rendered it unfertile, provided it could be washed freely and copiously by flood-waters, and drained. In the latter eighties he had carried out a large drainage-project in the Kadi Division of the Dominions of His Highness the Gaekwar of Baroda, when Chief Engineer of that State. The situation had been the following:—Many square miles of country had been totally unprovided with drainage, either artificial or by rivers or watercourses, with the consequence that during each monsoon the rain-water had collected in “bols” or depressions, some of them miles long, which had seldom overflowed, and then only into each other over flat saddles; the result had been that the natural salts which were abundant in the soil of the uplands had been carried in solution into the bols, where they had remained on and in the beds when the water had evaporated or had been absorbed into the ground. After generations, the soil in and around the bols had become barren, and increasingly so in area and degree with the lapse of time; and the cultivated area had decreased annually, to the loss of the cultivator as well as of His Highness's Government. By connecting the bols with drains, at the heads of which were waste-weirs and regulating-sluices, the monsoon flood-waters, when more or less saturated with salt, were run off and the salt thus removed. The crests of the waste-weirs and the sills of the sluices were designed so as to allow of retaining in the reservoirs, after the first floods, water sufficient to supply the domestic and other wants of the neighbouring villages. The purification of the soil by this process had been so rapid that, during the first cold weather, or annual dry season, succeeding the completion of the works, immense areas of splendid wheat and other grain crops had been grown on land where, within the memory of man, nothing had grown before.

Mr. Reynolds. The areas so treated were far from the sea, so that the land had only gradually been contaminated and rendered barren; the case was different in the Mokul Rann, where the purification would be much slower owing to the frequent periodical submersion of the land by sea-water. Mr. Benson's project provided for the flooding of the whole 60 square miles of the Rann by the silt-laden floods of a drainage-area of 4,000 square miles, the effect of which by 1902 had been a rise of 2 feet in the level of a large area. An immense quantity of salt must, owing to its affinity for water, have been washed into the sea at the same time, over the Gosa Bara bund and through the main drain. It was to be noted that, by this project, water was stored only between the banks of the River Bhadar, as well as in the Sanbu and Ojat channels; the banks of the first were 600 feet apart at the weir, and 300 feet apart 7 miles higher up—for which length the river-bed was practically level—while the creek extended $5\frac{1}{2}$ miles farther, so that the reservoir would not, as was usual, in what the Author, in common with many engineers in Bombay, called “tanks,” spread over a wide extent of land, and irrigation would therefore be, to a large extent, if not altogether, by lift. This was a very favourable feature of the scheme, conducing to economy in the use of water for crops; because owing to the labour of lifting, the cultivator would not raise more water than was necessary. It was evident that on the right bank, at least, of the Bhadar, its character was deltaic; that was, the bank was highest near the river and descended towards the Rann: irrigation would therefore be by natural flow from the lifts westward. The water would probably be raised by Persian wheels, which were not uncommon on this coast eastward of Patan in the Gaekwar's territory, or by the “Mot,” of which appliance *Fig. 2* was a sketch in section. Every part of the Mot could be made or repaired in every village, and it was applicable to a river-bank or to a well; the leather bag in its best form had a trunk, T, open at the upper end. The water raised was automatically discharged through the trunk on to a concrete platform, and flowed, through holes in the side walls of the platform, to the irrigation channels. Bullocks attached to the main rope supplied the power; they descended and ascended the slope shown in the sketch. With regard to the effect of the weir on the bed of the Bhadar River, it would be interesting to know whether it was being silted up. The Author stated that it was found difficult to keep the Sanbu channel open; so that he was already having experience of silting difficulties. In western Khandesh, where there were numerous weirs of varying heights up to 27 feet, the river-beds invariably silted up to the

weir-crest: inasmuch, however, as these weirs were not for storage, Mr. Reynolds but for raising the water-level in the rivers sufficiently for the water to flow down the canals, this silting was not a serious drawback. In the Bhadar, however, it would be otherwise. If and when its channel silted up, irrigation would no longer be possible to the same extent; in the meantime, however, the Rann soil would doubtless be fertilized throughout, much irrigation would be feasible from one or more of the "tanks," the sites of which were indicated in Fig. 1, Plate 3, and the rest of the Rann would, in

Fig. 2.



years of good or fair rainfall, produce monsoon and cold weather crops, just as the rest of the surrounding country did. With regard to the streams other than the Bhadar, it was of interest to speculate what would become of them when the Mokul Rann was silted up; some would doubtless find their way or be trained to the Gosa Bara bund, others to the Bhadar. Another item of interesting speculation was the probable effect of irrigation and flooding on the subsoil water-level. At the site of the weir the river-bed was a tenacious clay with hard impervious limestone

Mr. Reynolds, rock below, at no great depth. Similar conditions probably existed over the whole area of the Mokul Rann. The Author would no doubt be able to give the Institution his views on these points. The damage by floods to the stone filling mentioned, under the head of "working of the weir," as having occurred below the weir "to a depth of about 15 feet below the level of the sill," apparently extended to the lower side of the sill. The usual artifice was to make a water-cushion on the lower side of the weir; probably the Author had good reason for not adopting this precaution or remedy. As the estimated cost of the works—the actual cost was not given—was Rs.313,500, and, taking as the proportion of plant finally chargeable to works at half the original cost, *i.e.*, Rs.155,500, the total capital charge might be put at Rs.469,000. There were 42,000 acres irrigable, which, at the very moderate charge of 1 rupee per acre, would return 9 per cent. gross.

Mr. White. Mr. C. A. WHITE thought it would be instructive to learn in future years whether the obstruction to the tidal flow of the Bhadar River caused trouble from silting, and also to see how the iron, steel and teak withstood the corrosive action of salt water, and the attack of mollusca, etc. On the Bengal coast, cast iron was found to last better than steel or wrought iron, and teak was very soon destroyed by the attacks of different kinds of mollusca, unless sheathed with copper or other sheeting. Considering that, since 1898, a large portion of the 60 square miles of the Rann had been raised 2 feet by silt-deposits, it must be only a question of time for the whole of the Rann to be silted up, which would cut off the spill-area for the floods: would not this cause a serious raising of the flood-level at the weir; as 9,215 square feet of water-way could hardly dispose of a serious flood off a watershed of 4,000 square miles, liable in parts to a rainfall of 23 inches in 11 hours? Could Mr. Benson give an approximate estimate of the discharge of the highest recorded flood? Besides the proposed 50 lakhs of rupees for storage-reservoirs, would not a considerable sum be required for works for distributing the water over the Rann, and was there any probability of the revenue covering maintenance-charges and interest on the capital; or were the works only intended for protection from famine?

He desired to ask Mr. Preston for information on the following points:—The approximate proportion of the monsoon irrigation (rice) to the cold- and hot-weather irrigation (wheat, etc.); whether much silt was brought down by the waters of the melting snow; and whether there was any reason why the Bengal

system of 5-year to 10-year leases of fixed blocks, 50 acres to Mr. White. 2,000 acres or more, should not be adopted, instead of the tedious method of noting and measuring annually the acres irrigated, field by field (about 1 acre each), which must require a very large subordinate staff.

Mr. G. B. WILLIAMS observed that Mr. Preston's Paper was so Mr. Williams. largely concerned with the administrative side of the Indian irrigation question, that he ventured to ask the Author to supplement it with some information about the Indian laws affecting the abstraction of water for this and other purposes. If the whole of the irrigation of India were in the hands of the Government, the legal question would be much simplified; but a large portion of the country was irrigated by private works; so that the question of riparian rights and prescriptive powers to abstract water must presumably be taken into consideration when constructing any work of the kind described in the Paper. On the importance of the legal aspect of the question Sir William Willcocks laid stress in his report on irrigation in South Africa, in 1901, wherein he recommended that, as a preliminary to any large scheme, the whole of the rivers and torrents throughout the Colony should be proclaimed as public domain. He cited the precedent of Italy, where a similar step had been taken on the consolidation of the country under Victor Emmanuel. The effect of imperfect legislation had been apparent in the United States, where the development of irrigation had been much hindered by the indefinite and contradictory laws in the various States. Riparian rights were not recognized throughout most of the Western States. In some places every owner of irrigable land appeared to have the right to obtain water from any convenient stream or river; while in other States, until recently, there appeared to have been no enactments at all on the subject. The origin of most of the European irrigation laws could be traced to Roman law, which regarded running water as being in the same category as air, a necessity of human life, which all might use but none could possess. A distinction was made, however, between the water itself and the rivers in which it ran, which were public property if navigable or capable of being made so, and usually private property in other cases. The right of conducting water through lands of another was recognized, and could be obtained by prescription, agreement or expropriation. French law considered rivers as public domain, and unnavigable watercourses were put into a class of things which belonged to no one. In Italy the rivers and streams were public domain, but springs were the

Mr. Williams. property of the owner on whose land they rose. Under the old Spanish law, running waters were in some cases held by municipalities as a common property for domestic use, irrigation and other purposes. Many other examples might be given of the diversity of the laws in different countries which limited the use of water for irrigation purposes. He hoped Mr. Preston would be able to give some information as to the principles which had governed legislation in the country which contained the most successful modern examples of irrigation engineering.

Mr. Benson. Mr. BENSON, replying to Mr. Joyner's remarks, gave the following levels: lock-sill, 77·00; low tide, 78·00; weir-sill, 80·00; mean Rann level, 85·50; high tide, 86·50; full-supply level, 88·00 (which could be raised to the lock-coping and beam level, 91·00 when the Rann had been warped up); cultivated land near weir, 88·00; ditto 8 miles up river, 96·00; highest flood, 96·50. Land formerly cultivated was irrigated by lift. Much of the Rann was now under command. Eight villages had no fresh water in the subsoil, and depended on the Bhadar for their supply. The principles aimed at were correctly stated by Mr. Joyner; also the cost (7s. 4d.) per acre reclaimed. Similar land 20 miles south of the weir fetched Rs.11 (14s. 8d.) per acre per annum. The mouths of the river were rocky and narrow, therefore the high floods spread over the Rann, and fell into the sea at Porbandar, Gosa Bara, and Navibandar. With regard to the time at which the shutters were moved, the river was observed 80 miles up-stream and telegraphic intimation was given of a flood rising; the flood reached the weir in 18 hours. The shutters were in the meantime removed. This was generally done early in June. The weir was left open during the rains till the 1st of October, and closed then if there was no flood. The shutters were put in at a neap tide. If the flow in the river was too small to fill up the bed as quickly as the tide rose, and some sea-water was admitted into the river, the water was run out during the next low tide, and in a day or two the river was sweet. The slight leakage in the shutters was stopped by caulking. At the time of the paving referred to in the Paper the shutters had been watertight. Silting up of the river above the weir was not possible, as the river was not interfered with during the monsoon, the only time when it could be scoured. The effect of the works was to prevent the removal of the silt deposited on the Rann during the monsoon. It was not claimed that they caused the deposition of silt in the Rann. The rivers flowing into the Rann would cut channels as the Rann silted up. The lake-like bed north of Kesod (Fig. 2, Plate 3) had silted, and the river now joined the Hugli. Training these would

be out of the question, as wave-action would be severe on any banks. Mr. Benson. The subsoil-water was salt, and the drains must be lengthened as cultivation extended. The cost of the works given in Table IV. was actual, including plant: Mr. Reynolds had not quoted the figures given in the Paper. The mouth of the river would possibly be choked annually; but the trade had almost left this port since the construction of the railway to Porbandar 18 miles to the north. It would be beneficial if the mouth were closed annually before the monsoon, because the first floods, silt-laden, would be impounded (as in 1900) to a good depth over the Rann, and would deposit all the silt before bursting the sand barrier on the coast. The highest recorded flood (31 July, 1900) had risen from 89·50 to 95·00 (5·5 feet) at the weir in 10 hours—8 A.M. to 6 P.M.—when the sand barrier had burst. It had continued to rise for 12 hours, up to the level 96·50. The area within the 92·25 contour-line was at least 80 square miles. Therefore the river-discharge had amounted to 350,000 cubic feet per second for the 10 hours. This included the discharge at Porbandar (the only outlet) of 10,000 cubic feet per second. The mouth of the Bhadar viewed during this flood from Navibandar Fort, which rose from the rocky shore line, was a remarkable sight. The shelving limestone was nearly level for 2 miles along the shore, its crest being midway between low-tide and high-flood levels. Over it the water fell 18½ feet in an unbroken line, from a comparatively smooth lake on one side into the rough sea on the other.

Mr. PRESTON, in reply, remarked that no doubt leases, as suggested by Mr. Arnott, would be possible, but they had never been popular with the cultivators in the Punjab; moreover, irrigation was intimately connected with the land-revenue assessment of the country, and the policy of the revenue-officers of recent years had been to replace fixed win-or-lose assessments by fluctuating assessments on the crops actually matured, which, in his opinion, was a wise policy, as a fixed assessment must be low, in order to allow for bad years or indifferent yield. In reply to Mr. Joyner, the soil of the Rechna Doab was the ordinary light alluvial soil of the Punjab, but there were no sand-hills as in Sind or in the Sind-Sagar tract in the Punjab, and consequently the distributaries did not get choked with drift sand. Very careful records had been kept from the commencement of the construction of the canal, both of the rainfall and of the depth of the subsoil spring-level, and the gradual rise of the latter was watched carefully. In addition to the water-rates there was a land tax which amounted to about 1 rupee 4 annas, say 1s. 8d., per acre. In

Mr. Preston, connection with the weir across the Chenab River, there was an extensive system of training-spurs and banks, and there was therefore no anxiety as to the stability of the river. There were some "Reh" tracts in the Rechna Doab, but they were not very extensive, and it had been found that the soil of many of them had been much improved by growing rice for 6 or 7 years consecutively, after which it had been found possible to grow cold-weather cereals. In regard to the sale of water by volume, there was little doubt that it would be an ideal system; but there were extreme difficulties in the way. Measurement of the volume used by each cultivator would be necessary, entailing an enormous number of modules, which must be so designed that they could not be tampered with; and so far he had heard of none at a moderate price. The information given above replied also to the enquiry by Mr. White; but it might be added that leases to blocks of 50 acres to 2,000 acres might be suitable where there was a Zemindari proprietary, but would be impossible on the Chenab Canal where the land had been given out almost entirely in peasant holdings of under 28 acres. The following was the information asked for by Mr. White in regard to the proportion of crops grown for the year 1901-1902:—

		Acres.
Hot-weather crops . .	{ Sugar-cane . .	60,871
	{ Rice	35,937
	{ Cotton . . .	169,394
	{ Indigo . . .	111,308
	{ Millets . . .	106,732
	{ Miscellaneous .	181,866
		<hr/> 666,108
Cold-weather crops . .	{ Wheat . . .	796,332
	{ Barley . . .	22,408
	{ Rape seed . .	131,076
	{ Gram	13,375
	{ Miscellaneous .	118,830
		<hr/> 1,082,021
		<hr/> 1,748,129 Acres.

In reply to Mr. Williams, the waters of all Indian rivers were the property of the State, and a royalty was charged to any individual who was permitted to take a private canal out of a river. Mr. Williams was incorrect in saying that a large portion of India was irrigated by private works, unless in "works" were included the innumerable wells in the country; there were some private canals, but they were not of large extent, the vast bulk of the irrigation canals belonging to Government. A special Act called the Northern India Canal and Drainage Act

had been passed in 1873 (VIII. of 1873) which was applicable to Mr. Preston. the Punjab, United Provinces, and North West Frontier Province, and, under Section 5 of that Act, when the Government desired to construct a canal it issued a notification saying that from a date to be fixed the water of the river specified would be used in a projected canal.

17 March, 1903.

JOHN CLARKE HAWKSHAW, M.A., President,
in the Chair.

The discussion on the Papers by Messrs. Benson and Preston on "The Irrigation Weir across the Bhadar River, Kathiawar," and "Recent Irrigation in the Punjab," respectively, occupied the evening.
