Absorption loss in Distributaries.

This may be taken as 10 per cent. of their head discharge = $\frac{1}{01} \times 2{,}257{,}513 = 225{,}751$ cusec days.

Spread over the whole area of 3,385,000 acres this is equivalent to 0·132 foot depth.

Absorption loss on Watercourses.

Kennedy found on the Upper Bari Doab Canal that the loss in watercourses was 0·034 foot depth per hour. This he applied to an average watercourse on that canal and found that the loss amounted to 22 per cent. of the canal head discharge, but the watercourses on that canal carried very small discharges, an average of only 0·5 cusec, as compared with nearly 2·0 cusecs on more modern canals.

Taking the same figure for the rate of absorption and applying it to a modern watercourse of 2·0 cusecs discharge the average length in flow may be taken as 10,000 feet, and the width of surface as 5 feet whence the loss is

$$10{,}000 \times 5 \times 0{\cdot}034 = 1{,}700 \text{ cubic feet per hour.}$$
$$= 0{\cdot}47 \text{ cusec, or say } 0{\cdot}5 \text{ cusec,}$$

which is 25 per cent. of the watercourse head discharge.

The volume entering the watercourse is 2,257,513 – 225,751 = 2,031,762 cusec days, so that the absorption loss, 25 per cent. of this, will be 507,940 cusec days, which is equivalent to a depth of 0·299 foot, or say 0·3 foot over the whole area.

The balance, 1,523,220 cusec days, is spread over the fields, and is equivalent to 0·894 foot depth over the whole area.

APPENDIX II.

Irrigation per cusec of discharge on the Lower Chenab Canal.

Year.	Kharif.	Rabi.	Annual total.
	Acres.	Acres.	Acres.
1909-10 ...	82	189	271
1910-11 ...	73	190	263
1911-12 ...	78	199	277
1912-13 ...	77	237	314
1913-14 ...	73	236	309
1914-15 ...	74	190	254
1915-16 ...	73	230	303
1916-17 ...	79	230	309
1917-18 ...	95	197	292
1918-19 ...	84	211	295
Total ...	...	...	2,897
Average ...	...	...	289·7, say 290

That is to say that on the average of the past ten years each cusec of water entering the canal head has irrigated 290 acres of crops.

From Appendix I it is seen that only 75 per cent. of the water which enters the canal head reaches the outlets, so that the average duty at outlet will be $\frac{100}{75} \times 290 = 390$ acres per cusec nearly.

PLATE II

LOWER CHENAB CANAL

CROSS LINE No II

SCALES {

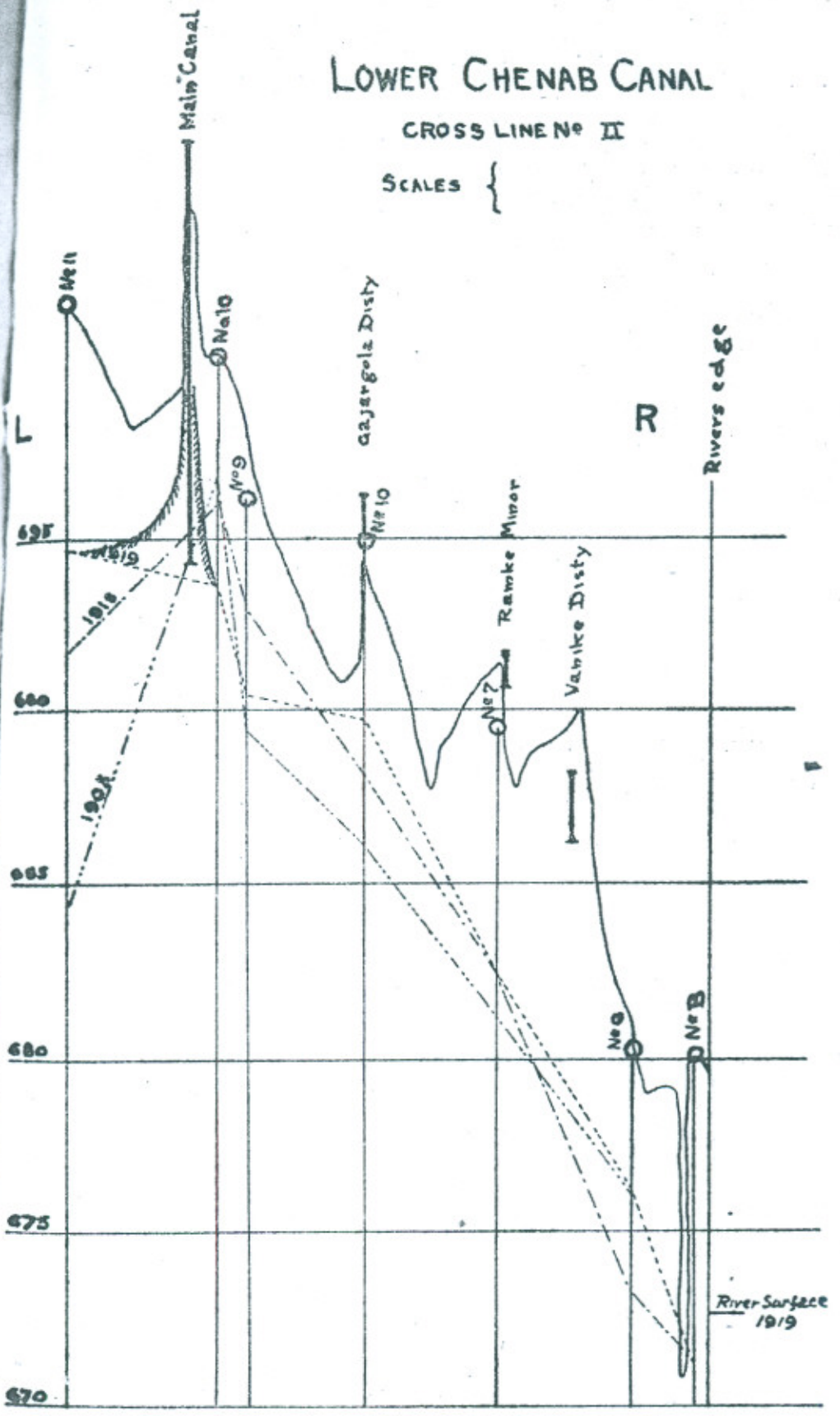


Fig. 10

L.B.D.C. Section 6

Scales { Hor. 4 miles = 1 inch
Vert. 1/200

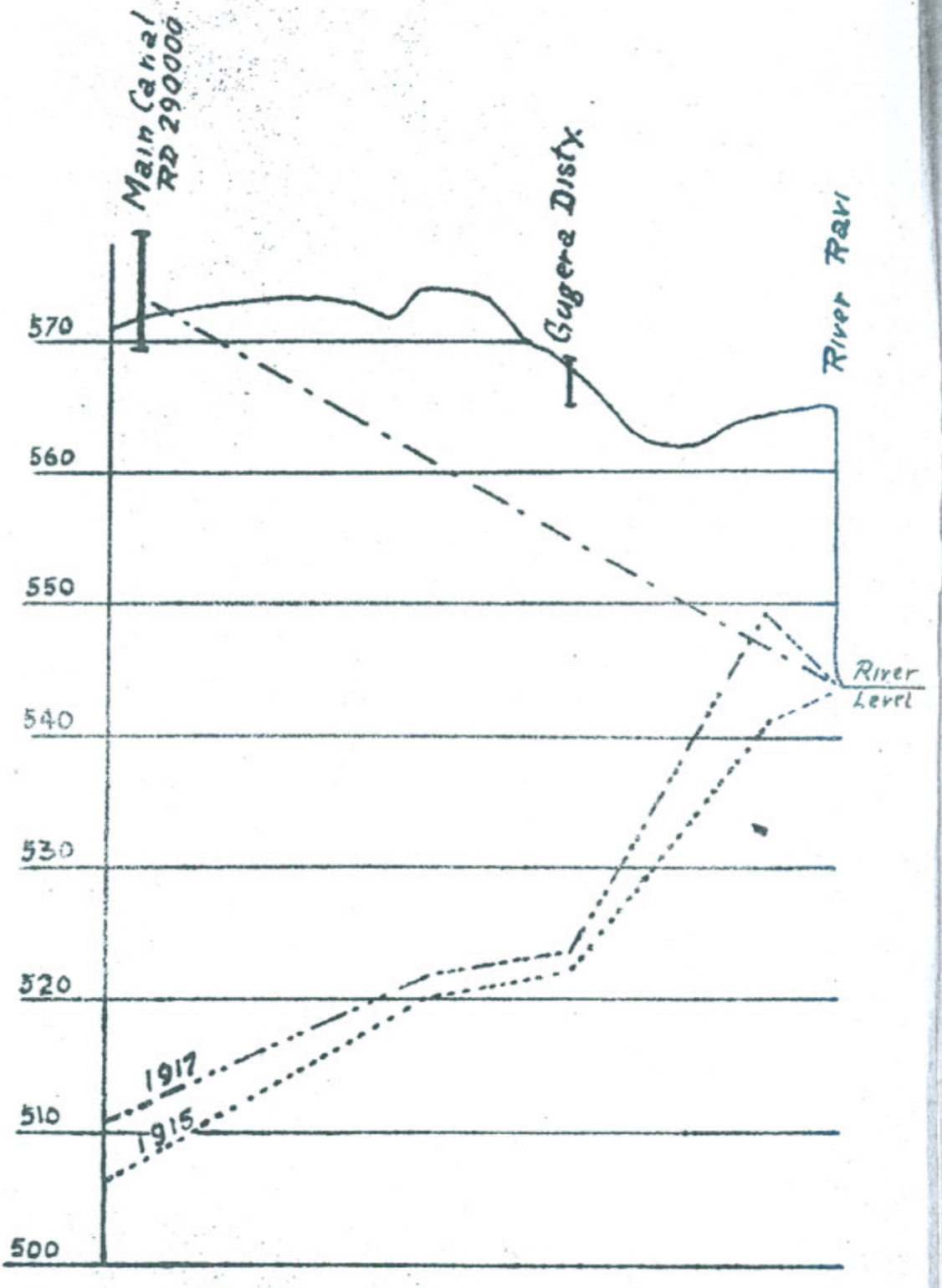


Fig 17

LBDC - Section 5

Scales { Hor. 4 miles = 1 inch
Ver. 1/200

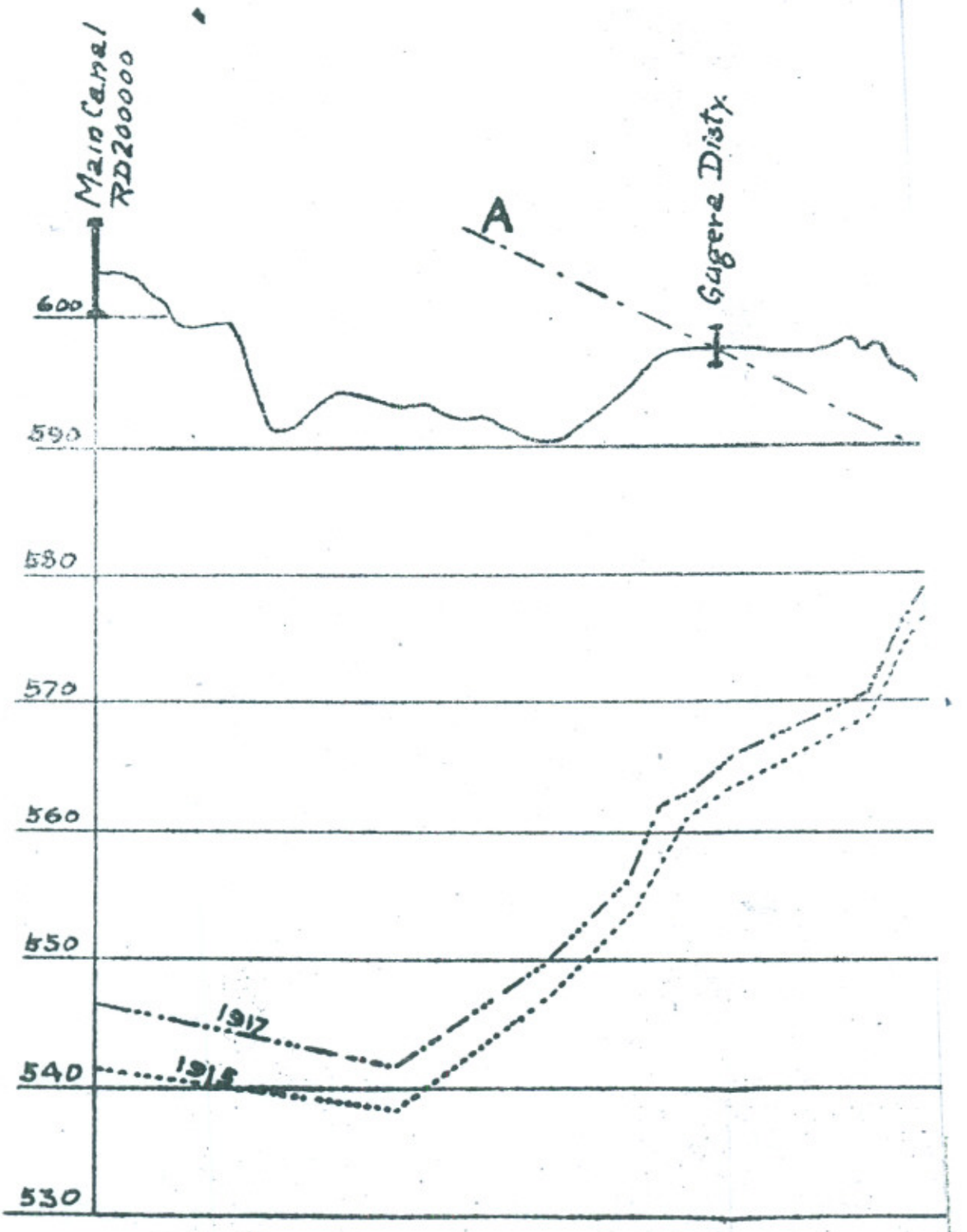


Fig 16

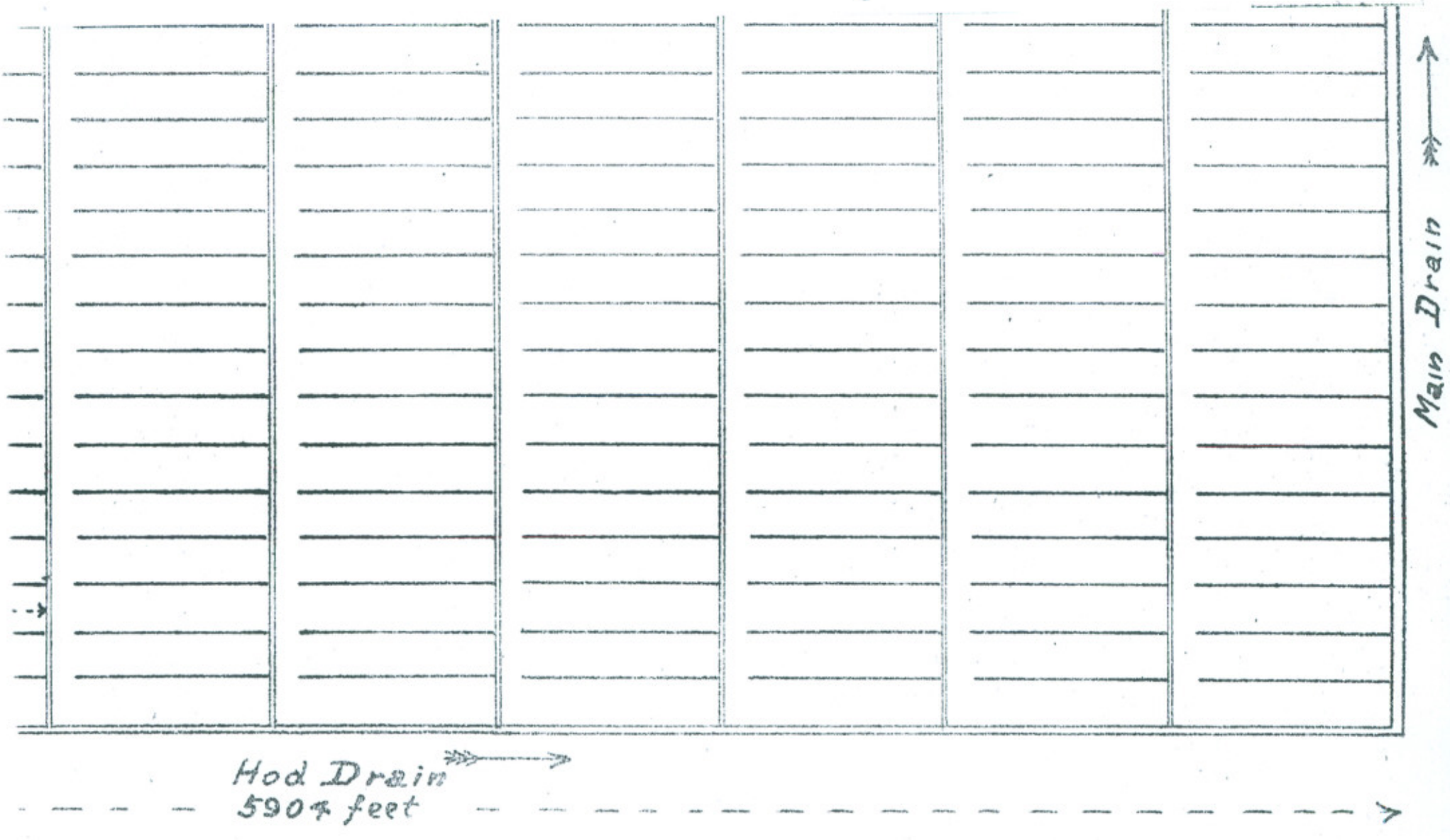


Fig — 19

DISCUSSION.

Mr. J. H. T. MIDDLETON in the absence of the author introduced the paper. He greatly regretted that the author was not present, as he felt he could not do the paper justice. However, it was on a subject in which he took considerable interest.

In 1918 he considered it in connection with the Thal Canal Project, and what he then wrote on the subject had appeared in an appendix to the Thal Canal Project which was sent to the Public Works Department Secretariat, where it was pigeon-holed and another project prepared. He unearthed his copy of what he had written sometime back, and began putting it into shape for submission to this Congress, but was unable to get it ready in time, and now that Mr. Elsden had presented this very excellent paper, which covered considerably more ground than he intended, it was no longer worth while completing it.

But it might be of interest to members to know that he arrived at several conclusions which were the same as those of Mr. Elsden, notably those regarding seepage drains and what Mr. Elsden referred to as percolation cones, though he worked different lines.

With these few remarks he read out the introduction which Mr. Elsden had forwarded to him, adding that he would do his best to reply to any points which might be raised in the discussion, but to disarm criticism in certain directions, he would say that he was forced to the conclusion that there was a loss from the sub-soil reservoir not mentioned by Mr. Elsden which operated throughout the area of the reservoir. Water either escaped into the bowels of the earth, or, as appeared more likely, passed off into the atmosphere through the interstices of the soil as a vapour. He would not give you his reasons for coming to the conclusion, as he hoped that some member present would be able to prove it more definitely than he could. He then read Mr. Elsden's introduction as follows :—

"At the time of writing this paper I had not been able to consult any authorities on the subject of the influence of crops on the quantity of water lost by the soil, and my assumption, on page 43 that 90 per cent. of the water applied to cropped soil is disposed of by evaporation and transpiration was not supported by any actual figures.

Since proceeding on leave I have been able to peruse Widtsoe's book "The Principles of Irrigation Practice", and find that my assumption is a very fair one, as the following figures show.

Taking wheat as an example, which is by far the most important winter crop in the Punjab, Dr. Leather found in India that the transpiration ratio, that is, the weight of water transpired per pound of dry matter produced, varied from 422 to 1,133 pounds. Take 750 pounds as the average value. An average outturn of dry matter will be 16 maunds of grain and 20 maunds of straw, to which we must add 4 maunds of roots, making a total of 40 maunds of dry matter per acre. From these figures it follows that wheat will transpire 40,000 cubic feet of water per acre, which is equivalent to a depth of 11 inches. This figure takes no account of the water which will also be evaporated direct from the surface of the soil.

Experiments carried out in Utah in the United States of America show that the transpiration ratio increases with the quantity of water applied, and the following figures are given for the evapo-transpiration ratio for wheat, that is to say, the quantity of water in pounds which is both evaporated and transpired per pound of dry matter produced.

When 15 inches of water were applied the evapo-transpiration ratio was found to be 1,038, which is equivalent to 15·2 inches of water, or slightly more than was applied, 101·3 per cent. of the water applied. When 25 inches of water were applied, the evapo-transpiration ratio was found to be 1317, which is equivalent to 19·3 inches, or 80 per cent. of the water applied.

It would therefore seem that my assumption of 90 per cent is not an unreasonable figure.

On page 58 of my paper I have suggested that bituminous sheetings should be tried for the purpose of waterproofing canals, and following up the suggestion, I have since arriving in the United Kingdom made it my business to get into communication with manufacturers of such materials in order to ascertain whether this material is likely to prove successful.

Some of the manufacturers, a minority, are not at all encouraging, but I am inclined to think that this attitude is largely the result of that notorious disinclination of British manufacturers to modify their wares to suit special needs and

markets, for others have replied to my enquiries in most promising terms, and are taking a keen interest in the proposal.

My enquiries are not yet complete, but, so far as they have gone, I am more than ever of the opinion that in some form of bituminous sheeting will be found the best solution of the problem of waterproof lining for canals and the most satisfactory safeguard against waterlogging. At any rate there can be no doubt that this material ought to be exhaustively tested.

It is a matter of regret to me that I am not able to be present when my paper is discussed, but I trust that the discussion will be a full one, for the subject is one of great importance to the Punjab, and requires to be thoroughly threshed out. In my unavoidable absence I shall do my best to reply by correspondence to the points raised in the discussion."

MR. C. QUINN-YOUNG explained by means of a sketch on the board how the saturated sub-soil or sponge would gradually become unwatered were canal supplies cut off.

He referred to page 32 of Mr. Elsden's paper, in which the author said : " This effect of an impervious stratum underlying a canal at no great depth has been actually exemplified in the Punjab on the Upper Jhelum Canal, where complaints of serious waterlogging have arisen in lands adjoining some reaches of the canal within three years of the canal being first opened. Such an early appearance of water-logging is attributable wholly to the presence of a stratum some ten to twelve feet below the bed of canal." He did not consider that the presence of this stratum was solely responsible for this action. In fact the existence of the stratum had not been proved as extending in an unbroken lamina below the canal. Highest authorities had not accepted the conclusion arrived at in this regard.

In his opinion the greatest contributing causes were that the canal was in high embankment ; that it formed a loop round the water-logged area ; that two distributaries took off from ends of the loop, and thus the loop and the distributaries entirely circumvented a drainage which ran through the centre of the affected area.

He also offered a few remarks about the danger of trying to stop percolation at the toe of canal embankments by means of sheet piling, and the adverse influence of such on the hydraulic gradient through a canal bank.

MR. F. H. BURKITT thought that Mr. Quinn-Young exaggerated the difficulties of sheet piling. The possible sloughing of the banks could easily be got over in either of two ways, either by putting the sheet piling on the inner side of the bank or, if the piling were put at the outer toe of the bank, by making a gravel toe to the bank ; this gravel toe running just inside the top of the piles and drained at intervals if necessary.

The effect of a drain in moderately heavy soil was extraordinarily local. As Messrs. Bates and Dixon could bear him out, in the Chak Qazi tract pools could be seen right on the edge of a drain, spring level in the pools being some three or four feet above water-level in the drain, shewing a hydraulic gradient of about 1 to 1 in the vicinity of the drain.

He doubted if there was any evidence to show that surface drains in moderately heavy soil had ever proved successful in curing water-logging where the latter was entirely due to sub-soil conditions. Where, as was often, if not generally, the case, water-logging was partly due to rainfall and surface flooding, he had found surface drains eminently successful.

MR. W. P. THOMPSON pointed out that on page 23 of his paper Mr. Elsden anticipated that spring level would rise from the concave line A, C, B to the straight line A, D, B.

There did not appear sufficient justification for this anticipation, as the period of time previous to the opening of the canals was sufficient for the water from the river to fill the void A, C, B, D were this possible with pre-canal conditions.

The concave line A, C, B represented a stable condition of affairs. There were equilibrium between the water entering the Doab from the rivers and the water lost through the soil by evaporation.

Referring to pages 26 and 27, Mr. Thompson desired to point out that it was important to avoid crossing drainages, as whenever the canal crossed a drainage by means of a high embankment leakage was most apparent, and water-logged conditions appeared as on the Upper Jhelum Canal.

Mr. Ross here remarked that near Rasul the canal was in cutting, but water-logging had occurred.

Mr. Thompson then pointed out that the conditions near Rasul were such that, although apparently in cutting, the canal

was really in a natural embankment, namely the river bank, and the low lying plain between the river bank and the stream, formerly dry, was now a marsh.

On page 37 of Mr. Elsden's paper, where Mr. Elsden wished to illustrate that water-logging would first occur in the fork between the canals, Mr. Thompson pointed out that he had been unfortunate in his selection of an example, because the Kot Nikka Branch could not have added to the water-logging in the locality mentioned for the reason that it was a small channel, the depth in which was never more than two feet

Besides, the water accumulated in that angle was brought in by the Jhattaranwali drains.

It would never be contended that the lining of the channel had any effect on the conditions outside, as the observations by means of the tubes sunk in the vicinity of the Kot Nikka Branch throughout the reach lines showed no change in the spring level conditions. The changed conditions mentioned by Mr. Elsden were attributable to the drain which was constructed to relieve the locality. It was unfortunate that previous to the lining of the Kot Nikka Branch (only part of the 7-mile reach was lined) that no one had taken the trouble to determine what the loss by absorption was.

A comparison with the loss subsequent to lining would have been instructive.

The lining in that reach was not primarily meant to stop percolation, but to find out what thickness of lining was required and how lining should be done. It was laid in various thicknesses, and no repairs had been done since it was executed.

The lining had no effect in that reach.

As regards impermeable strata, which are next discussed by Mr. Elsden, Mr. Thompson stated that nothing less than a sheet of India-rubber would be impermeable. The percolation losses per unit area of wetted surface were so small that the leakage from 100 square feet of canal bed, namely ·0008 cusec, could pass through the joints in a lining consisting of concrete slabs, as no joint had been devised thin enough to overcome this small leakage.

Mr. Thompson thought that it was unsafe to base any reasoning on the assumption that soils were impermeable.

MR. C. V. G. SCOTT said that the author was very doubtful of the efficacy of drains in checking water-logging, but in the reasoning given on page 47 and explained by figure 18 he appeared to have overlooked the fact that the rate of the flow of underground water through the interstices of the soil must be very much slower than the rate of flow in an open drain, therefore his assumption that the increased upward flow of sub-soil water would neutralize the action of the surface drain did not appear to be justified.

Surface drains might not be the radical remedy for water-logging, but there were instances where undoubtedly they had proved effective, hence surface drains should not be condemned on purely theoretical grounds.

On page 48 the author had said that it had yet to be decided what constituted water-logging, so perhaps the following definitions taken from the transactions of the Punjab Drainage Board might interest him :

(i) **When the average spring is less than 10 feet below the natural surface (excluding clayey soils) that area is said to be water-logged from a sanitary point of view, because when spring level rises above this limit " dampness " results and health is affected.**

(ii) **Soil may be said to be water-logged from an agricultural point of view when the height of the standing water-table is such that in wet seasons it is liable to rise to such an extent as will endanger the root system of the crops growing in the soil. In the case of millets and crops which do not grow in standing water, the root system may be taken to reach 6 feet below the surface. In the case of rice to a lesser depth.**

The above definition, therefore, indicated that a limit of 6. feet in wet season in the case of dry crops might be taken as the limit beyond which water-logging resulted. If the limit did not rise to 4 feet from the surface, no great harm would be done.

From both definitions 10 feet might be taken as the depth of water-logging that would be prejudicial to health, and 4·0 feet as that prejudicial to agriculture.

He agreed with the author that lining of channels (provided a suitable material at reasonable cost could be found) was the

radical remedy for water-logging, and that the material must be waterproofing, plastic, and easy to lay. He hoped shortly to lay before the Punjab Drainage Board some suggestions on this subject with figures of probable cost that he was preparing, but it would be premature to mention in detail these proposals now.

MR. R. P. HADOW noticed that papers read before the Congress by irrigation engineers fell under two broad classifications. There were those which related to silt—its causes, its crimes and its cures—and those which were concerned with water-logging. As regards silt, it appeared that irrigation officers were fully alive to its dangers, for it was, like the poor, always with them. The paper now under discussion, however, served the very useful purpose of uttering a note of warning; it showed that water-logging was stealthily creeping upon them, and would become an evil to be fought as strenuously as silting in the near future. The papers already read before the Congress on water-logging and its allied subjects had dealt principally with descriptions of remedies carried out or suggested and of observations made in various localities. Mr. Elsden's paper, which appeared to the speaker to be a masterly expostion of the whole question, differed from the previous papers in that the subject was treated generally as a whole and was a call for a more active policy. It must be accepted that the irrigation engineer had introduced unnatural conditions by pouring water on to areas where nature had not intended it to go, and consequently engineers were responsible for remedying the evils which they had introduced. The paper came at a most opportune moment—just after the creation of the post of a Drainage Engineer to the Province—and it served to focus attention on part of the work to which the Drainage Engineer might be expected to devote himself. It was an immense field for enquiry : the Drainage Engineer had a vast amount of statistics to examine and heavy work to accomplish in sifting the grain from the chaff ; and he would find, too, that he had nothing at all to base any enquiry on in many tracts and would have to fall back on conjecture. The speaker hoped, therefore, that the Drainage Engineer would not be hustled and that he would be given time to examine and study before he was expected to produce results.

Turning to the paper itself, Mr. Hadow was glad to see that Mr. Elsden had exposed the fallacy of the idea that a canal crossing a surface drainage always tended to obstruct sub-soil flow ; it was an idea which had been generally accepted in the past, and it was to be hoped that it would now take its place as an

impostor along with the "water-logging rules" of 1901. Mr. Elsden's theory of solid and dispersed cones seemed very reasonable, but it had yet to stand the test of corroborative observations, which the speaker hoped that the Drainage Engineer would put in hand. He agreed that the effect of seepage drains could only be local, and, as long as they removed what was principally surface water, they could not be held to cure water-logging. Cases might occur, of course, where seepage drains did all that it was necessary to accomplish, but they only touched the fringe of the question. He agreed with Mr. Elsden that lining channels was the only way to strike at the root of the evil, and he trusted that the proposals which Mr. Scott was about to lay before the Drainage Board would prove to be feasible. Although Mr. Elsden held that main canals and watercourses were the principal authors of the loss of water in the canal systems, Mr. Hadow thought that the first experiments with suitable linings should be taken over the whole length of a good sized distributary, so as to avoid what might be termed the engineering difficulties in the lining of a main canal, whilst at the same time giving results which could be measured with ordinary means. Finally he asked that the Drainage Engineer should be given time and opportunity to study the question as a whole, to establish its causes, to evolve remedies, and then, and not till then, be asked to apply them to individual cases. It was difficult to avoid the easy successes of draining a few swamps, but future history would show that unless the difficulties were tackled now as a whole and at the root, the province would be faced with a position demanding the most desperate remedies, which would still remain unexplored.

MR. A. S. MONTGOMERY said that there was a small scheme under consideration for the establishment at Rasul of an experimental station to deal with hydraulic problems, such as, canal lining and silt problems, etc., and urged Mr. Bates to back up the scheme as it would be of very great advantage to all Canal Engineers in dealing with such problems. He considered that if Mr. Scott, the lately appointed Drainage Engineer, could give his attention to the proposed experimental station, a lot of data would be forthcoming.

MR. A. R. ASTBURY suggested that the information on the records of the Irrigation Branch warranted a further conclusion in addition to those formulated by the author at the end of his paper. The nearer the subsoil water was to the ground sur-

face the greater was the effect of rainfall in causing fluctuations in the subsoil water level.

As an example the case of well No. XIV, 6, near Amritsar was quoted. The record commenced with 1895,

October	1895	... 744·26
,,	1917	... 748·31
,,	1918	... 741·16

The 1917 level was the highest on record since 1895, and the 1918 level was the lowest on record, the fluctuation being about 7 feet. The ground surface was 755·41..

It was difficult to eliminate the effect of rainfall in such cases and determine whether the canal was having any effect on the subsoil water level, but it seemed that open drains serving to carry away rainfall rapidly would be likely to reduce the rise in subsoil water level due to rainfall, and to this extent at least might be useful in delaying water-logging.

Another advantage in a good rural surface drainage system was the rapid removal of flood water and the consequent diminution of fulminant malaria. He invited Colonel Mackenzie, Sanitary Commissioner, to address the Congress on this point.

He greatly regretted the absence of Mr. Wilsdon at this discussion as he was sure that Mr. Wilsdon would have been able to throw light on the " dispersed cone " theory from the results of experimental work he had been doing at Lyallpur.

LIEUT.-COLONEL H. M. MACKENZIE said that this particular problem of water-logging was very important from the point of view of health. Mr. Scott had said that the Drainage Board has laid down a standard above which the spring level should not rise. As a matter of fact this particular problem was very far from being worked out. Most authorities said that a very high spring level would result in bad health. He quoted certain heights of spring level which would normally produce the best health. High spring level, he said, varied with different conditions. He considered that surface drainage would obviate temporary collection of water and would have a corresponding effect on lowering the rate of mortality.

MR. F. T. BATES spoke about the experiments he had made as regards suitable lining for canals. He said that American papers had laid stress from time to time on the fact that in making any effective lining it was absolutely necessary that the lower part of the lining should combine with he surface on

which it was laid, and he thought that it was right. He also described the process of combination between the surface and the lining. He considered that this combination was a very necessary thing on which members might make experiments, as it was a point which was often lost sight of. He said that the lining must be continuous. He had tried lining with very fine joints, but failed, as the joints in lining vitiated the whole effect. He asked the Congress to convey their thanks to Mr. Elsden for his most interesting paper. The question of water-logging now related to the health of people and had passed beyond the stage where agriculture only was affected.

MR F. V. ELSDEN, replying by correspondence to the discussion, wrote that respecting Mr. Quinn-Young's remarks on the instance quoted in the paper of the early appearance of water-logging on the Upper Jhelum Canal due to an impermeable sub-stratum, it was immaterial within limits whether the stratum of low permeability extended as an unbroken lamina under the canal or not. All that was necessary was that it should cause such obstruction to downward flow as to make lateral flow over the top of that stratum the path of least resistance. He was unable to agree with Mr. Quinn-Young's alternative explanation, which appeared to confuse drainage with sub-soil drainage, and, even so, ignored the fact that none of the channels mentioned by him obstructed the surface drainage of the tract. Moreover, there were many places in the Punjab where canals were in equally high embankment, but water-logging had not resulted, at any rate after so brief a lapse of time from the opening of the canal.

MR. BURKITT'S remarks on the effects of drains coincided on the whole with the author's views, but the figures given by him for the Chak Qazi tract were even more condemnatory of the use of drains for subsoil drainage. An hydraulic gradient, as quoted by Mr. Burkitt, of 1 in 1, if commonly needed, would put all forms of underdrainage entirely out of count. The author had lately had an opportunity of seeing something of land drainage in Europe, and found that in carrying out underdrainage there even the stiffest clays appear to be satisfactorily drained by tile drains laid 21 feet apart and 2′ 6″ deep. But in Europe the conditions were different in that there was not the same continuous supply of ground water from beneath that there was in a tract like Chak Qazi, and it was evident that the drains would need to be closer together where there was such a continuous subterranean supply of water. It was, nevertheless, something of a shock to consider that, as suggested by Mr. Burkitt's figures,

it might be necessary in such circumstances to lay drains only 3 or 4 feet apart.

As remarked by Mr. Burkitt, surface drains would certainly achieve some success where surface flooding was the principle cause of water-logging.

Mr. Thompson seemed to have misapprehended the author's remarks on page 23 of his paper. Referring to the diagram (Fig. 2), the author had not intended to suggest that in pre-canal conditions the watertable would actually rise in course of time from the line A C B to the line A D B, but to point out that the fact that it had not done so clearly indicated that there was somewhere an outlet for ground water which had enabled a condition of equilibrium to become established.

The point raised by Mr. Thompson relating to pages 26 and 27 had already been dealt with in the paper, where it was pointed out that local water-logging may result from crossing a surface drain. This, however, was a minor point, which did not affect the author's main contention that the crossing of a drainage does not necessarily in any way affect *subsoil* drainage.

In his remarks regarding the Kot Nikka Branch, Mr. Thompson was perhaps correct, nor had the author claimed this as a reliable instance of water-logging occurring first at a bifurcation. He would, all the same, hesitate to be so definite as was Mr. Thompson in denying all effects to the lining, even though he had little faith in the lasting power of such impermeability as cement lining possessed.

He was in agreement with Mr. Thompson in his view that no lining having open joints could possibly be of any use, but considered Mr. Thompson's view that nothing less than a sheet of India rubber could be impermeable to be an unnecessarily pessimistic one. On the other hand he was hopeful that something far less costly, more durable, equally impermeable, might before long be arrived at.

The author found considerable difficulty in following Mr. Scott's remarks concerning the relative rate of flow of underground water and of water in an open drain. The rate of flow in an open drain did not appear to him to have any bearing on the question, which was ruled solely by the level of the watertable, the level of water in drain, and the permeability of the soil, but he agreed with Mr. Scott that in some circumstances, as remarked also by Mr. Burkitt, surface drains served a useful purpose.

As to what should be held to constitute water-logging, the author was obliged to Mr. Scott for the definitions supplied, but doubted if these could be considered as in any sense final, in which view, he noted, he had the support of Lieut-Colonel Mackenzie. The question seemed to be largely one of climate, for in Holland he had found that the usual depth was about one metre, or 3' 3", which was in that climate found to be sufficient both from the point of view of public health and from that of agriculture. In fact, at one town which he had visited, Aalsmeer, the depth to water-table was under 9 inches, and the public health was, even so, said to be good. In India the question of alkali also seemed to have an important bearing on this point.

The author feared that Mr. Hadow had been unduly appreciative in his description of his paper, but he was much interested in his remarks and gratified to find his views so thoroughly endorsed and his warnings so emphatically repeated. Mr. Hadow's suggestion that experiments on waterproof linings should in the first instance be made in a large distributary was an idea which had also occurred to him and had much to recommend it, but owing to the difficulty of reproducing in a distributary the conditions which prevail in a larger channel, he had on further consideration come to the conclusion that it would be more satisfactory to make also some tests on short lengths of large canals in order to ascertain what difficulties of construction would arise.

Mr. Astbury's conclusion that the effect of rainfall in causing fluctuations of the level of the water-table became greater the nearer was the normal water-table to the ground surface seemed to the author to be perfectly sound. It was explicable on the ground that the greater depth of soil above the water-table provided a greater storage capacity in the form of capillary water, so that the quantity of water reaching the water-table by gravity would actually become less the greater was the depth to water-table. This conclusion provided an additional reason for keeping the water-table low.

In common with several other members, Mr. Astbury had pointed out the utility of purely surface drains in reducing the amount of water which would enter the soil. This use undoubtedly existed, but in an irrigated area it was largely discounted by the obstruction to run off caused by the water-courses and dowels which, while a necessary accompaniment of surface irrigation, could not fail to check surface drainage.

The author regretted that from the written report of Mr. Bates' remarks he was unable to understand either the nature of, or the need for, the process of combination of a waterproof lining with the surface on which it was laid. He was, however, entirely in agreement with Mr. Bates as to the necessity for avoiding open joints, however fine, in such a lining. The process of underdrainage by means of tile drains illustrated this in converse, such drains consisting of unperforated, almost impermeable tile, laid with joints as close as possible, but dry, the joints being found to be ample to admit water to the drain and drain the soil.

The author wished in conclusion to thank the members of the Congress for their kind reception of his paper. Conscious of shortcomings, he had prepared himself for much more severe handling, while in the upshot most of the remarks made had been confirmatory rather than critical of his views. He trusted that this open discussion of the subject might lead to more active investigation of the problems involved and to their early and satisfactory solution.

CORRESPONDENCE.

Mr. W. G. QUINTON wrote that on page 37 *et seq* of Mr. Elsden's paper references were made to water-logging on the Lower Chenab Canal, and at the top of page 39 the following words occurred : " No complaint has yet been made regarding water-logging in the area between the Main Canal and the Gugera Branch ".

This statement was quite at variance with facts. Sagar compound was water-logged, so much so that the garden had to be moved to the right of the Sagar bifurcation regulator, while Pirkot village lower down the fork was badly logged.

Somewhile back the Sagar drain was deepened and a drain from Pirkot dug *via* Karyala as mentioned by Mr. Thompson in his paper.

He would also say that the cone below the head reach of the Kot Nikka Branch was probably not " dispersed " because spring level was so high. If this were so now, then there was much to be said for the cement lining in the head reach of that branch.

Regarding page 40 and Mr. Elsden's remarks on the subject of water-logging between the Main Line Lower Bari Doab Canal and its Gugera Branch, he was in full agreement. The condition there was almost an exact replica of that on the Lower Chenab Canal ; with the Sukhrawa Nallah in lieu of the Ahmedpur, Kot

Nikka Nallah ; and the Main Line Lower Bari Doab Canal and its Gugera Branch on either side of its drainage in lieu of the Main Line Lower Chenab.Canal and the Kot Nikka Branch on either side of its drainage.

Time alone would probably show the necessity for drains in the Sukhrawa area just as they had been necessary in the Ahmedpur Kot Nikka area.

Regarding the crossing of drainages, it was practically impossible so to design a Canal Main Line to avoid such crossing, but it was generally possible to do so for Branch Canals, and it seemed to him unsound design not to follow this rule.

Mr. Woods was apparently insistent on this point, and he thought it should be incorporated as a fundamental principle of any design apart from any question of water-logging.

REPLY TO CORRESPONDENCE.

In reply to Mr. Quinton's written remarks the author wrote that he was indebted to him for the information he gave that there had been complaints of water-logging in the area between the Main Canal and the Gugera Branch of the Lower Chenab Canal, which shewed the existence in fact of a trouble anticipated by the author on theoretical grounds.

Mr. QUINTON'S view that the crossing of surface drains by canals was radically unsound seemed to be an expression of opinion founded on nothing more solid than the views expressed by Mr. Woods. The author did not feel that this was sufficient to render nugatory the reasoning by which he had arrived at a different conclusion, so on this point, as on some others, he ventured to disagree with Mr. Woods' view, and saw no reason to change the opinion which he had stated in his paper.