PAPER No. 194.

FLOODING OF ROHTAK CIVIL STATION IN SEPTEMBER, 1933, AND MEASURES TAKEN FOR RELIEF AND FOR FUTURE SAFETY

By Mr. Kanwar Sain, I. S. E., Executive Engineer (Irrigation).

Rohtak district experienced a sudden and heavy inundation in September 1933, which necessitated the pooling of all resources to supply immediate relief to the inhabitants. The Punjab Government granted a large sum of money for relief measures, in addition to heavy remissions in *abiana* and land revenue on a very liberal scale.

While in the *mofussil* it was mostly the *kharif* crops that suffered damage, in the Rohtak *Mandi* and the Civil Station the very lives and abodes of the people were threatened. Some of the buildings stood in as much as ten feet depth of water.

The rain which occurred at Rohtak on the 18th September, 1933, was unprecedented, at least, for the last ninety years. A fall of eleven inches was recorded in four hours in the afternoon at Rohtak. The total rainfall in about 32 hours from midnight of 17th-18th to the early morning of 19th September was recorded as 26.24 inches.

The pitiable condition of the town on the 18th-19th night can be better imagined than described. Some idea of what happened can be gathered from the photographs attached to the paper. The area flooded and the depths of water at important places are shown on the map of the Civil Station enclosed as Plate I.

Rohtak is situated half-way on the metalled road between Delhi and Hissar. The Civil Station and public buildings lie east of the town. The first Civil Station was situated north-west of the city, by the Gaokaran tank ; but the present site was adopted before 1830.[1]

As will be obvious from the contoured map on Plate II, Rohtak Civil Station is situated in a saucer-shaped depression. It appears that the early settlers in this district made their abodes on the edges of depressions, out of sheer necessity, in order to find a pasture for their cattle to graze and a good source of drinking water for themselves and the cattle. " The sweet wells [1] are found principally in the naturally flooded tracts, which thus have a great advantage over the other portions of the district. Few of the wells are naturally sweet ; they are made so and kept so by the tanks and floods of the streams..... The sweet wells are nearly always sunk on the edges of tanks, and their water ceases to be sweet as soon as these dry up."

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[1] Gazetteer, Rohtak District, 1883-84, page 139.

The town itself is situated on high ground ; but the *Mandi* and the Civil Station have sprung up in the neighbouring depression.

The Rohtak and Bhalaut Distributaries cut off Rohtak from the bigger catchment area between the two branches, Butana and Delhi, of the Western Jumna Canal. More closely Rohtak lies between the Rohtak distributary and the Railway line from Rohtak to Panipat.

The area north-east of Rohtak between the Rohtak distributary and the Rohtak-Gohana Railway line, measures 32 sq.miles or 20,480 acres. The whole area between the two distributaries measures 88 sq. miles or 56320 acres. The Civil Station of Rohtak is so situated that it is subject to inundation from the run-off from this area. Even if one-hundredth of the rainfall over the smaller catchment, assuming a uniform precipitation of 1" an hour, were to reach Rohtak, the discharge approaching Rohtak would be 206 cusecs.

The position of Drain No. 8 with reference to Rohtak requires a detailed exposition, as it came in for a lot of ill-informed criticism both in official as well as non-official circles.

This drain begins as a. independent unit near Gohana, and acts as the outfall for many tributaries (*see* Plate III). It is designed to carry 550 cusecs, assuming 1 per cent. run-off from a rainfall of one inch intensity during 24 hours. In most years, the discharge is negligible and the drain is much appreciated in its lower reach where it is utilized for irrigation.

The bed slope of the drain above Rohtak is 1 in 8000, and below Rohtak the bed slope is 1 in 20,000, the change taking place at the bridge on the Delhi-Hissar road. Below this bridge, the country does not admit of a steeper slope. This is the reason why water accumulates above this bridge, especially as the country just south of Rohtak is high and the drain has to pass through a cutting, as shown by the L-Section, reproduced in Plate IV.

With the exception of local depressions to the right and left, the drain itself lies in as low an alignment as can be found through the tract ferved. But the vulnerable position of Rohtak will be easily realized from the fact that the water level in Drain No. 8 on the 30th September eleven days after the rain-storm, was at R. L. 719.3, whereas the ground level of some parts of Rohtak is even lower than R. L. 710.

Intervening between this drain and Rohtak town, is the Rohtak distributary. (*see* Plate II). Between the Rohtak distributary and the drain are situated two villages, Sunderpura and Singhpura. In years of normal rainfall, the cultivators of these villages make small cuts to give water from drain No. 8 to their fields. During heavy rains when

the water entering through these cuts threatens to flood the area round these villages, the inhabitants cut the banks of the Rohtak distributary in order to let the water pass on to the low area in which Rohtak is situated.

The chief sources of inundation were :—

(*a*) the run-off from the catchment area between the Rohtak-Gohana Railway line and the Bhalaut distributary coming through the breaches in the Railway bank near Makrauli Railway Station ;

(*b*) the run-off from the catchment area between the Rohtak distributary and the Rohtak-Gohana Railway line ;

(*c*) and the overflow from drain No. 8 coming through the cuts made by villagers in the banks of the Rohtak distributary. A small quantity overflowing from the drain reached Rohtak through a railway culvert after filling up the contour of R. L. 716, but this was negligible.

An attempt has been made at evaluating the volume of water which flowed into this area from the above mentioned sources.

Taking first the run-off from east of the railway line to Gohana as far as the Bhalaut distributary, the area is 56 sq. miles and the precipitation was recorded as below :—

	From 17th to 18th morning.	From 18th to 19th morning.
Saragthal ..	0.9	10.3
Rohtak ..	3.0	23.24
	3.9	33.54
Mean rainfall for the catchment area ..	1.95	16.77
Total for the storm ..		18.72 inches

Assuming a run-off at the end of the catchment as 5% of the total precipitation, the volume of water reaching Rohtak comes to 2795 foot-acres.

This volume collected in the east of the railway line, breaching the railway embankment near Makrauli Railway Station at 14·30 hours on the 18th and causing the flooding at Rohtak on the 18th evening.

The area west of the railway line is 32 sq. miles and the rainfall in this area was as below :—

	From 17th to 18th morning.	From 18th to 19th morning.
Sanghi ..	0.0	11.0
Rohtak ..	3.0	23.24
	3.0	34.24
Mean rainfall over this catchment area ..	1.5	17.12
Total for the storm comes to ..		18.62 in.

The volume of run-off from this area on the same assumptions comes to 1587 ft. acres.

The total area flooded in the Civil Lines, the *Mandi*, the railway *bazar* and tanks and depressions around the town was 1490 acres. This area would be covered to an average depth of 3.0′ by the volume of water coming from the above two sources.

Lastly, we have to estimate the overflow from drain No. 8, which came through the six cuts in the banks of Rohtak distributary.

On the 20th of September, the discharge coming through the six cuts was estimated to be 300 cusecs. On the 19th it may have been 400 cusecs.

As far as it has been possible to ascertain from local enquiries, the distributary bank was cut during the night of the 18th and 19th and the cuts were again closed on the 21st by 2.0 p.m. Thus the cuts remained in operation for about 2½ days. The total volume of water from this source comes to 1700 feet acres.

It may be noted that this volume had to fill a considerable area between the drain and the town before it could add to the water level in the town.

The first thing to do was to stop the overflow from Drain No. 8 towards Rohtak, as the waterlevel in drain No.8 was still about nine feet higher than some of the low parts in Rohtak. By continuing the work at night, all the six cuts in the left bank of the Rohtak distributary were closed off by 2.0 p.m. on the 21st, although there was considerable difficulty in obtaining dry earth and in arranging for labour. The wages of coolies had gone up considerably asthe residents were prepared to pay at an abnormal rate to get out their valuables from the flooded

houses. A police guard was posted to patrol the left bank of the Rohtak distributary day and night, so that the inhabitants of Singhpura did not breach this bank again. Right up to the 10th of October this bank was a source of the greatest anxiety as the water level in drain No. 8 had not subsided below R. L. 719.0.

The next important step was to discover, if it was possible to drain off the flooded area by means of gravity flow by making cuts in any direction.

A perusal of an old contoured map (*see* Plate II) indicated that the country on all sides of the Rohtak Civil Station was higher, with the exception of natural depressions near Maina and Simli villages. With a view to explore the possibility of draining off the water into these depressions, a line of levels was run, up to Simli. It was found that the water level in the Simli depression was 2′ lower than that in the Rohtak Civil Station, but the depression was cut off by a double ridge. Between these ridges stood a sheet of water about 3′ higher than that in the Civil Station. Water from this valley if connected to Simli depression would have raised the waterlevel there, thus reducing the chances of relief of the flooded area at Rohtak.

Moreover, the distance was about five miles and the depth of the cut came to more than 8 feet at places. The earthwork involved was so heavy that it was considered futile to attempt a cut towards Simli depression, especially as the water level at Rohtak was going down rapidly by absorption and percolation.

To relieve the local areas the Engineers of the Public Health Circle obtained six pumps from Kurukshetra and Lahore. Their capacities and dates of installation are given below :—

Engine.	Size of suction.	Date of installation	Discharge capacity in cusecs.
Petter Engine ..	4″	24th Sep.	0.76
Petter Oil Engine (8 B. H. P.)	6″	24th Sep.	1.1
Petter Oil Engine (8 B. H. P.)	6″	26th Sep.	1.1
Petter Oil Engine (5 B. H. P.)	4″	26th Sep.	0.33
Bernard Petrol Engine (8.B H. P.)	4″	26th Sep.	0.38
Bernard Petrol Engine (8 B. H. P.)	4″	27th Sep.	0.38

The total capacity of all the pumps was 4.05 cusecs, while the total expenditure on pumps including running charges, pay of establishment, and railway freight for plant came to Rs. 8,202 . While the pumps did create a lot of impression on the layman's mind and proved very useful in drying up small local places, it is doubtful if the actual benefit derived was commensurate with the expenditure incurred.

In order to increase the passage of the accumulated water into the subsoil, the steinings of as many as eighteen walls were broken through and the water let down into the wells. It was found that each well could account for a discharge of about 1/15 cusec on the average.

The total expenditure on breaking the steinings and making connections and carrying out the necessary repairs amounted to Rs. 1000 approximately.

Considering that Rohtak suffers from shortage of water in many more years as compared to flooding, the well owners naturally objected to their wells being rendered less fit for purposes of yielding water. Also the benefit derived was, in the opinion of the writer, very small, as water level was rapidly going down through natural absorption.

An attempt was made to increase the rate of percolation into the subsoil, by disturbing and fissuring the soil by means of explosives. As the soil round Rohtak is sandy clay or hard clay mixed with *kankar*, the fissures caused by explosives closed up quickly. After several trials, it was concluded that the method was not worth continuing.

As the idea was original, it may interest some members of the congress to pursue the detailed report made by Lieut. M. Du. B. Floyer, R. E., Commanding a Detachment No. 8, A Tps. Coy. K. G. O. Bengal Sappers and Miners, who was in charge of the operations. The report is given as Appendix A, along with a geological section of a bore made by the North Western Railway at Rohtak Railway Station. The total expenditure incurred on this experiment was about Rs. 1,100 including cost of explosives and railway fares of sappers and miners.

The only effective means by which the great volume of water disappeared was natural absorption and percolation.

Evaporation also played its part, though to a much smaller extent, as the air was already fully saturated.

A lowering of water level of 0.1 ft. over one acre in 24 hours is equivalent to 1/20 cusec.

On the first day the water surface was lowered through absorption and percolation by 0.8 ft. This is equivalent to 0.4 cusecs per acre.

The area under water in the Civil Lines, the *Mandi*, and the Railway *Bazar* was 250 acres. The rate of loss of water on the first day over this area comes to 100 cusecs.

The rates of lowering of the water level in the Samdasar tank and opposite the Intermediate Government College are shown graphically on Plate V. It may be noted that 3 pumps were pumping out water from the Government College depression into the Samdasar tank. On the same plate are plotted water levels in Drain No. 8 to show how easily Rohtak is liable to be flooded from this drain.

It would be interesting to compare this rate of absorption with the results of an experiment* carried out by Mr. R.G. Kennedy in June 1882 in a plot of land, 27,000 sq. ft. in area, in Chhanga Manga plantation. The experiment was made at the driest time of the year, the ground was the loamy soil which is general on the Upper Bari Doab canal and it had not been irrigated during the previous twelve months. These results also are plotted on Plate V for facility of comparison.

The following values for absorption losses in various soils given by E. A. Moritz are taken from page 402 of *Engineering News* of August 28, 1913 :—

Character of soil.	Loss in cubic ft. in 24 hours per square foot.
(*a*) Impervious clay loam	0.25—0.35
(*b*) Medium clay loam underlaid with hardpan at depth of not over 2 to 3 feet below bed.	0.35—0.50
(*c*) Ordinary clay loam, silt soil, or lava ash loam	0.50—0.75
(*d*) Gravelly clay loam or sandy clay loam ..	0.75—1.00

The values given for (*c*) and (*d*) are close enough to those observed at Rohtak.

The usual practice in the Punjab is to allow 8 cusecs for evaporation and absorption per million square feet of wetted area. This is equivalent to 691,200 cubic feet per day, so the loss in depth amounts to 0.69 feet.

To determine a reasonable compromise between the protective measures and expenditure to be incurred, it was important to study

*Punjab Irrigation Branch Paper No. 10 (1905,) page 12.

the variations of rainfall from year to year. A statement is enclosed as Appendix B showing the monthly rainfall at Rohtak from 1845 to 1933. The mean rainfall has been worked out and the probable error of this mean has been computed.

By the probable error is meant that the real error of the adopted mean is as likely to be under as over the value of *t*.

This mean is compared with the rainfall in the wettest and the driest year in the figures given below :—

Number of years for which mean is taken ..	79 years.
Mean rainfall at Rohtak	19.44 inches.
Probable error of the mean	0.71 inches.
Ditto ditto	3.65 per cent of the mean
Rainfall in the wettest year	55.17 inches.
Rainfall in the driest year	2.70 inches.
Number of years with rainfall above 38.88 inches *i.e.*, double of the mean.	2 years.
Number of years with rainfall below 9.72 inches *i.e.*, half of the mean.	12 years.

A perusal of these figures shows that Rohtak lies in a region which is characterised by very heavy local variability of rainfall.

To a very great extent, if not exclusively, the problem of abundant or scanty monsoon rainfall resolves itself into that of the conditions that determine whether the monsoon indraught of Western India is mainly drawn from a more northerly or more southerly sources. "To solve this ulterior problem we should require a very complete knowledge of the meteorology of the Asiatic Continent as well as that of the Equatorial Seas, of the currents of the higher as well as of lower atmospheric strata." A detailed discussion on these points will be outside the scope of this paper ; for this, the reader is referred to the valuable publication namely, "Anomalous Variation of the Rainfall," by H.F. Blanford (The Indian Meteorological Memoirs, Volume III).

There is one fact, however, which is obvious from the statements referred to in the above para., *i.e.*, the number of dry years is far in excess

of those which show a heavy excess. In dry years rainfall in this tract is definitely a blessing rather than a curse. Even, the heavy flooding of September 1933 was a blessing as far as the next Rabi crop was concerned, the yield being much more than in normal years. It is, therefore, evident that while repetition of the downpour of September 1933 is a very rare occurrence, dry years are met with much oftener. This is an important point to be borne in mind in considering the proposals for protection against future flooding.

The main sources of inundation have already been given. Preliminary measures for future protection were discussed at a meeting of various officers including the Superintending Engineers, W. J. Canal and Drainage Circles and were outlined only a few days after the flooding by R. B. Sant Ram, then officiating as Chief Engineer, Roads and Buildings Branch, in his report dated the 23rd September 1933. These outlines have formed the nucleus of all subsequent discussions and proposals. In brief, his suggestions were :—

(*a*) To improve the design and outfall of Drain No. 8 and to explore the possibilities of draining off the hollow in which Rohtak Civil station is situated.

(*b*) To prevent the overflow of drain No. 8.

(*c*) To strengthen the right bank of Rohtak distributary to serve as a second line of defence.

(*d*) To raise the length of Delhi-Hissar Road between the high portion of the town and the railway bank crossing, to serve as a third line of defence.

(*e*) To provide a bund in the north of the Civil Station and a drain to lead water possibly into Drain No. 8.

(*f*) To close the two culverts under the Southern Punjab Railway bank.

As the Irrigation Department looks after the drainage of the catchment area, the run-off from which inundated Rohtak, it devolved upon this branch to work up the proposals and carry them out.

Detailed investigations were carried out by the officers of the Irrigation Branch. The various proposals made but rejected on various grounds are narrated later. The estimated cost of some of these was more than a lakh of rupees. The proposals as finally accepted and carried out are given later.

The first and foremost thing that appeared to be called for was the improvement of the drainage system. The possibility

of draining the hollow, in which a part of the Civil Station is built, was thoroughly explored. The proposals put forward in this connection are briefly discussed below :—

(*a*) An alternative alignment for Drain No. 8 beyond the Southern Punjab Railway, tailing into the Mangeshpur Drain and eventually into the Najafgarh Jheel drain was considered. Besides the very heavy first-cost of this proposal, there was another objection, namely, that the Mangeshpur Drain which collects all the water between the right bank of the Western Jumna Canal and the Rohtak-Delhi Main Road has itself a poor outfall ; most of the water collects in the Najafgarh Jheel and renders a lot of land unfit for rabi cultivation. The Najafgarh Jheel Drain passes through a very heavy cutting before reaching the Jumna River, and any proposal to enlarge and deepen this drain would be very expensive, specially as the drain crosses a large number of important metalled roads in the Delhi area.

(*b*) The other possibility was to construct a drain on the east of the Rohtak-Panipat railwy line, leading to Simli depression. This, however, was objected to by the inhabitants of the villages which are situated in this depression. (See Plate II).

(*c*) A smaller drain proposed through the high land in the south (shown on Plate II), was also rejected, as it was liable to endanger the Delhi-Bhatinda railway line and to shift the site of a possible breach nearer Rohtak. The outfall available for this drain was very poor and it involved the construction of culverts under two metalled roads and many water-course crossings.

In the absence of a possible drainage the only other alternatives were either to abandon the present site of the Civil Station or to prevent the run-off from the neighbouring catchments running into the Rohtak depression. The former would have meant a very heavy loss to the public as well as to Government as expensive buildings have been built in the Civil Station by both; thus recourse had to be taken to the latter alternative.

The main sources of inundation have already been given. A detailed scheme for preventing the run-off from these sources was sent up in May 1934 to the Chief Engineer, Irrigation, by the Superintending Engineer, W. J. Canal Circle. This scheme provided (*i*) a bund north of Rohtak, (*ii*) a drain along this bund, (*iii*) culverts on the drain for roads, (*iv*) syphons for water-courses and Rohtak distributary (*v*) a bridge for the left bank of drain No. 8 and (*vi*) an outfall for the proposed drain into drain No. 8.

The bund was to have a top-width of 12 feet with top at R. L. 725 from the railway line to the Rohtak distributary and at R. L. 723.5 from this point to drain No. 8. The cost of the whole scheme was estimated to be nearly Rs. 44,000. The proposed alignment of the bund is shown on Plate II.

The Chief Engineer accepted the scheme, but reduced the top-width of the bund to 7·0 feet and suggested substitution of Irish bridges for economy.

The final proposals were submitted in December 1934, and carried out in 1935. These are given in the next para.

The various protective works as actually carried out consist of the following :—

(*a*) *Protection Bund.*—The alignment in the head reach has been shifted slightly so as not to cut off the famine tank from the drainage. This change enabled the use of an existing inlet into this tank, constructed some years ago by the District Board to safeguard the Rohtak-Gohana metalled road. This inlet has a linear water-way of 31 ft. and even with a depth of 1 ft. can pass about 100 cusecs of water safely over the road. The section of the bund has been kept 7 ft. at the top with side slopes of 2 to 1 and 3 to 1. The bund join the railway embankment at a distance of 22,140 ft. from the Rohtak railway station. The top of the railway bank at this point is 725.33 against 725 the proposed top of the bund. The railway bank from this point slopes down from R. L. 725.33 to 722.83 in a distance of 3000 feet. It was in this reach that the disastrous breach occurred on the 18th September 1933. A culvert has been proposed in this reach to drain off the area to the east of the Rohtak Panipat Railway line.

The alignment and L-Section of the bund are shown in Plates VI and VII.

(*b*) *The drain.* As an inlet into the famine tank exists no drain has been constructed between the Panipat-Rohtak railway line and Gohana-Rohtak metalled road. The drainage water will enter the tank by this pacca inlet and spill from it into the drain in the west, which takes off at this point. The drain is given a bed-width of 15 ft. and a depth of 2 ft. It consists principally of borrow-pits required for the bund. In dry years it is not expected to flow, while in case of excessive rains the whole of the country-side of the north of the bund would serveas a drain. The R. L. of the bed of the drain at the starting point is 718.89

as compared with 719.85, the R. L. of the Rohtak-Gohana road at this site. The bed level of drain at the outfall has been kept the same as that of Drain No. 8, thus eliminating risk of retrogression and allowing more earth from digging for completion of the protection bund. The bed level from Sunderpura-Titauli bridge upwards has been raised by 2 feet to reduce earthwork in cutting.

(*c*) *Masonry works*. These consist of the following items—

(*i*) The District Board inlet which has been improved and remodelled.

(*ii*) V. R. Bridge on road from Rohtak to Chamari.

(*iii*) V. R. Bridge on Sunderpura-Titauli road. The top width of the bund from this bridge to the junction of Drain No. 8 has been made 12 feet, thus saving a bridge on the left bank of Drain No. 8.

(*iv*) The Rohtak Distributary and water-course crossings. The Rohtak Distributary aqueduct is combined with the bridge for the boundary road, the right hand girder of the bridge is common with the aqueduct. Washed *kankar* available near the site was used in the reinforced concrete work with a safe compression stresss of 500 pounds per square inch. This resulted in economy. The proportion 1:2:4 used on this work appeared to be suitable.

(*v*) No masonry work at the out fall into Drain No. 8 has been provided as none was considered necessary.

(*d*) To prevent overflow of Drain No. 8, its left bank has been raised and strengthened from its junction with the protection bund to a point where the natural surface is sufficiently high.

(*e*) As a second line of defence the right bank of Rohtak Distributary has been strengthened and raised, in order to stop the overflow from Drain No. 8, in case its left bank at any time gives way.

The total cost of the works connected with the protection bund was Rs. 23,000 while the cost of strengthening and raising the left bank of Drain No. 8 and the right bank of Rohtak Distributary was approximately Rs. 1300 and Rs. 2100 respectively.

The catchment area within the Rohtak-Gohana railway line, the Protection Bund and the Rohtak Distributary is approximately eleven square miles. The capacity of the local tanks in this area is sufficient to take care of the run-off from this small catchment.

APPENDIX A.

REPORT ON ROHTAK FLOOD RELIEF, 1933.

By Lieut. M. Du. B. Floyer, R. E., Commanding A Detachment No. 8, A. Tps. Coy., K. G. O. Bengal Sappers and Miners.

A detachment of Sappers and Miners arrived in Rohtak on the evening of Tuesday, Sept. 26th in response to a telegram, dated September the 25th, from the Executive Engineer, Rohtak Division, (Western Jumna Canal), and following on a general warning order received from Army Headquarters under their Telegram No. 33360/ S D 2, dated the 20th September, 1933.

The intention was to accelerate the rate of abatement of the floods by disturbing and fissuring the soil, thus increasing the seepage of the water.

The method which had been outlined was that a large number of small charges should be blown in the ground all round the edges of the flooded areas.

The flooded area on September 26th extended from south of the Mandi, near the Railway, through the Mandi and towards the North forming a Y-shaped *jheel*, whose length was about three miles, and the width of whose limbs varied from 50 yards to half a mile.

The maximum depth of water round buildings was 6 feet (in Government College Compound), and the daily rate of decrease was from 4 inches to 7 inches.

The surface soil consisted of a mixture of clay and fine sand, which seemed almost impervious. Pits dug within three feet of the edge of the water, to a depth of 12 feet remained dry even after two or three days.

This impervious soil was reported to extend down for about 30 feet, and beneath this was the porous sand.

The subsoil water level appeared to stand 36 to 40 feet below G. L. (measured in wells).

On the 27th, a trial undercharged mine (index 0.6) was blown with the object of disturbing the soil to a depth of 30 feet, and observing the result. Only guncotton was available from Ferozepore arsenal.

After the first rush of water into the crater, no more appeared to be absorbed. Further enquiries were therefore made to determine the nature of the subsoil. No records of bores were available, but fairly reliable information indicated that the water bearing sand was as deep as 65 to 75 feet below ground level, and that the intermediate soil was, for the most part, this same impervious mixture of clay and fine sand.

On account of the large expenditure of explosive which would be necessary to blow fissures to a depth of 75 feet, it was decided that mining was not a sound proposition unless a porous strata could be found near the surface.

By this time the water had receded into five separate areas, which, for reference, were named the South, Centre, North, West and North-west tanks.

A light porous sand had been met with in a few of the pits near the South tank, and in two pits near the West tank, at a depth of 10 to 12 feet.

In order to obtain further information about the sub-soil, other pits were examined, and also (since the pits could not be deepened beyond 13 feet without timbering) six 1½" bores were put down, in the South, North, North-west and Centre areas, and samples of soil were taken at vertical intervals of approximately three feet.

A summary of the results showed that there was a layer of sand from 6 to 10 feet thick, whose upper surface lay from 10 to 20 feet below datum level (D. L. being about 6′ above the Government College Ground-level.)

This sand layer appeared to be saturated except for the few isolated pockets mentioned above, though the grains were so tightly packed that there was no appreciable flow of water.

The remaining strata, it was confirmed, consisted for the most part, of almost impervious mixtures of sand and clay in varying proportions. *Kankar* beds were detected at 21′ at the North tank, and near the surface at the South tank.

With the apparatus at hand, investigations could not be carried below 30 feet, though the reported depth of the water bearing sand stratum was confirmed, to some extent, by the fact that the shallower wells, between 60 and 70 feet deep, did not drain the water away at a rate comparable with the deeper wells, which reached to 80 feet and more.

The lower parts of Rohtak are in a depression from which there is no natural outlet ; and it appeared, therefore, that the only possible method of draining the flood water, other than by natural seepage, would be by communication with the porous sand stratum some 75 feet below ground level. This communication was already provided to a small extent by the deeper wells, but those which absorbed large quantities of water were severely damaged. Apparently the soil in contact with, and beneath the steining became so fluid that skin friction was not sufficient to support the weight of the masonry, which consequently sank into the ground.

The only immediate action which could be taken, therefore, was to blow mines in selected positions, where pockets of unsaturated sand had been found. This was done and it was calculated that each mine fissured the soil to a maximum depth of 30 feet and radius of 50 feet. In one case, bubbles appearing in the water indicated that the effect had been felt at a distance of 90 feet from the charge.

While there was a good stream of water into the craters for some 20 to 30 minutes after the explosion the subsequent rate of flow was reduced to a very small figure, and it was considered that the further ex, penditure of explosives was not justified. In all 200 lbs. of guncotton were used.

It was impossible to record any actual effect on the water level, from these small scale experiments, as the daily rate of decrease in depth varied considerably, depending on the amount of evaporation, the effect of the pumps, new rainfall, and other inconstant factors.

Experiments were made to increase the flow of water down the wells, by exploding a small charge at the bottom.

The first experiment was made on a well 57 feet deep, which was absorbing no water. It was not successful, and it was concluded that the well was too shallow.

On another deeper well, a small increase of flow was observed. The charge had necessarily to be very limited for fear of causing the complete collapse of the steining.

By October 1st the water round the Government College was only about $2\frac{1}{2}$ feet deep, and most of the other built over areas were dry.

The Detachment left for Roorkee in the afternoon.

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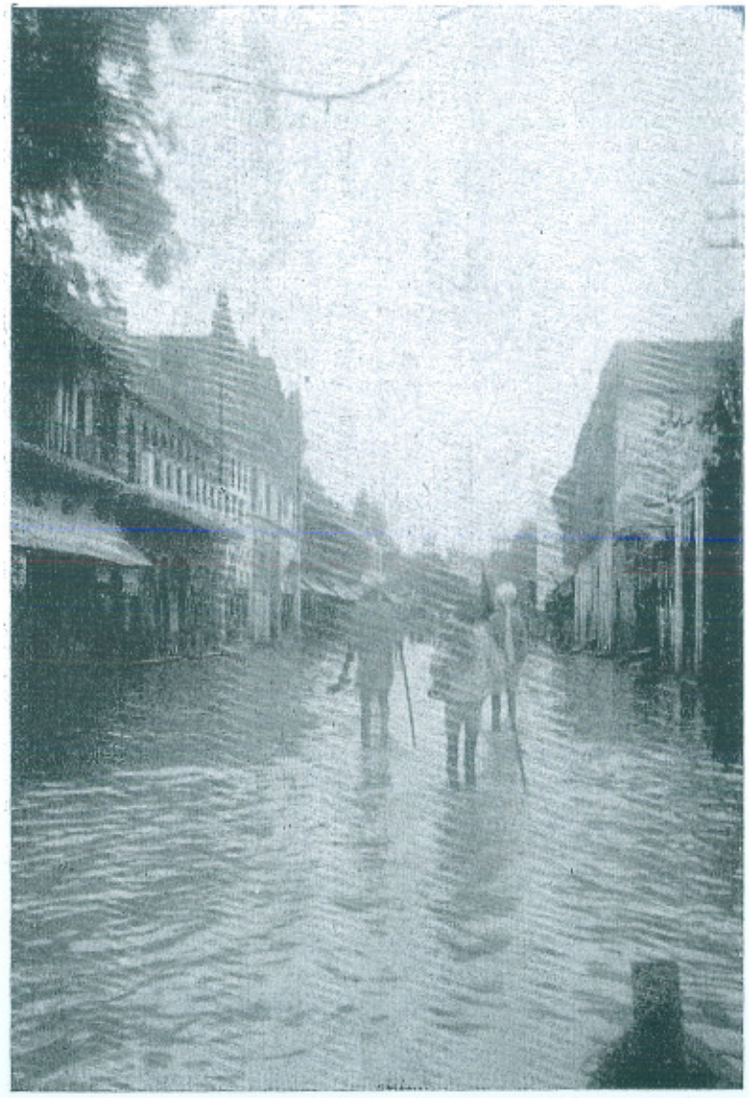
Rohtak Civil Station.



Rohtak Civil Station.



Civil Station, Rohtak.



Dak Bangalow, Rohtak.



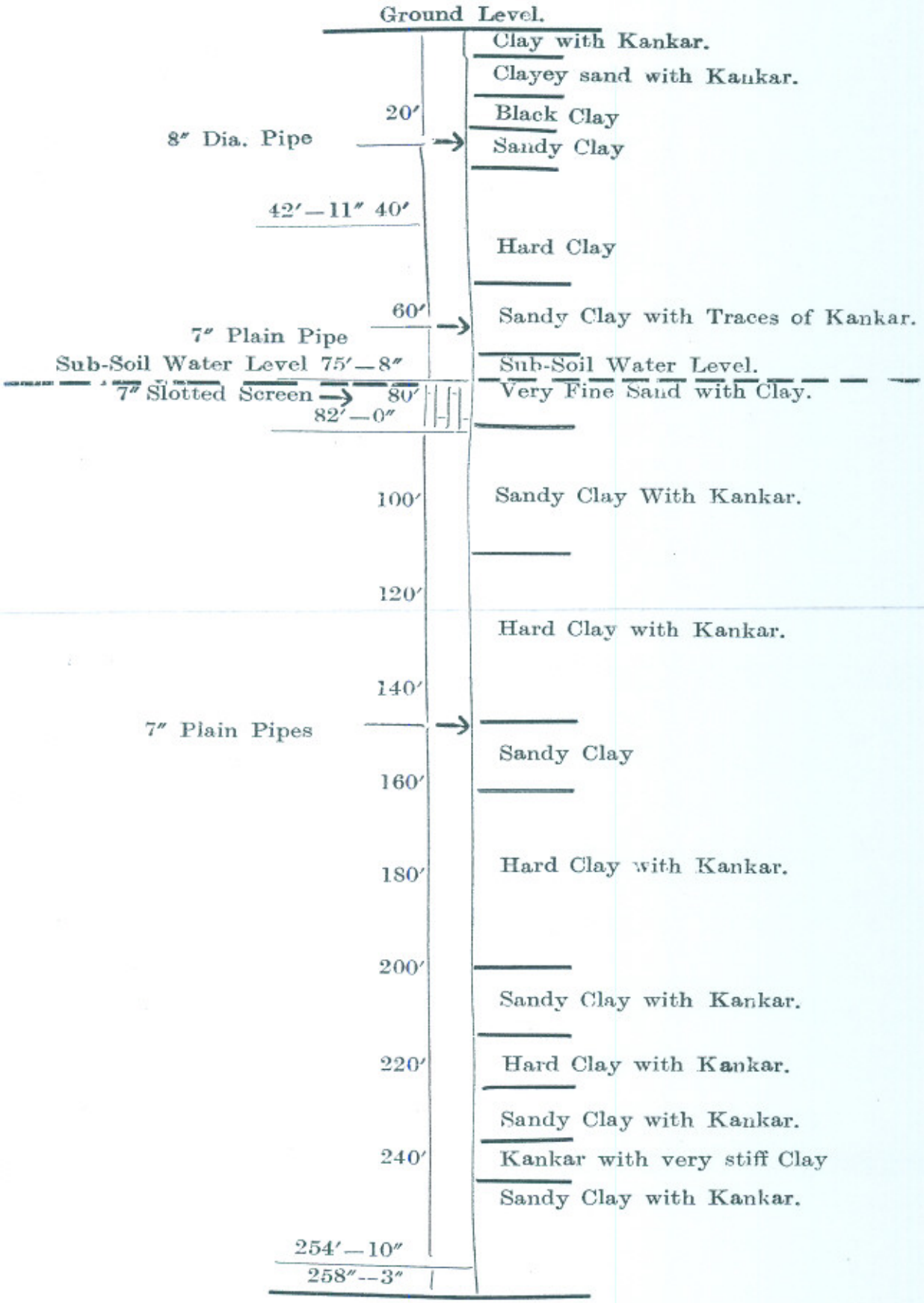
Rohtak Bazar.



Rohtak Bazar.

ROHTAK RAILWAY STATION. APPENDIX A.

GEOLOGICAL SECTION OF 7″ DIAMETER TUBE-WELL.



According to Drawing No. W. E. 226/D.L.-1 of Tube Boring Division.
Boring done in September—December, 1931.

1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933
..	0.4	..	..	1.4	2.4	..	.	.9	..	..	.8	2.0	.66	.43	.41	.80	2.1	..	.66	..	.3	.46	1.7	..	..	..	1.05
1.4	..	..	..	..	..	1.05	.2	1.7	.3	..	..	..	.65	.	.33	2.70	1.0	..	.	.81	1.08	..	.3	..	..	.35	0.25
0.60	..	..	..	1.3	..	.4	..	1.9	..	..	.4	.23	.28	..	..	.20	..	..	.9	.42	..	..	..	.63	1.11	.55	.60
..	..	..	3.2	..	..	.2	..	..	.3	..	.6	.1	.64	.26	..	..	..	..	..	.41	.	.79	.23	..	..	.36	.37
..	..	6.2	..	..	..	..	..	1.1	..	..	2.6	28	2.29	1.22	..	..	0.50	.56	.6	2.83	.17	.15	.18	..	.88	.42	2.63
0.70	..	.10	5.3	2	1.7	..	5.4	..	1.10	.9	1.6	1.02	..	4.67	1.51	4.22	0.90	2.20	3.85	1.15	.44	1.77	.31	2.85	2.22	.62	3.66
1.5	1.8	10.4	3.6	0.6	1.0	1.7	1.1	10.6	.7	3.7	8.3	..	6.87	8.59	4.84	5.06	5.35	3.72	9.35	7.9	6.78	5.4	4.43	9.19	10.51	5.22	7.30
3.10	0.5	9.5	5.8	5.8	1.3	1.8	..	1.6	1.4	7.9	7.4	4.36	9.42	..	7.28	5.43	7.55	3.84	6.3	7.02	10.3	5.1	5.03	.8	3.86	3.08	8.84
7.2	..	..	3.7	6.1	10.2	4.1	..	3.6	3.0	2.7	9.0	..	.29	.39	3.6	10.71	..	7.85	.20	1.58	.4	.71	.62	2.77	3.79	4.63	29.51
..	..	..	..	2	..	..	..	.6	..	6.0	2.5	..	..	..	2.0	..	..	3.8	.3	..	..	..	..	..	.36	..	0.55
..	..	..	..	..	.9	..	..	..	..	..	..	..	..	..	..	..	..	..	.6	..	..	1.35	..	.23	..	..	..
..	..	..	0.5	..	..	..	..	..	..	..	..	..	.7	..	..	1.32	1.25	.25	..	..	1.42	.54	61	..	..	0.83	0.12
17.50	2.70	20.20	22.1	19.2	17.5	9.25	6.7	22.0	4.5	21.2	33.2	8.89	21.92	15.54	19.77	30.41	18.65	22.22	22.76	23.02	20.9	16.17	13.41	16.47	20.73	16.04	55.17

APPENDIX B.

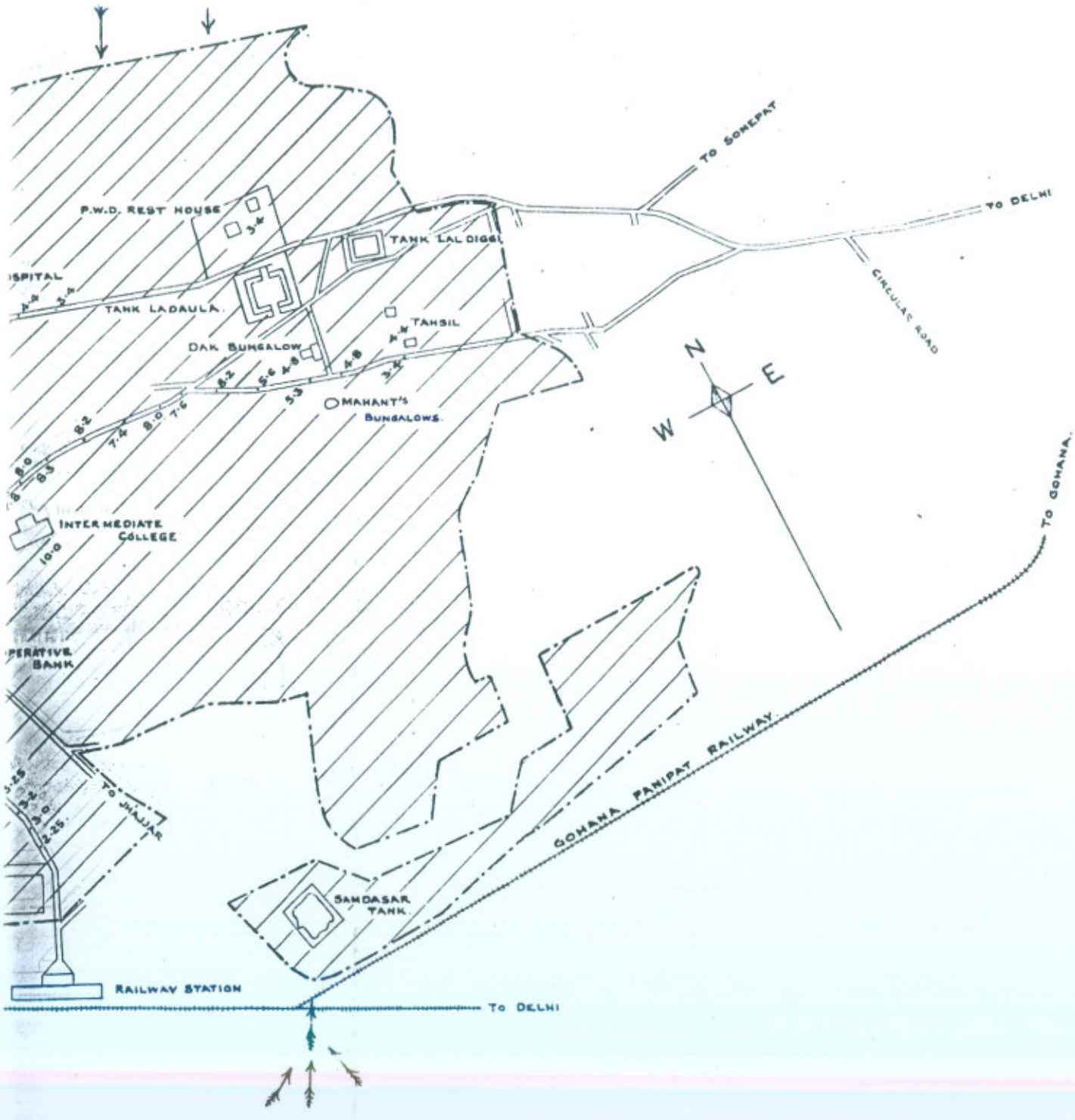
STATEMENT SHOWING MONTHLY RAINFALL AT ROHTAK FROM 1845 TO 1933.

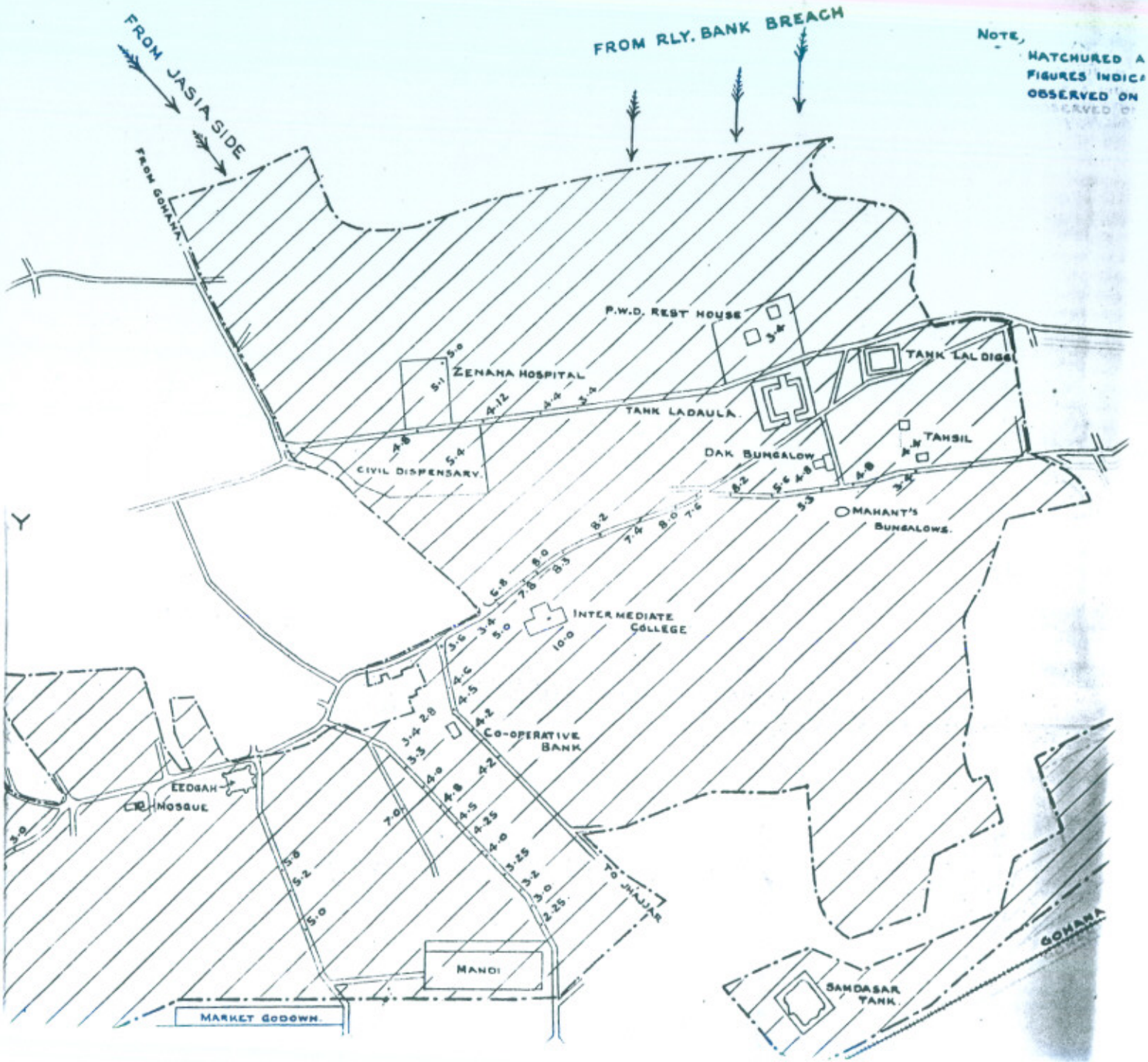
	1879	1880	1881	1882	1883	Mean.	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911
	..	..	0.10	2.21	[illegible]	0.66	..	2.80	2.70	.2	.6	.4	1.5	1.0	1.55	1.50	6.0	0.20	..	..	..	0.10	0.6	..	..	0.20	1.40	..	..	0.4	..	..	1.4	2.4
	0.50	6.80	0.30	1.90	..	0.61	..	..	..	.6	2.0	..	0.05	.48	.97	.40	..	0.50	..	1.40	..	..	0.9	..	..	..	0.40	0.40	1.4	..	..	..	..	..
	1.20	..	2.50	..	0.40	0.63	6.40	0.10	0.90	.5	.2	.3	1.01	..	1.32	..	0.20	..	..	..	..	0.20	..	..	..	2.50	0.40	0.10	0.60	..	..	..	1.3	..
	..	..	0.70	..	..	0.20	..	0.50	..	..	..	..	.25	.44	..	0.1	..	..	..	0.10	..	0.10	0.3	..	..	..	..	..	..	..	..	3.2	..	..
	..	..	0.30	0.20	1.11	0.50	..	2.20	0.40	..	1.8	..	0.40	1.81	1.17	1.6	..	..	..	0.80	1.70	..	..	..	0.6	..	0.30	..	..	..	0.2	..	..	..
	3.50	1.50	3.10	2.20	1.70	2.78	7.27	5.30	2.40	.4	1.8	.4	1.3	..	0.36	3.3	3.4	2.40	0.80	1.40	3.20	4.00	0.90	..	4.70	0.70	1.90	..	0.70	..	.10	5.3	2	1.7
	2.60	7.00	10.7	5.50	3.70	5.81	2.85	6.70	10.90	10.45	4.1	3.7	10.93	3.32	5.80	7.7	5.70	1.30	4.60	5.90	7.70	2.70	4.50	1.20	2.10	3.20	1.70	4.10	4.5	1.8	10.4	3.6	0.6	1.0
	10.80	..	5.7	2.70	0.50	4.56	6.40	28.70	4.30	16.6	5.23	5.0	8.21	6.40	11.96	4.3	5.30	1.20	1.20	8.20	2.90	1.0	4.90	2.50	1.80	0.60	4.50	0.40	3.10	0.5	0.5	5.8	5.8	1.3
	2.50	4.40	..	2.20	5.20	2.93	5.05	1.30	0.50	1.2	4.7	..	.2	1.26	7.65	10.0	7.70	..	..	3.90	1.10	..	7.90	0.80	1.20	1.60	1.20	1.30	7.2	..	..	3.7	6.1	10.2
	..	..	..	..	0.10	0.17	..	..	0.50	..	.6	..	.5	.15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..
	..	..	..	..	0.30	0.05	..	..	..	..	..	..	..	..	..	..	0.99	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	.9
	1.90	0.90	..	..	..	0.37	..	5.10	..	.7	..	..	.3	..	1.50	0.30	3.40	..	0.10	..	0.70	..	1.20	0.20	..	..	1.40	..	..	..	..	0.5	..	..
	22.80	14.60	23.40	16.0	13.50	10.80	21.97	4.50	22.60	30.65	21.08	0.80	23.57	14.86	32.28	29.2	29.40	5.60	6.70	24.70	17.30	8.10	21.10	4.70	10.70	8.6	15.30	5.30	17.50	2.70	20.20	22.1	19.2	17.5

STATEMENT SHOWI

Year.	1845	1846	1847	1848	1849	1850	1851	1852	1853	1854	1855 to 1861	1862	1863	1864	1865	1866	1867	1868	1869	1870	1871	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883
Month—																																	
January ..	..	..	0.36	0.94	4.73	1.51	1.75	..	..	0.60		..	1.20	0.10	0.90	1.20	0.10	0.20	0.70	..	..	0.40	0.30	..	..	..	0.60	0.60	..	..	0.10	2.20	0.7
February ..	2.10	..	1.44	0.31	..	0.09	1.99	0.41	..	0.70		..	..	0.90	0.60	0.20	..	0.80	0.30	..	2.50	0.30	..	0.40	1.50	..	0.60	0.60	0.50	0.80	0.30	1.90	..
March ..	0.32	0.70	..	..	..	0.32	0.08	2.88	..	..		..	0.50	..	1.30	..	1.30	0.20	2.10	0.40	.	1.10	.	1.50	..	0.40	1.10	0.20	1.20	..	2.50	..	0.1
April ..	0.04	..	..	..	..	0.69	0.71	0.45	0.50	..		..	0.20	0.80	0.40	0.30	1.20	..	..	0.20	0.60	0.30	..	..	..	0.10	0.70	1.40	..	..	0.70	..	..
May ..	..	..	..	2.37	0.78	..	..	1.50	1.60	..		1.60	0.30	1.60	0.90	1.20	1.60	..	..	..	1.00	0.70	0.40	..	0.30	0.80	1.60	0.80	..	..	0.30	0.20	1.1
June ..	2.25	12.68	4.19	1.69	6.79	1.28	1.17	3.60	6.90	..		2.30	3.70	0.30	1.00	4.70	0.60	1.80	..	3.10	2.50	2.00	0.40	5.20	0.10	3.30	3.30	1.70	3.50	1.50	3.10	2.20	1.7
July ..	13.19	3.45	9.46	2.45	1.60	4.71	0.62	1.60	6.30	..	Not available.	8.50	20.1	3.10	2.20	1.50	5.70	3.70	7.40	4.80	4.60	12.3	10.3	6.40	2.50	8.10	0.40	5.20	2.60	7.00	10.7	5.50	3.7
August ..	13.14	0.62	5.70	5.05	14.56	11.51	11.85	7.90	6.50	..		0.70	7.90	1.20	0.60	0.90	9.80	0.80	1.60	2.40	2.10	6.60	1.50	0.60	3.70	..	..	9.30	10.80	..	5.7	2.70	0.5
September ..	..	3.00	0.96	..	5.19	1.85	1.05	0.50	..	..		7.70	1.00	5.70	2.90	..	2.50	0.20	7.30	1.90	0.60	3.30	4.10	1.00	22.00	3.60	2.60	0.70	2.50	4.40	..	2.20	5.2
October ..	..	1.75	..	1.01	..	..	..	..	4.60	..		..	0.60	..	..	..	..	0.40	2.00	0.90	..	..	0.50	..	..	1.30	1.90	..	..	..	..	..	0.1
November ..	..	..	..	..	..	0.28	..	..	..	..		..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0.30	..	..	..	..	..	0.5
December ..	..	..	..	0.09	..	..	0.58	..	..	..		..	..	..	0.90	0.10	1.10	..	..	0.50	2.60	0.90	..	..	..	..	2.20	..	1.90	0.90	..	..	..
Total ..	31.04	22.20	22.71	13.01	33.83	22.54	19.22	18.27	26.40	1.30		20.80	35.50	13.90	21.2	13.7	23.9	8.30	21.4	13.9	16.2	27.9	17.5	15.10	30.1	17.60	15.30	20.50	22.80	14.60	23.40	16.0	13.5

Note 1.—The figures from 1845 to 1886 have been taken from Indian Meteorological Memoirs Vol. III 1886-1888 relating to Indian and other neighbouring countries published under the Directions of Henry F. Blanford for F. R. S.
Note 2.—From 1886 to 1908 from the record of Western Jumna Canal circle.
Note 3.—From 1908 to date from the Divisional Office records of the Delhi Division W. J. Canal.


TO SONEPAT
TO DELHI
P.W.D. REST HOUSE
TANK LAL DIGGI
TANK LADAULA
CIRCULAR ROAD
DAK BUNGALOW
TAHSIL
MAHANT'S BUNGALOWS
N
E
W
INTER MEDIATE COLLEGE
TO GOHANA
GOHANA PANIPAT RAILWAY
TO JHAJJAR
SAMDASAR TANK
RAILWAY STATION
TO DELHI

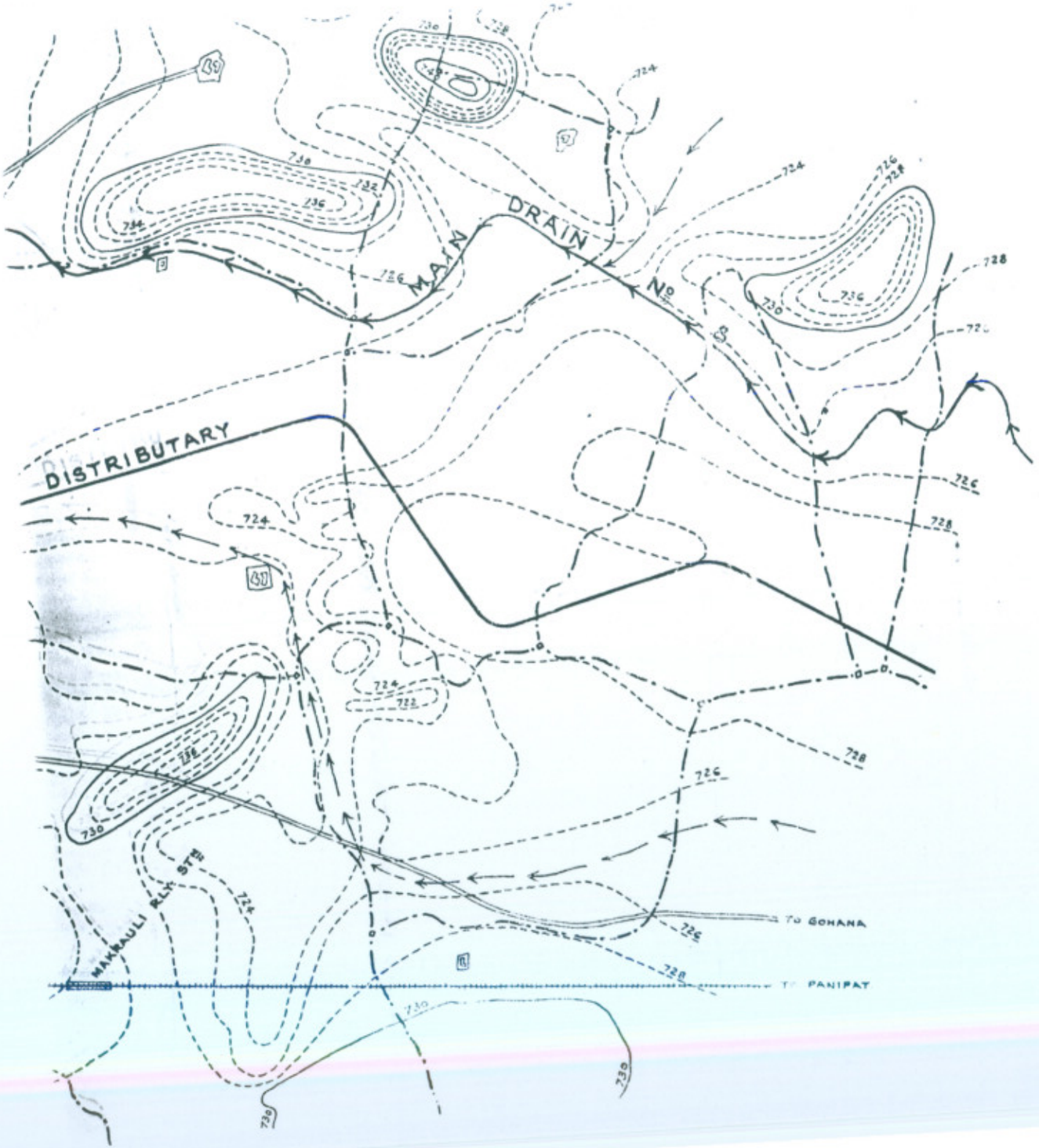

FROM JASIA SIDE
FROM RLY. BANK BREACH
NOTE,
HATCHURED A
FIGURES INDIC
OBSERVED ON
FROM GOHANA
P.W.D. REST HOUSE
ZENANA HOSPITAL
TANK LADAULA
TANK LAL DIGG
TAHSIL
DAK BUNGALOW
CIVIL DISPENSARY
MAHANT'S BUNGALOWS
INTERMEDIATE COLLEGE
CO-OPERATIVE BANK
EIDGAH
MOSQUE
MANDI
MARKET GODOWN
TO JHAJJAR
SAMDASAR TANK
GOHANA

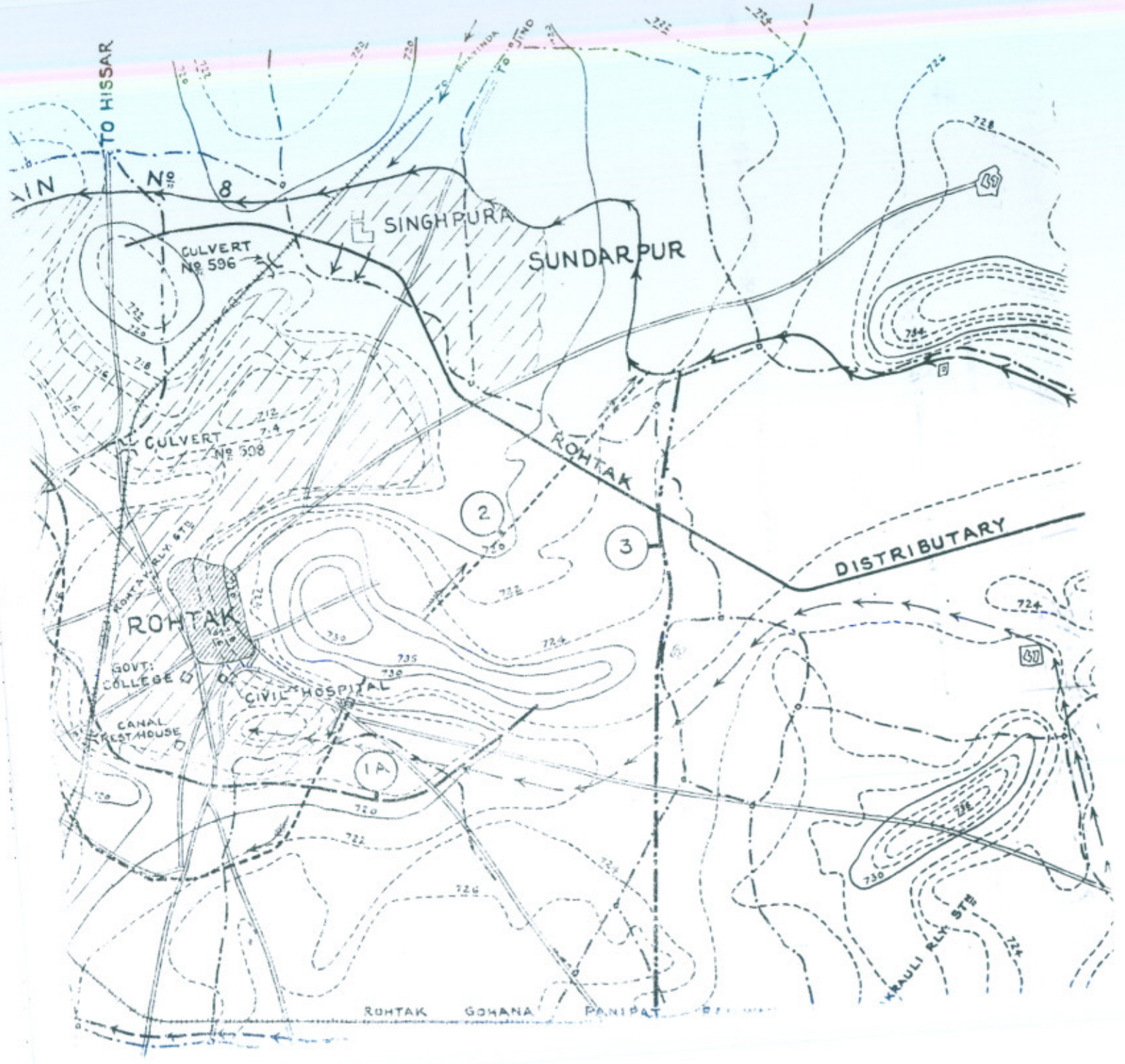
ROHTAK CIVIL STATION

SHOWING

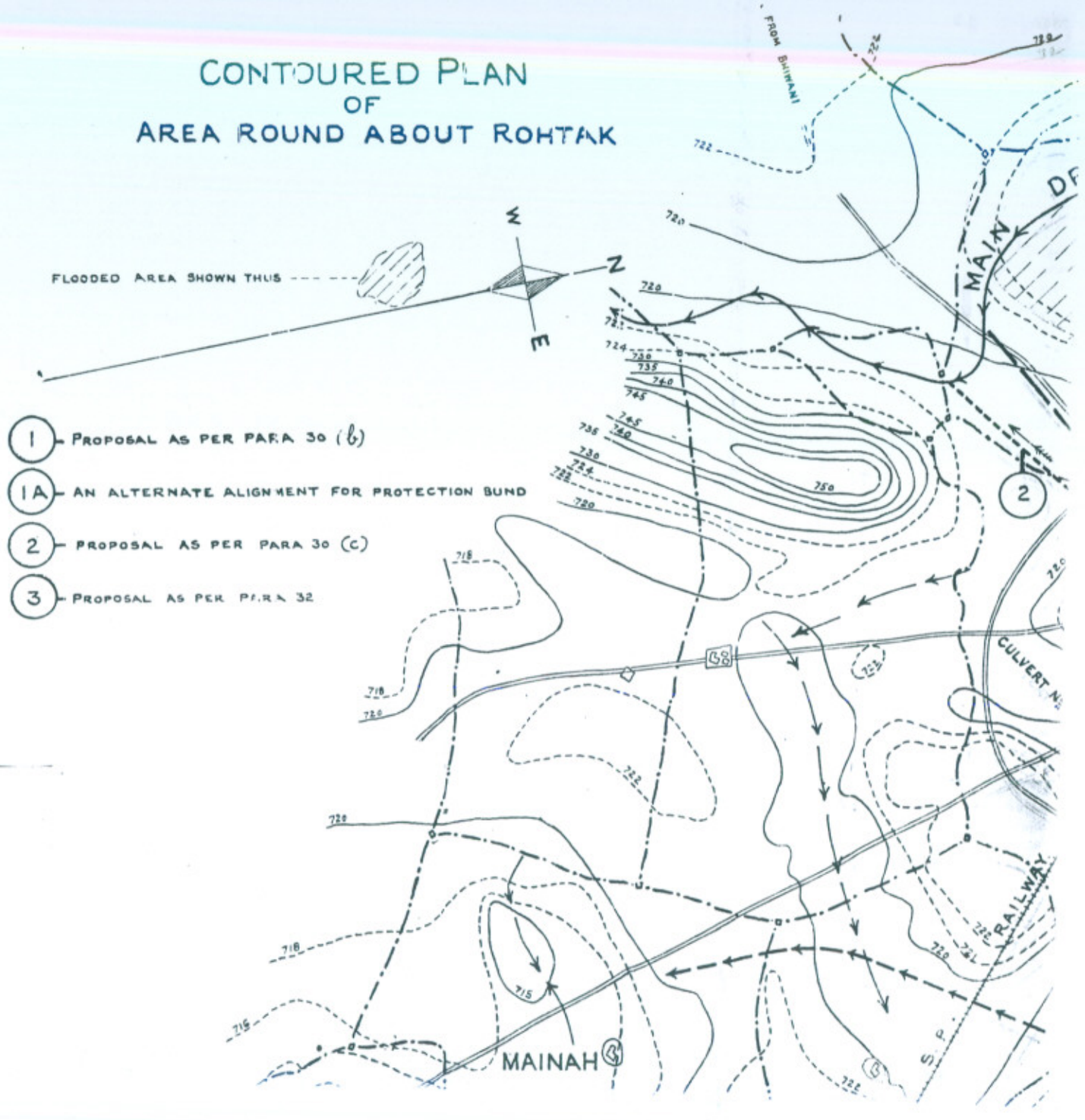
AREA FLOODED IN SEPT: 1933




MAIN DRAIN No. 8
DISTRIBUTARY
MAKRAULI KLY. STN.
TO GOHANA
TO PANIPAT


TO HISSAR
TO RAITINDA
TO JIND
SINGHPURA
SUNDARPUR
CULVERT No 596
CULVERT No 508
ROHTAK
DISTRIBUTARY
ROHTAK RLY STN
GOVT: COLLEGE
CIVIL HOSPITAL
CANAL REST HOUSE
KHAULI RLY STN
ROHTAK GOHANA PANIPAT

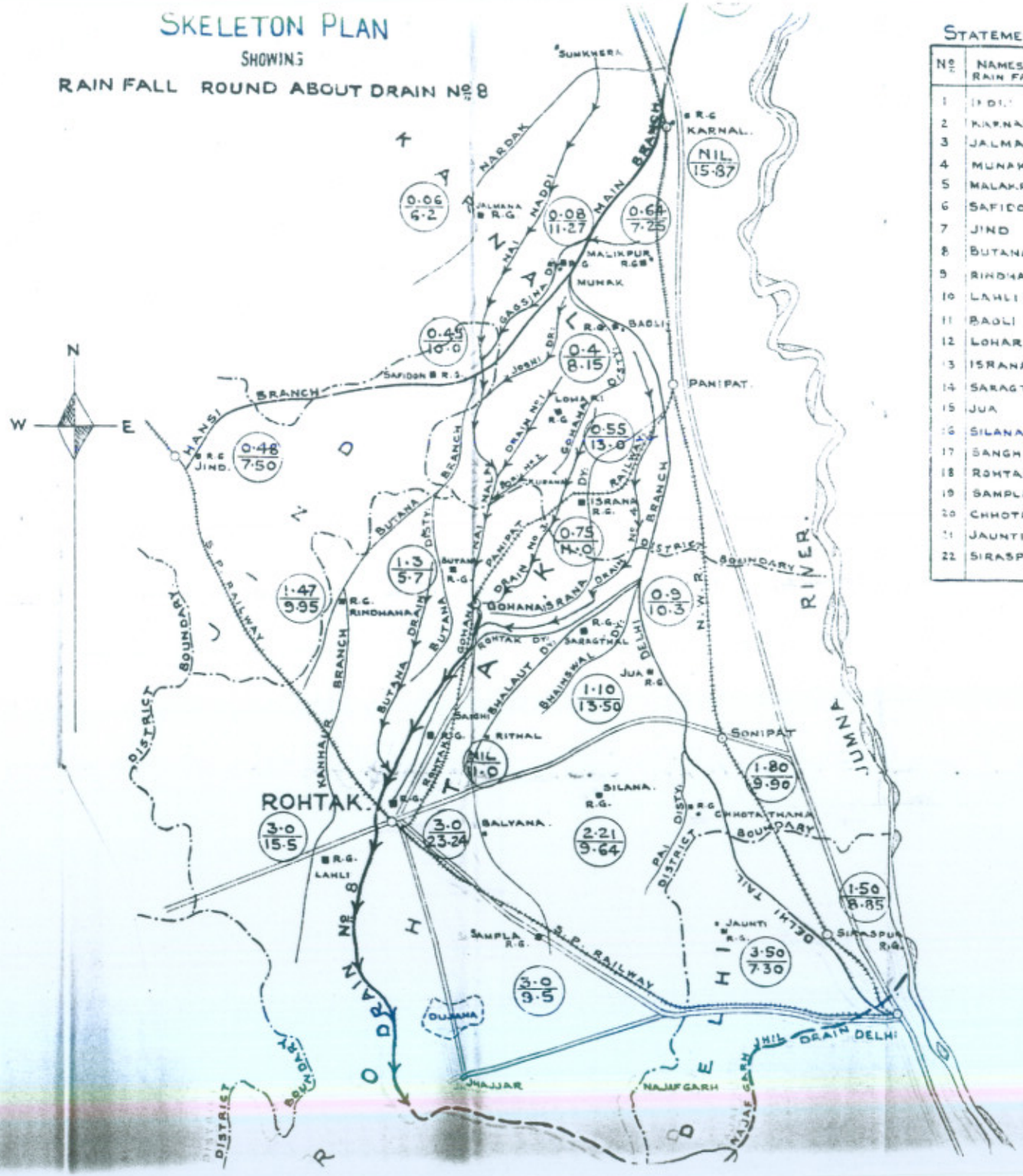
CONTOURED PLAN
OF
AREA ROUND ABOUT ROHTAK



SKELETON PLAN

SHOWING

RAIN FALL ROUND ABOUT DRAIN No. 8



STATEMENT SHOWING RAIN FALL

No.	NAMES OF RAIN FALL STN.	DATES	
		18.9.33	19.9.33
1	DELHI	-	6.5
2	KARNAL	-	15.87
3	JALMANA	0.06	6.20
4	MUNAK	0.08	11.27
5	MALAKPUR	0.64	7.25
6	SAFIDON	0.45	10.00
7	JIND	0.48	7.50
8	BUTANA	1.30	5.70
9	RINDHANA	1.47	9.95
10	LAHLI	3.00	15.50
11	BADLI	0.40	8.15
12	LOHARI	0.55	13.00
13	ISRANA	0.75	11.00
14	SARAGTHAL	0.90	10.30
15	JUA	1.10	13.50
16	SILANA	2.21	9.64
17	SANGHI	-	11.00
18	ROHTAK	3.00	23.24
19	SAMPLA	3.00	9.50
20	CHHOTATHANA	1.80	9.90
21	JAUNTI	3.50	7.30
22	SIRASPUR	1.50	8.85

LONG: SECTION OF DRAIN No 8

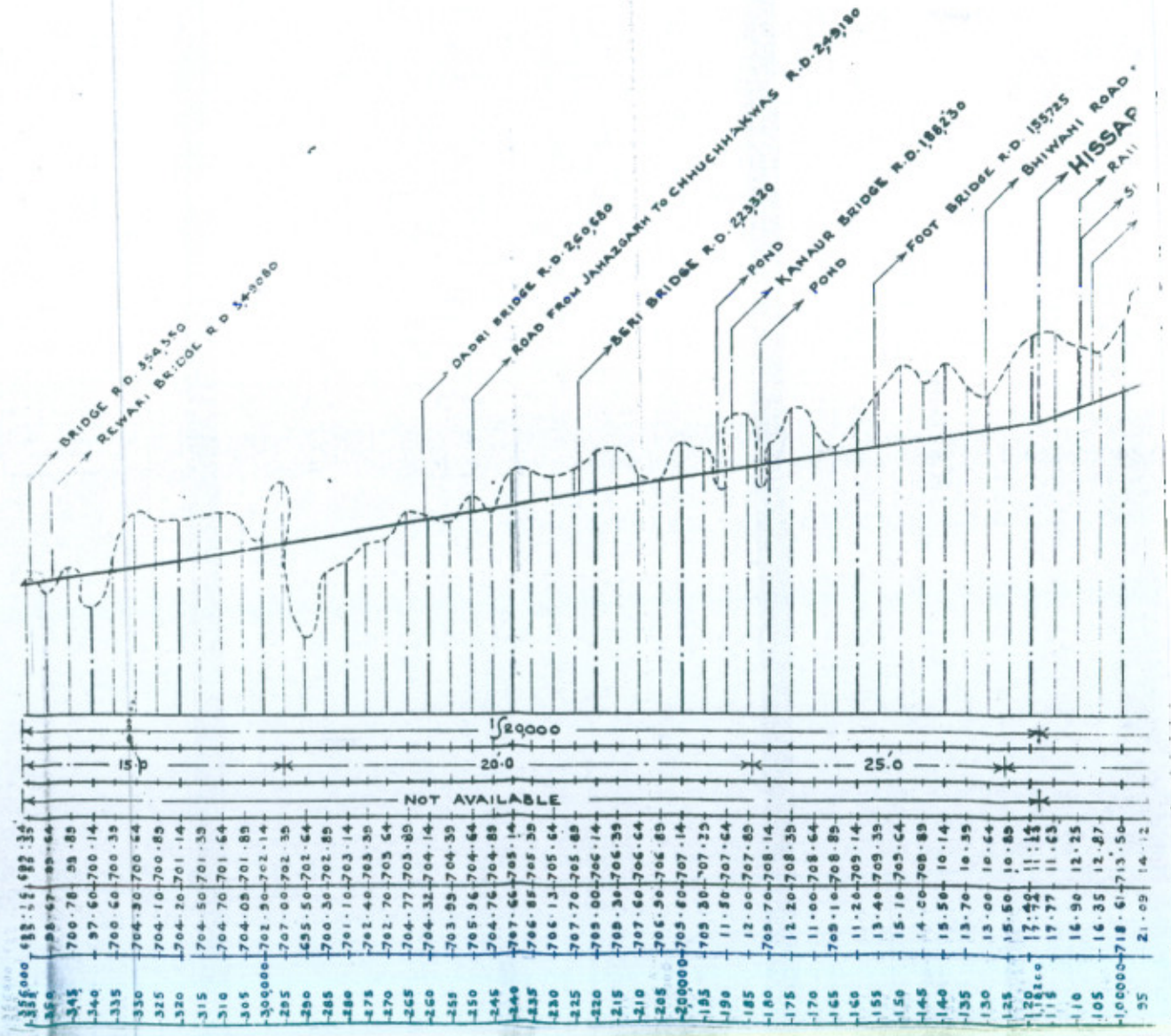


PLATE IV

194

LONG: SECTION OF DRAIN No 8

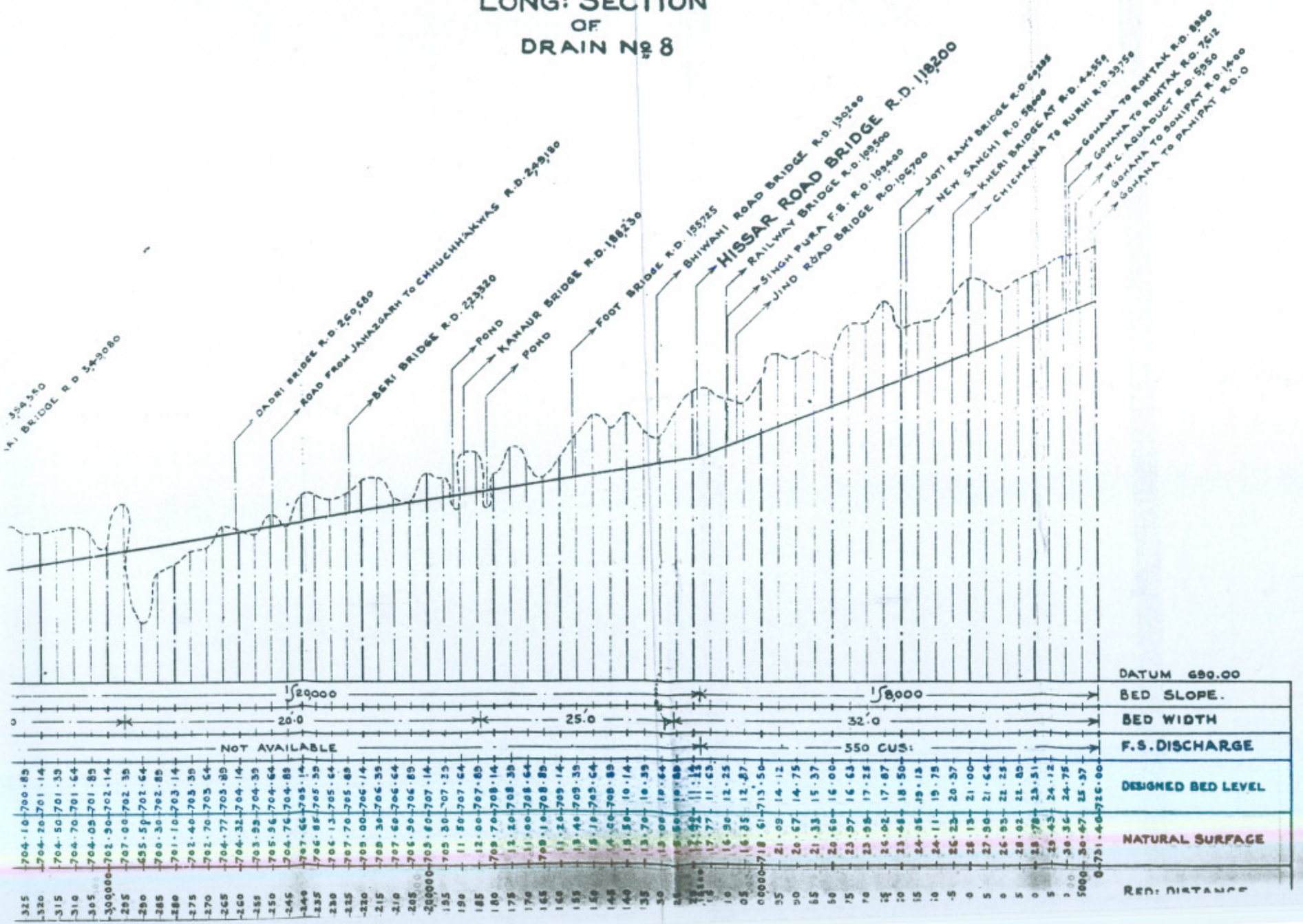
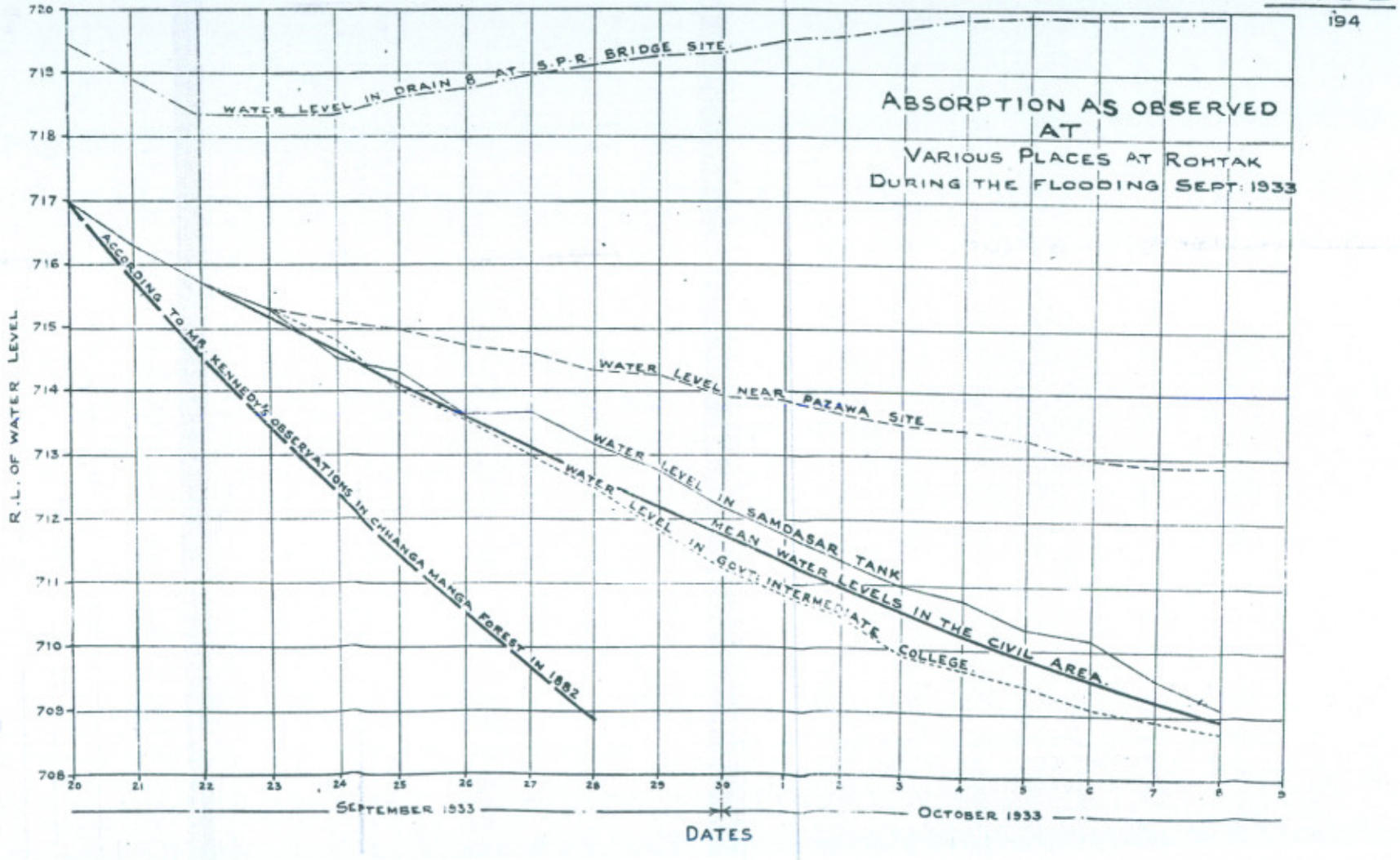


PLATE V

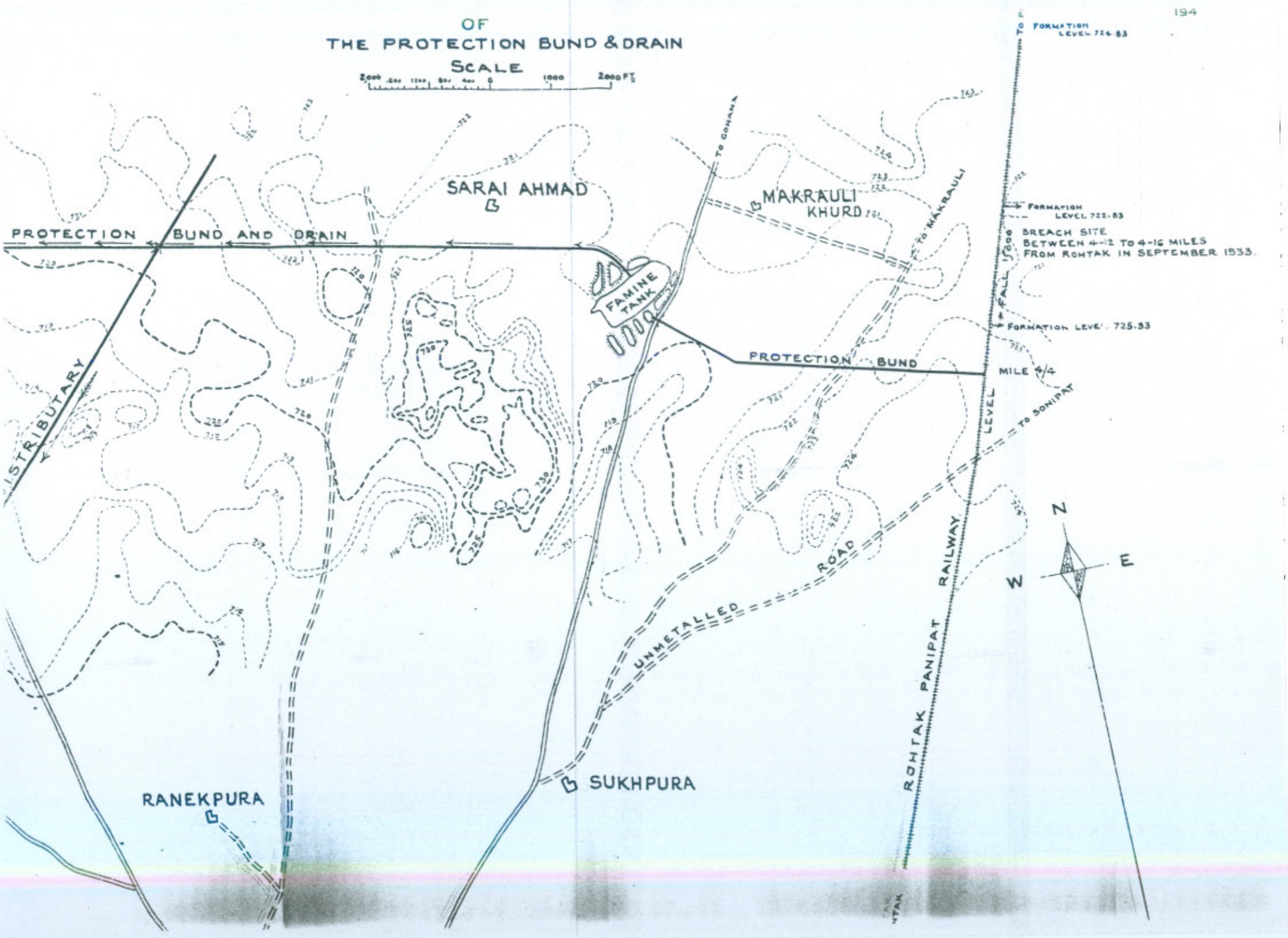
194

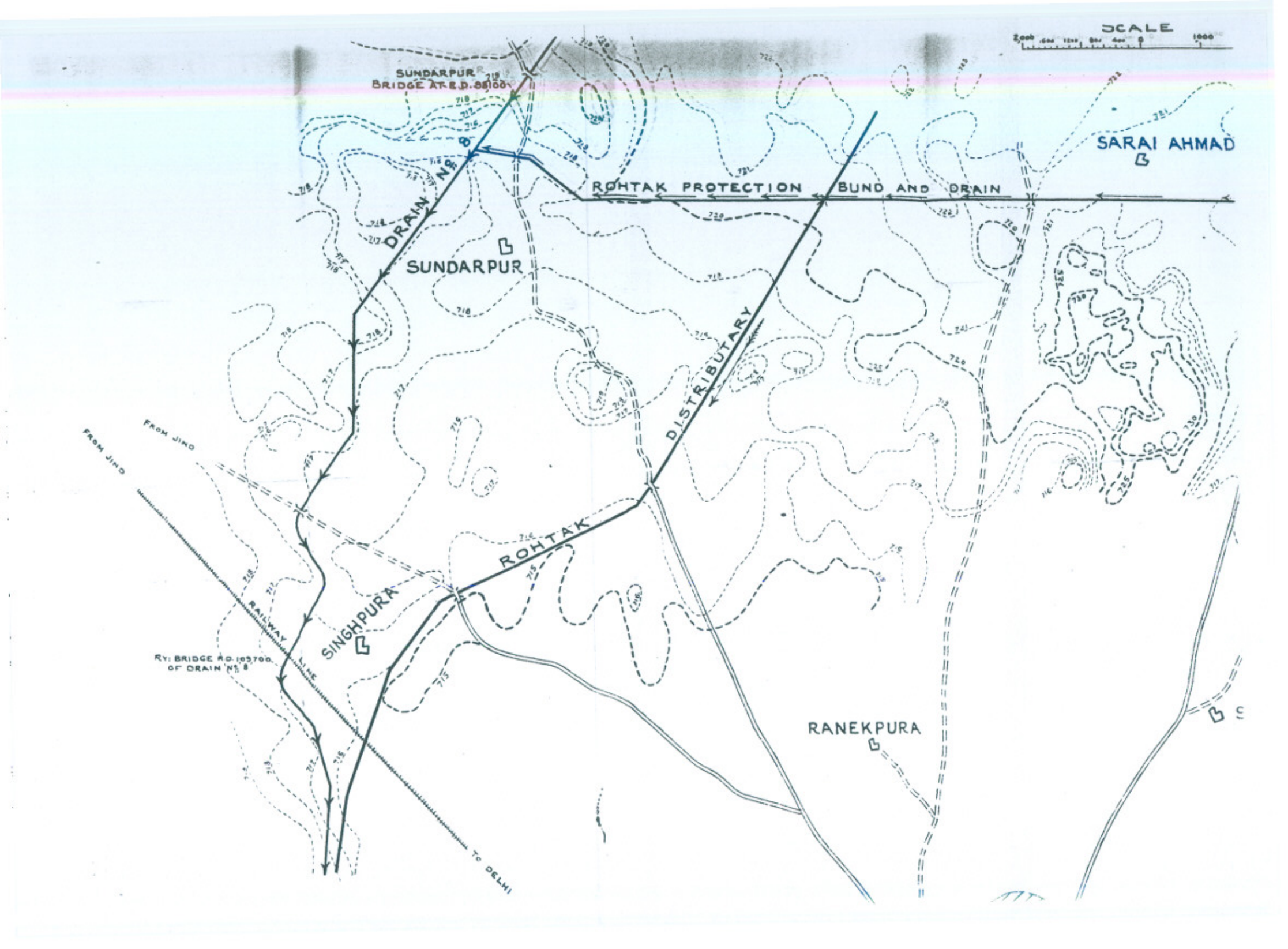

ABSORPTION AS OBSERVED AT
VARIOUS PLACES AT ROHTAK
DURING THE FLOODING SEPT: 1933
WATER LEVEL IN DRAIN 8 AT S.P.R. BRIDGE SITE
WATER LEVEL NEAR PAZAWA SITE
WATER LEVEL IN SAMOASAR TANK
WATER LEVEL IN GOVT. INTERMEDIATE COLLEGE
MEAN WATER LEVELS IN THE CIVIL AREA.
ACCORDING TO MR. KENNEDY'S OBSERVATIONS IN CHHANGA MANGA FOREST IN 1882
R.L. OF WATER LEVEL
720
719
718
717
716
715
714
713
712
711
710
709
708
20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8 9
SEPTEMBER 1933
OCTOBER 1933
DATES

OF THE PROTECTION BUND & DRAIN

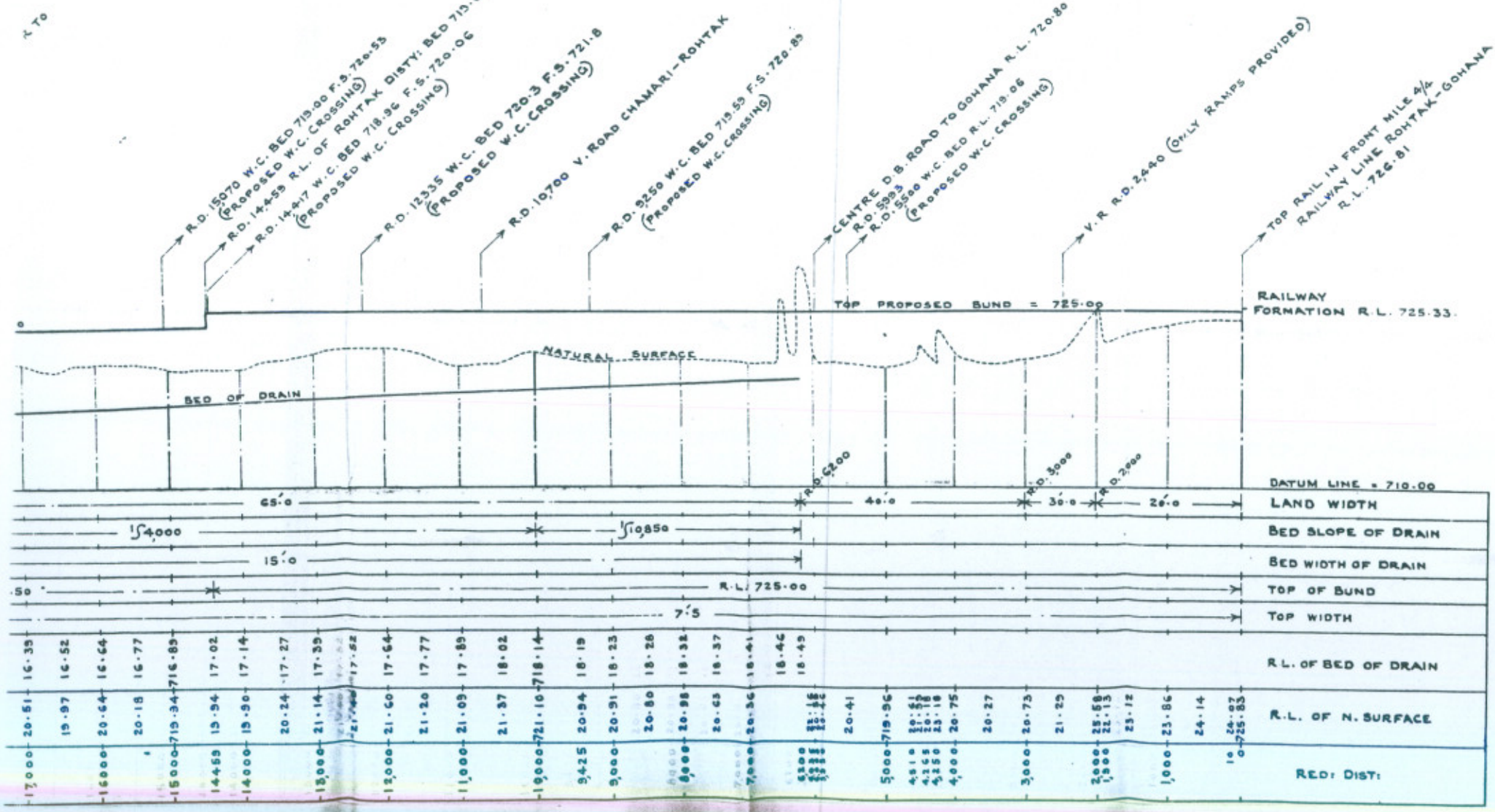
SCALE

2,000 1000 0 1000 2000 FT.

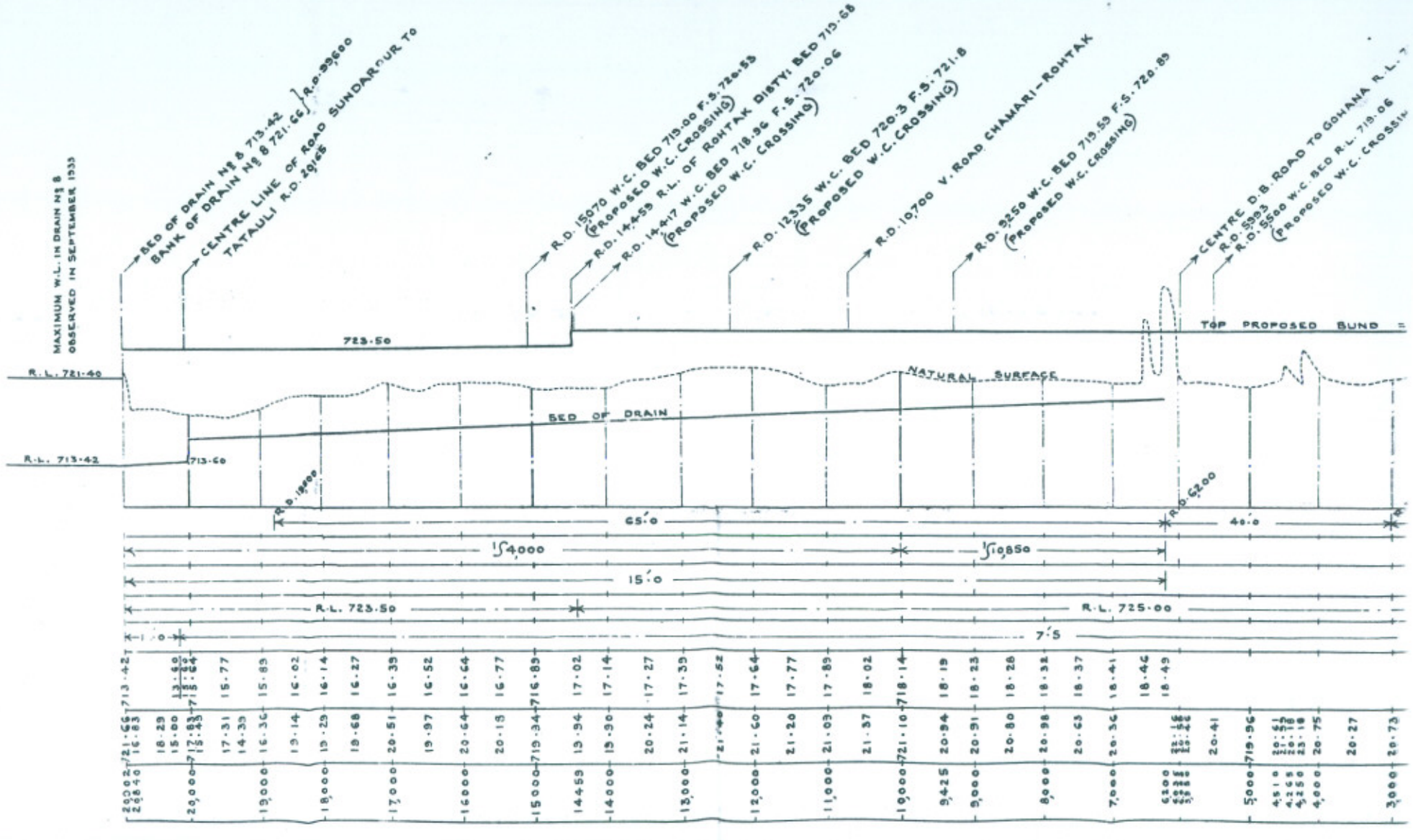



SCALE
SUNDARPUR
BRIDGE AT R.D. 98100
DRAIN No 8
SUNDARPUR
ROHTAK PROTECTION BUND AND DRAIN
SARAI AHMAD
DISTRIBUTARY
FROM JIND
FROM JIND
ROHTAK
SINGHPURA
RAILWAY LINE
RY: BRIDGE R.D. 103700 OF DRAIN No 8
To DELHI
RANEKPURA

LONGITUDINAL SECTION OF ROHTAK PROTECTION BUND & DRAIN



Longitudinal Section
of
Rohtak Protection Bund & Drain



DISCUSSION.

Mr. **Kanwar Sain** introducing his paper drew attention to a few mistakes in printing.

The fourth photograph was the view of Rohtak bazar while the fallen building in the fifth photograph was the Dak Bungalow. These photographs had been taken on the 20th of September, 1933. On plate II references to various proposals had been made. During printing the paragraph Nos. had been scored out by the Congress officials ; but unfortunately references on this plate had not been corrected. The proposal marked (1) was as per page 100 (*b*) and the proposal (2) was as per page 100 (*c*), while proposal (3) was as per first para. on page 101.

He stated that the total remissions of land revenue and water-rates for *kharif* 1933 for Rohtak District alone came to more than Rs. 8 lakhs. Rohtak was so notorious, for its famine that one would hardly believe that there could be any complaint of excessive rainfall in that district. In fact, in the history of its country-side, famines served as epochs. The memory of at least fourteen well-known famines in a period of 150 years was still cherished in the local folk songs. About one of these famines the official report said that "an ox sold for a piece of bread and a camel for a farthing." He next referred to page 98 and stated that the mean rainfall at Rohtak was 19·5", the mean being taken over a period of 79 years. Against this mean annual rainfall a fall of 26" in 32 hours on the 18th and 19th September 1932 must be considered as very abnormal.

In considering the proposals for future protection against such abnormal rainfall, a compromise had to be struck between the expenditure and what might be termed as " reasonable measures " for future protection.

From an engineering point of view, Mr. Kanwar Sain classified the floods in four categories :—

(*a*) Frequent floods, which will probably recur at intervals of three to four years.

(*b*) Unusual floods, which may be expected at intervals of about 20 years.

(*c*) Probable maximum, which are likely to recur not more than once in a 100 years.

(*d*) Catastrophic floods caused by bursting of clouds or other extraordinary meteorological phenomena. The ratios of the intensity of the first three classes of these floods were usually taken as A=·5, B=·8, C=1. The intensity of the catastrophic floods may be, even, more than twice of the probable maximum. The flooding at Rohtak on the 19th September, stated the author, could easily be placed in the last category.

The provision to be made for floods in any engineering structure must depend on the nature of the work affected. In the case of an ordinary drainage scheme in which the overflow water in a period of storm would cause only a temporary and comparatively harmless inundation of joining land, a conservative allowance might be considered sufficient. The flooding of Rohtak Civil lines, however, would endanger not only valuable property but human life as well. Thus the problem assumed a much greater importance than an ordinary drainage scheme. Too much expenditure was to be avoided. A happy compromise had to be struck. The Rohtak town itself is almost fully protected by the protection bund, while a heavy expenditure on joining the Drain No. 8 to the Najafgarh Jheel Drain to lead the storm water into the Jumna river was considered unnecessary.

In a long succession of rainless years which are frequent in the Rohtak district, the protection works described in the paper might be considered unnecessary and their maintenance neglected. It was to emphasize this point more than anything else that the paper under discussion had been written so that the lessons of September 1933 might not be lost to the coming generations.

The author expressed his indebtedness to R. B. Sant Ram, and Mr. W. P. Thompson, from whose official reports a lot of useful information had been included in the paper.

Mr. **Brij Mohan Lal** said that the author was to be thanked for bringing on record in the proceedings of the Congress the unprecedented and unimaginable flood at Rohtak. The year 1933 was a year of very heavy rainfall in the South-East Punjab when every district therein viz., Hissar, Rohtak, Gurgaon and Karnal got more than double the mean annual rainfall. The climax was reached in the third week of September, when between the 17th and the 20th, more than twenty inches rain fell practically everywhere in the districts mentioned above. While conditions of flooding were experienced in some other parts also, Rohtak suffered the most, as the incidence of rainfall was the most severe there, 26 inches falling in 32 hours. As no river or stream flows in the vicinity of Rohtak, flooding could be least expected there, and it was a great surprise to him when daily papers on the 20th September gave accounts of the heavy flood, and telegrams were received by him from his Sub-Divisional Officer at Rohtak and the Chief Engineer at Simla. On reaching Rohtak by rail on the evening of the 20th, he found great panic on the railway station, where all the population of the Civil Stations had collected. It was fortunate that the flood did not rise upto the Railway Station, the Circular Road and the houses of the Deputy Commissioner and the Superintendent of Police, otherwise the relief measures would have been much more difficult and expensive. From the photographs and Plate No. I of the paper, it would be clear that the depth of water was as high as 10 feet in places. The road from the District Courts to the Railway Station *via* the Intermediate College and the *Mandi*,

was the most deeply flooded. It was difficult to imagine the running of boats and various kinds of improvised rafts in the bazars of Rohtak. Empty tar drums belonging to the P. W. D. proved very handy for this purpose. The author had described in detail in his paper the various methods proposed and adopted for dealing with floods, but there was no doubt that the only effective means by which the great volume of water disappeared, was natural absorption and percolation. The utility of work done by the various pumps worked under the directions of Messrs. Brosmage and Vesugar could not, however, be so minimized as referred to in the first para. of page 96. When not only the general public but also the M. L. C.s and M. L. A.s of Rohtak and the Civil Officials were jeering at the large number of Engineers collected there and were thinking they had only come there for a picnic, the arrangements of six pumps made within a very short period of three days, went a very long way in keeping intact the prestige of the Engineering profession, and also of Government. The pumps also did very useful work in clearing the compound of the Intermediate College and the plot near the *Mandi* of water which had not dried up till the first October, and rate of further absorption had become very slow.

On page 98, the author had mentioned a probable error of the mean rainfall but he could not find anywhere in the paper how this had been worked out and its utility.

On page 99, the author had mentioned under ' suggestions for preventing future floods ' the raising of a portion of the Delhi Hissar Road. The idea of doing this was abandoned in consultation with the Superintending Engineer, Western Jumna Canal, as proposals under *b*, *c* and *e* were being carried out. The raising of the road would have extended upto *Idgah* requiring interference with houses on both sides of the road, and the drains, and would have been very costly. With the construction of the bund on Gohana Road and the strengthening of the banks of Rohtak distributary and Drain No. 8, it was not considered necessary to raise the road.

The author had not referred in his paper to the damage caused by the flood to buildings, private and public, in the Civil Station which was, however, not so heavy as would be imagined from the extent of the flood. As there was very little velocity of flow of the flood water in the Civil Station, and water was practically standing still, only those buildings were damaged which were very old or built of very inferior materials. Soon after the drying up of the flood, houses were put into order by ordinary repairs. The Government building most deep in flood was the Intermediate College, where water level reached the top of verandah arches and did not dry up for about fifteen days, but no break whatever appeared either in walls, floors, or arches. The only buildings that fell down, were the Tehsildar's Quarters and the Dak Bungalow, which

had been constructed about 1850. The Tehsil building was very badly cracked and it was first proposed to build a new Tehsil on a site free from the danger of flooding. But, as it would have cost half a lac of rupees to do so, and funds were scarce the Chief Engineer decided to get the building repaired with a minimum expense. The big cracks in the walls were filled up with cement grout, walls plastered with cement mortar and floors and roofs replaced where necessary. The total cost of rejuvenating the main and auxiliary buildings, having a plinth area of 8000 s. ft came to Rs. 5000 only. A new Tehsildar's quarters had, however, been built at a cost of Rs. 5000, in the same compound as the Chief Engineer, Irrigation Department, considered it justifiable to take the risk of reconstructing the buildings on the old sites. For making other buildings habitable, wherever mud plaster and lime pointing had been washed away, cement plaster and cement pointing were done upto a height of 6 inches above the high flood level. The floors were repaired and cement-pointed, the doors were eased and compounds were cleared. Thus by the 7th October, *i.e.*, within a week of the drying up of the flood, all the buildings had been made habitable, except the Intermediate College, where too the work was in full swing in spite of the water surrounding it to the plinth level.

The Civil Hospital building belonging to the Municipal Committee was badly damaged, but as they expressed their inability to restore it, due to their weak financial position, His Excellency the Governor on his visit to Rohtak on 5th October, ordered the provincialization of the hospital. Consequently a number of residential buildings were practically reconstructed at a cost of about Rs. 8,000. All work of restoring damages had been completed by March 1934 and the total cost was Rs, 40,000 which was quite a low figure considering the big flood.

Mr. **Vidya Rattan** stated that there were just one or two points in the paper which were not clearly understood. He requested the author to explain the points given below :—

(1) First in regard to the drain along the protection bund, (Plate VII), a bed slope of 1 in 10850 was given in the reach 6000 to 10,000 and 1 in 4,000 lower down to 20,900. Such widely differing slopes were not understood. Was the slope fixed from hydraulic considerations or just arbitrarily to keep the drain more or less two feet all along ?

The L—Section did not show the maximum discharge for which the drain had been designed, and there was no mention of this in the paper either. On page 101 it was stated that " the drain is given a bed width of 15′ and a depth of 2′. In dry years it is not expected to flow, while in case of excessive rains the whole of the country side north of the bund will serve as a drain." The contours north of the bund as shown in Plate VI did not fall. It was, therefore, not quite clear how the country side, north of the bund, could take up the spill from the drain.

As far as one could see the drain was intended to deal with the run-off from the catchment east of the Rohtak Gohana Railway Line, *i.e.*, the area lying between the Bhalaut distributary and the Rohtak Panipat Railway line. This area was 56 sq. miles and of all the sources of inundation, the heaviest as well as the most dangerous flooding resulted from this source. The maximum run-off in cusecs was not given. Mr. Ratna worked it out. One way was to calculate the precipitation on a standard area of 5 sq. miles from the heaviest recorded rainfall in 24 hours. 5 sq. mile was taken because the heaviest rainfall is very partial, *i.e.*, the record at a station for a particular storm applies only to a very limited area perhaps about 5 sq. miles around the Station. Equally heavy rainfall may occur at the other points in the basin but not in the same time, and as the basin increases the chances are that the flow from ground near the point of discharge will have ceased before the flow from remoter portions has had time to come in.

In the case under consideration the maximum rainfall from 18th to 19th morning at Rohtak was 23·24 inches and the discharge therefore came to $\frac{5 \times 5280 \times 5280}{24 \times 60 \times 60} \times \frac{23 \cdot 24}{12} = 3000$ cusecs (nearly).

This might be considered wide of the mark. So Mr. Ratna took what the author himself had assumed.

He had worked out the volume of water from this catchment to be 2795 foot-acres and as all this rainfall had fallen in 32 hours from midnight of 17th, 18th to the early morning of 19th September the maximum discharge comes to $\frac{2795 \times 4840 \times 9}{32 \times 60 \times 60} = 1050$ cusecs.

A drain 15′ wide and 2′ deep was ill suited to cope with this discharge, because the country-side north of the bund could not drain off the overflow from this drain, the rising contours precluding any such possibility. In all likelihood, therefore, a very considerable volume of this run-off calculated by the author as 2795 foot-acres, an equivalent of over 1000 cusecs would hug the bund and endanger its safety. It was therefore reasonable to conclude that either the drain should be enlarged or the bund made stronger than just 7 feet at top.

(*ii*) All this run-off of over a 1000 cusecs would augment the discharge of Drain No. 8, the overflow from which considerably increased would, in the absence of any proposal to enlarge No. 8 itself, impound east of the Jind Delhi Railway line and endanger the Railway line.

(*iii*) A word or two about the villages Sunderpura and Singhupura. To quote the author, " In years of normal rainfall the cultivators of these villages make small cuts to give water from drain No. 8 to their fields." This, the villagers would no longer be able to do, when the left bank of the drain and the right bank of the distributary had been raised; with the formation of the protection bund in the north, the irrigation of

these two villages would be cut off. This was not a small loss knowing that the number of the dry years was far in excess of those in which it rained heavily. One would like to know if anything had been done in this direction by way of providing vents or openings in the drain.

(*iv*) Lastly, a word about the nanner in which the author had evaluated the run-off from the sources of inundation. He had assumed that 5 per cent. of the total precipitation reached the end of the catchment.

Mr. A. F. Bruce in the proceedings of the institution of the Civil Engineers Volume CXXXVII, page 60 speaking of the flow off into Tansa Lake of the Bombay Headworks said, " At the commencement of the Monsoon when the ground was dry very little reached the lake. But as it advanced the proportion increased. Thus on 29th July 1897 of 3½ inches of rainfall only 43 per cent was accounted for in the lake, whereas in three days from the 23rd July to 25th July in the preceding year of 15·08 inches 94 per cent and in a like period 28th to the 30th of the same months out of 20·65 inches 97 p. c. flowed off. In the latter years the rains began early and the ground was much saturated when the storm referred to occurred. On page 315 Buckley gives 50 p.c. as the figure for the percentage of rainfall flowing off the catchment. The catchment was a tract 100 miles near Calcutta and the land had a small slope as may be expected in a deltaic region.

From the above it was clear that the condition of the catchment produced an enormous effect on the discharge. In the case of the rain storm in Rohtak the storm occurred on the 18th and 19th September ; before this there was rainfall in August to the extent of 8·84 inches, in July 7·69 inches, in June 8·6 inches and in May 2.63 inches. All this would show that the ground was saturated. And as the author had stated evaporation was also small as the air was fully saturated. Surface soils according to page 103 consisted of a mixture of clay and sand which seemed almost impervious. The declivity of the catchment judging from the contours was fairly high. In view of all these facts one would think that the figure of 5 per cent. of the total precipitation as reaching the end of the catchment was unreasonably low.

Mr. **Wazir Singh** said that the floods of 1933 described by the writer of the paper, according to the local historians were unprecedented ones, for the last 90 years. This tract of the country ordinarily remained very dry but on this occasion heavy floods visited not only the Rohtak district but affected the adjoining districts of Gurgaon and Karnal as well.

He was in charge of the Railway lines ; the Southern Punjab Railway, one of the main routes of communication between Delhi and and Lahore *via* Bhatinda, and Rohtak-Gohana-Panipat Railway, a branch line connecting Rohtak with Panipat and hence he came in close contact with the flood-affected areas.

The Civil Station of Rohtak town was very badly flooded and some places were actually as much as 10 feet under water, as mentioned by the author and illustrated by photographs attached to the paper. As several breaches had taken place in the night between the 18th and the 19th September on the Rohtak-Gohana-Panipat Railway he reached Rohtak on the 19th morning and saw the people of the town floating on temporary rafts made of bamboos and sleeper planks to save themselves from the floods leaving all their valuables behind.

The first portion of the breaches on the branch line was opposite culvert No. 601 (Plate II) where water flowing from *Lakar Mandi* to the *Samdasar* tank through this culvert had breached the line in 3 different places. The next set of breaches extended over about a quarter of a mile between miles 4/12 and 4/16 near Makrauli station. Here the line was crossing a depression, with low bank and without any outlet for flood water. After, necessary repairs had been quickly carried out, the Railway, embankment there served as a protection bund for it stopped further flow of water from Makrauli depression, from the upstream side of the bank, into Rohtak town.

After making this portion of the track fit for traffic and leaving the Sub-Divisional Officer in charge of further operation Mr. Wazir Singh proceeded on motor trolly towards Gohana to investigate the damage done further ahead ; there he saw nothing but huge sheets of water on both sides of the Railway track. One bridge, 5 spans of 40 feet, near Gohana with a fairly high bank was nearly submerged under water and was passing threatening floods through it ; the condition between Gohana and Mundlana was still worse ; in several places earthwork of the bank along with packing from underneath the sleepers had been completely washed away and the permanent way remained suspended.

The labour rates at Rohtak during the first few days of the floods had gone very high and labour was scarce even on Rs. 2 a day and hence all the labour for the repair work had to be imported from outside. The labour for railway repairs was brought from Delhi along with the provision for them and all the material for repairs such as pitching stone, ashes, gunny bags, etc., had also to be imported from outside. Further the task of repairs was not an easy one and hence taking into consideration the heavy cost involved and the importance of the line, the repair work was suspended and the line was closed for traffic for about a week till the floods had subsided. The above narrative though not alluded to by the author of this paper was given by the speaker to show the intensity of the floods and havoc caused thereby.

Much unmerited blame was thrown on Drain No. 8. This Drain was never designed to take such a voluminous discharge as was passing through it on this occasion and even if there were no cuts therein, water would have overflown the bank near Singhpura village, as the grade beyond the Southern Punjab Railway bridge and the Delhi Hissar road

was flat. With the closing of the cuts in the Rohtak Distributary as mentioned by the writer of the paper at the bottom of page 94, further outflow of water from this side into Rohtak town was stopped, but this left the village of Singhpura in an unenviable position.

Along with drain No. 8 the embankment of the Southern Punjab Railway also was subjected to a strong criticism. It was wrongly believed that the railway line was damming up the water and if some cuts were made therein the situation could be eased. As mentioned in the paper, in para. 2 page 95, some means had to be adopted for the outflow of water from Rohtak town. Gravity flow with possible cuts here and there was the simplest and the cheapest method and it was under these circumstances that cuts were actually suggested in the embankment of the Southern Punjab Railway. Mr. Wazir Singh was not averse to ameliorating the position of the inhabitants of Rohtak town and if he could be convinced that some cuts were necessary in the Railway embankment, he would have co-operated with the Civil Authorities and Engineers of other branches even at the risk of cutting off railway communication on this important route. To meet any such emergency, as a matter of fact, a ballast train loaded with pitching stone and sand bags was kept ready. However, in his opinin, cuts in the Railway line would not have improved matters at all. He was approached by the Deputy Commissioner, Rohtak, on this point and he had to take him with Mr. Kanwar Sain and other Civil Officers on the portion of the line which was supposed to hold up the water. There was about 10 feet deep water on both sides of the Railway track. Culverts No. 596 and 598 (Plate II) were discharging little, as there was small difference of level in water surface on the two sides of the track. Such heavy floods having not been experienced for the last 90 years this contingency was not at all looked into. The joint inspection of the site, and further running of several lines of levels by Mr. Kanwar Sain's staff, convinced him and the Deputy Commissioner that no cuts in the Railway embankment would help matters. This, however, did not satisfy the people. Frantic wires and phone messages were sent to Simla by some of the very important personages of Roktak with the result that the Railway Board from Simla telephoned the Agent, North Western Railway, Lahore, to send down a senior officer for examining the situation further. As a result of this effort, the Deputy Chief Engineer, North Western Railway, Lahore, had to come down there. The whole situation was examined by him and he agreed that the Railway embankment in no way held up the water and no cuts therein would have eased the situation. The Deputy Chief Engineer after inspecting the site called upon the Commissioner, Ambala Division, who was at Rohtak all these days and personally explained the situation to him. The Commissioner admitted that the Deputy Commissioner had been assured definitely by the writer of the note that the cuts in the Railway embankment would not help matters and no reports to this effect were actually made either by him or by the Deputy Commissioner to the authorities at Simla. Later on Drain No. 8 close to

Singhpura village where cuts were suggested in the Railway embankment, was inspected by His Excellency the Governor of the Punjab in company with other Civil Officers and the writer of this note. After the inspection His Excellency the Governor did not offer any criticism and this was a proof that the Railway authorities' view-point was accepted by him.

Mr. Kanwar Sain in his paper had shown the flow of water at the site of the Railway bridge on Drain No. 8 from Samar Gopalpur side towards Drain No. 8, but the speaker's observations led him to believe that the case was otherwise. He thought cuts in drain No. 8 on the bank on the off-side of Rohtak town helped matters considerably, as a lot of water passed through these cuts and flowed down right up to Samar Gopalpur, a station about six miles from Rohtak towards Bhatinda and caused some anxiety to him over there.

Mr. **R. T. W. Goodman** said he did not recollect any one actually measuring the discharge into wells and in this connection he was told, although he never personally saw it, that water levels fluctuated as considerally, as if sudden rushes of water into the subsoil caused by some blocking of particles giving way was happening. He considered the gross effect of the wells was greater than the author had stated.

He did not consider wells were rendered less fit ; practically every well put into use had already been flooded by flood water. The pressures created by filling of the wells would tend to improve future supply and it was believed that this was what happened. Persons probably did object to their wells being used as pipes to the subsoil water level, but he believed the consensus of opinion was that their wells being so used did more good than harm and in any case people were prepared to do anything to get rid of water.

He agreed that in point of fact the water went of its own accord by natural percolation. On the other hand he did not think that other efforts to accelerate the disappearance of the water should be viewed so dispassionately. In these matters, he said, every little thing helped and where calamities were concerned, one had to think not so much in terms of mathematics as mass psychology. The people saw efforts being made to rid them of water and they saw the water going and the effect was to start them off setting their places in order instead of just sitting down on a heap of bricks bemoaning the remains of their property and the valuables buried and spoiled beneath the remains.

He said he would very much like to know the author's comment on the efficiency of this bund at the point where it joins the railway embankment.

How was this filled and what was done with the drain running alongside the railway embankment? He was always nervous of this.

The first proposal to be worked out did, as the Author had said, run to a lakh or two; this, however, was based on a proposal of the Chief Engineer for a complete ringing of Rohtak and an outfall into drain No. 8 south of Rohtak. Now, Drain No. 8 when in flow, had a total fall of 3 feet between where the new and existing bund causes surface flow into Drain No. 8 and where a new outfall south of Rohtak could have been located. Drain No. 8 flows on for a considerable period after local rain and local flooding and it is conceivable, therefore, that the area north of the new and existing bund could remain far longer under water then if it were drained by a small and less circuitous drain to join drain No. 8 south of Rohtak.

Mr. **Vesugar** remarked that the Engineers who arrived first on the scene were Mr. Kanwar Sain and himself, although neither of them were in any way concerned with the affair. Having arrived, they were both roped in and there they stayed. Mr. Kanwar Sain did signal service and should be called the Saviour of Rohtak, by obtaining and arranging information about contours and levels, without which everyone was working in the dark. The contour map reproduced as plate II was instrumental in saving Rohtak because it was with the aid of this map that they finally succeeded in turning the Civil Authorities from the idea of cutting the Railway Bank, which they wanted to do in obedience to public opinion.

He further added that it was absurd to expect that any number of 4″ and 6″ pumps could succeed in draining such a vast area. Actually with all the work that these pumps did, the level over the whole area could not have been lowered a fraction of an inch.

It was, however, not true that the only service that the pumps did was to produce a feeling amongst the stricken town's people, who heard the little Petters working day and night, that something was being done by Government. Besides this, the pumps served two extremely useful purposes.

The first was that the town's people maddened by the holocaust within their midst, and seeing the water up against the railway bank with certain ponds and things on the other side of the bank, immediately wanted to cut the bank, and nothing would induce them to believe that cutting the bank would let more water in. This feeling was only allayed and the facts believed, when they actually saw the water being pumped over and across the bank.

The second very useful purpose that was served was that certain important streets were isolated by means of bunds and the water drained by these pumps. This restored communications to a certain extent, which were only by boat the first two days. As soon as communications were restored, pumps were set to draining certain important *mohallas*

and *mandis*, which were geographically so situated that they could be isolated by bunds.

Mr. **A. N. Khosla** remarked that Rohtak seemed to be a land of contradictions. There were years when there was shortage of drinking water and yet there was the possibility of a deluge of the type that occurred on the 19th September, 1933. A range of annual rainfall between 2·7 and 55·17 inches was extremely unusual.

It was remarkable that while the town itself was situated on higher ground, the civil station, which appeared at a much later date, was in a depression. Another notable point was that a drain ran with a water level nine feet higher than some of the low parts in Rohtak.

Mr. Kanwar Sain had mentioned the various emergency remedial measures, namely, pumping, draining through existing wells and fissuring. Could he please assign the relative benefit derived from those measures in percentages as against what Nature achieved by means of natural absorption and evaporation?

The author's estimate of run-off as 5 p. c. of the rainfall appeared much on the low side.

Mr. **Sardari Lal Malhotra** stated that as he was connected with the Rohtak Flood Protection works for a short time over the completion stage, he would like to say something on the admirable work done by the author. For the final design as executed at site, the credit goes to the author though it was evolved after the problem had been tackled by various engineers. As evident from the contour plan the town, like all old human habitations, lies by the side of a depression in which the Civil Station has sprung up. The position of the area flooded, therefore, was specially suited for the deluge experienced. It was only due to the scanty rainfall in the previous years that the dangerous situation was not realized till 1933. As pointed out by the author the locality experienced more dry years than wet and hence the Civil Station went on developing with a false sense of security. Tempted by the favourable situation Nature tried to repeat the history of the ruins lying in the North-West of the town, which might have been victims of some such deluge in the past. Instead of yielding to the elements, however, the aid of the engineer was sought and the measures taken, though not enough to legislate for such unprecedented on-slaughts, aimed to make the town safe against floods of usual occurrence. It had been designed to evacuate the area on the east of the Railway line, gradually into the famine tank, and thence along the new drain into Drain No. 8.

The author must have carefully calculated the approximate foot-acres which are liable to run-off from the area north of Rohtak and east of Rohtak-Panipat Railway line a breach in which was the real cause of 9133 floods. He had not mentioned, however, what size of culvert the N. W. R. Authorities were asked to construct and what time would be required to evacuate the area. No attempt had been made by the author

to explain how he had arrived at the size of the drain and water way provided under the water-course and Rohtak distributary aqueducts. Some details regarding the capacity provided for these works would have been very helpful to gauge the safety of the works constructed. The magnitude of the works provided should be such as to approach at least to some extent, the limit of safety against floods of 1933, because it was only in such an unprecedented happening that necessity for the works had arisen. Ordinarily, in the known history of drainage of this area, there had never been any inconvenience to the inhabitants, and if the works did not provide some measure of safety against a flood approaching 1933 intensity, their usefulness and necessity for the expense could be questioned. He asked the author if necessity for such works had ever been felt before. If not, and unless the design was safe against a recurrence of 1933 floods, the provision of the works appeared to have only served the purpose of inspiring a sense of safety in the inhabitants, instead of being an absolute necessity. He pointed out that the drain did not function in 1935, the year of its completion and it was doubtful if it ever would, except in unusual years.

As the absorption and evaporation were the only two factors which managed to remove the volume of water impounded in the town in 1933, would it not have been enough to depend upon these factors and to have strengthened the Railway bank instead of providing a culvert in it, and constructing another bund north of the town, with top dimensions less than the railway bank. Strengthening the railway bank and bank of Drain No. 8 would have made the town secure against the sources of inundation in 1933.

Further, the author must have worked out the foot-acres of water which entered the town from the sources mentioned in 1933. In the case of such a recurrence, had the author calculated the height of bund required for impounding such a quantity and compared it with the provision he had made? The real usefulness of the works could have been appreciated only if such a comparison had been put before the Congress, and the extent to which the works constructed provide safety had been clearly shown.

The author had made a useful contribution towards cheapening the reinforced concrete works by using well washed locally available *kankar* in place of costly stone ballast. It was, however, still to be determined, if the quantity of mortar allowed was enough, as the voids in the *kankar* ballast were in a much higher percentage than in bajri and consequently the same rati oof mortar was insufficient for compact work. He asked the author to state definitely what percentage of mortar was to be allowed in this concrete. It was quite possible that in localities where *kankar* was available, it would oust the stone ballast in reinforced concrete work and hence its correct proportions for sound work should be determined.

R. B. **Bawa Natha Singh** said he would like to take this opportunity to impress on the members of the Congress the need for much greater co-operation between the different Departments of Government than was the case in practice.

In the case of Rohtak town while the old town is rightly built on high ground and is not subject to flooding, the Civil Station built by the Engineers of Government, was located in a hollow causing flooding of the nature experienced in 1933. This faulty location of the Civil Station could have been avoided if the Department, who was responsible for building the Civil Station, had consulted the Irrigation Branch who possess contour plans of practically all the areas in the Punjab.

Similarly in the case of Gujranwala and Sheikhupura towns both of them had been built on drainage lines, with the result that serious flooding took place whenever there was heavy rain. This flooding had caused the spring level to rise dangerously high in both these towns and Government had to incur very heavy expenditure on pumping with a view to keep the spring level down.

There is another town named Phullarwan which was built recently after the opening of the Lower Jhelum Canal. While the location of this town was not open to objection the design of the storm-water-drains in the town itself was entirely faulty. All these drains flow against the contours of the country into a tank which is built on the north side of the town while it should have been built on the south side. The result of this wrong design was that when rain started falling, the drains discharged into the tank, and when the amount of rain-fall was more than what could be contained in the tank, the tank overflowed and flowed bank into the town causing serious damage. This mistake could have been easily avoided, if the Department responsible for its design and construction had simply asked for a contour plan of the area from the Irrigation Branch.

In replying to the discussions Mr. **Kanwar Sain** thanked the members of the Congress who had participated in the discussion. He particularly thanked such members who had given a vivid account of what they actually saw at Rohtak during the latter part of September 1933.

There were four points in general raised by more than one member which required a reply from the author. He took up these points one by one. The author said that he had already admitted in the paper that the pumps created a lot of impression on the public mind and had proved useful in drying up local depressions. What he, however, doubted was that an expenditure of Rs. 8,000 appeared to be somewhat incommensurate with the benefits derived.

The next point raised was that the run-off of 5 per cent. assumed in the paper was very much on the low side. The author remarked that

the proof of the pudding was in the eating. The volume of water calculated from this 5 per cent. basis gave an average depth in the Rohtak area of about 3·5 ft., which tallied with the actual observations on the 21st September.

The design of the drain was absolutely arbitrary. The object really was to put in a protection bund to keep off the run-off water from the catchment area in the north of the bund. Advantage was taken to connect the burrow pits to form a regular sort of drain which would lead water into Drain No. 8, when the water level was sufficiently high. A lot of area in the north of the bund would serve as a drain. This was amply clear from the contours.

Some of the members considered that the entire works as constructed were unnecessary. They seemed to have forgotten that the water level in the Drain No. 8 twenty days after the heavy rain was about 9 ft. higher than the N. S. round about the Government College. It was considered that a reasonable measure of protection had been provided by the works constructed to inspire sufficient confidence into the minds of the inhabitants of the town. All the catchment area in the north which formed the chief source of inundation had been cut off and if the maintenance of the bund in the north of the town was not neglected in the future, it was expected that it would protect the town against being flooded. In any case, the people would know when another emergency of this kind had to be met with, what line of action they had to take?

For the benefit of Mr. Brij Mohan Lal the author gave the formula by which the mean rain fall had been worked out. This was :—

$$\Psi = 0{\cdot}6745 \sqrt{\frac{\Sigma (v)^2}{n\,(n-1)}}$$

where in Ψ is the probable error of the result, $\Sigma (v)^2$ the sum of the squares of the excess and deficiencies in all the years and n the number of years. By mentioning the probable error of the mean, the object was that the mean rainfall as given was pretty accurate.

In reply to Mr. Vidya Ratna the author said that Drain No. 8 continued to flow for more than 20 days after the rainfall of the 19th September. Therefore, it was not necessary to have the drain of such an enormous size as would drain off the run-off almost instantaneously, as the cost of such measures would be prohibitive. It was to be remembered that the Drain No. 8 was desiged to drain off the area above Gohana and not to drain off the Rohtak depression.

Regarding Sundarpura and Singhpura villages the author stated that they were receiving irrigation from the Rohtak Distributary.

Mr. Wazir Singh had graphically described the damage done to the Railway. It was true that numerous and insistent demands were made by the public and the Civil Authorities to make cuts in the bank of the Southern Punjab Railway. The author assured Mr. Wazir Singh that he was not responsible for such demands. In fact, he opposed them specially after a line of levels had been run by his staff from Rohtak to the Simli depression. This line of levels indicated that there was a valley between two ridges, in which water was held up at a higher level than that in the Rohtak Distributary and the danger of making a gravity drain from Rohtak to Simli was that the water from this might add to the already standing water of the Civil Station. It was this argument which finally succeeded in putting down the demand for a cut in the railway bank.

The author said that the strain on the North Western Railway was great indeed and remarked that he would be guilty of a serious omission if he failed to mention the willing co-operation which the N. W. R. authorities gave to the Civil Authorities and the Irrigation Engineers in these days of stress.

Replying to Mr. Goodman the author said that the calculation of the discharge of the well could be done by the application of simple arithmetic. It had been observed that a well filled upto the top took about 24 hours to go down to the bottom. Taking the area of a well as 10 ft. × 10 ft. and the depth as 50 feet, the discharge absorbed by the well came to $\frac{10 \times 10 \times 50}{24 \times 24 \times 60} = \frac{1}{18}$ cusecs. Mr. Kanwar Sain said that it was far from his intentions to put in any remark to belittle the work of those Engineers who had taken part in bringing relief to the town as every little bit of help was of a great value. He said, however, that it was easier to be wise after the event and it was to record this experience that he had mentioned the facts in the paper.

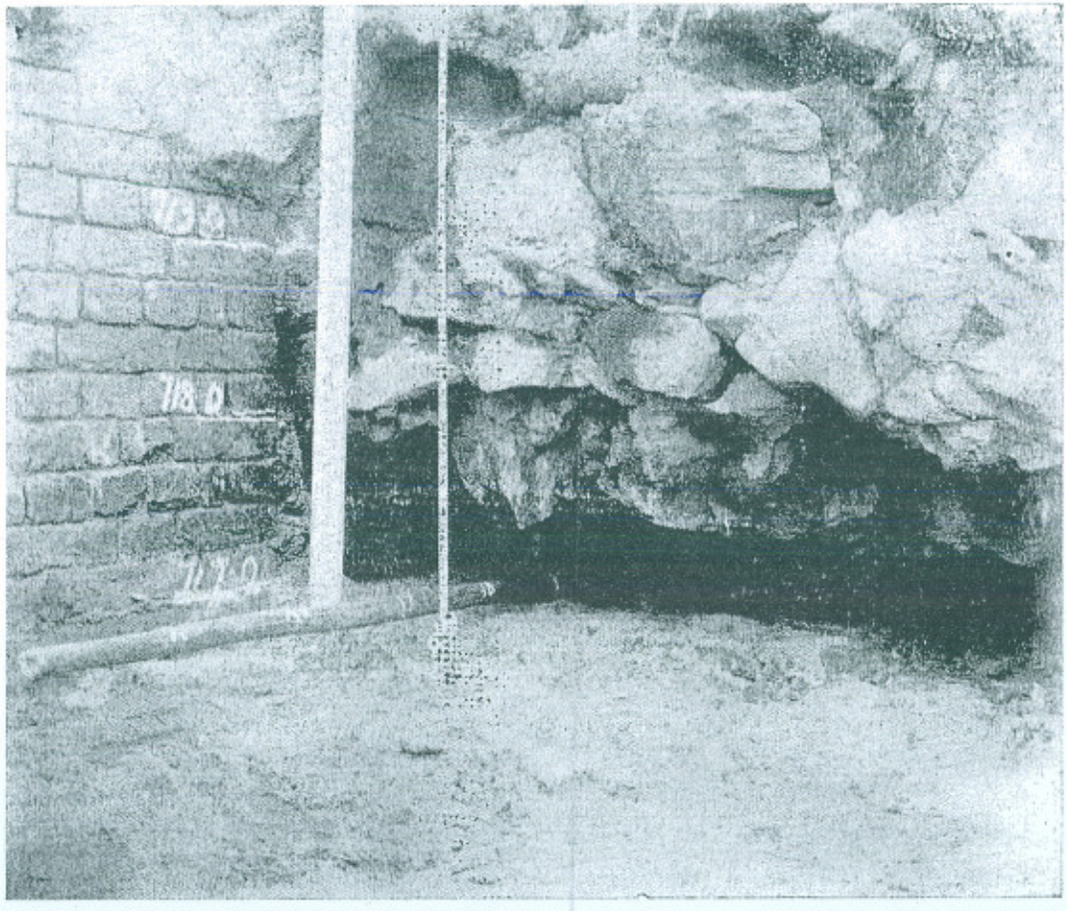
The protection bund had been joined with the railway bank; there was no distinct drain at site. In any case, the water from this drain would easily be led by the drain constructed just in the north of the bund.

The author thanked Mr. Vesugar for the compliments paid by him. The credit if any was equally shared by Mr. Vesugar, who was in the same boat with him.

Replying to Mr. Sardari Lal Malhotra the author said that most of the points raised by him had already been replied to. The top of the bank was kept higher than the maximum water level observed in September 1933.

The proportion of *kankar* concrete used in the works described in the paper was the usual 1 : 2 : 4. The author, however, suggested that the proportion should be determined for each individual case as the voids in *kankar* varied a good deal.

CAVITY UNDER KHANKI WEIR (PIER 5)



This cavity took 900 cft. of cement and sand to fill in.