PAPER No. 150.

SOME EXAMPLES OF CONTROL OF FLOODS IN TORRENTS IN THE PUNJAB.

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Preliminary.

The examples of flood control of torrents described in this paper are those which the writer had to deal with in his official duties. Different sites have their own problems and should be dealt with according to local conditions existing at the site. It does not therefore follow that if a method of controlling floods has succeeded at one place it must do so at another place or is also not capable of improvement there. The paper, however, will give an indication of the various points to be investigated and of the possible solution to be arrived at.

Gurgaon sailab bunds.

The first way to control torrents is the holding up of torrent water against bunds near the foot of the hills.

This method was successfully employed in Gurgaon district. The district has 3 ranges of hills from which torrents flow during the monsoon, and the water collects in 5 *Jhils* named Sikri, Khalilpur, Qutubgarh, Chandeni and Ujina (See plate 1). These torrents carry discharges varying from a few cusecs to as much as 800 cusecs. The biggest torrent called Landoha has its origin in Alwar State, but is swelled by torrents coming down the two ranges of hills on either side of its valley in Gurgaon district. The torrent would fill up large depressions lying to the North of Nuh Town, but a bund called Kotla bund diverts the water to Ujina Lake from where it flows southwards towards Bhartpur State in high floods. Only a small portion on the east of the district is irrigated by the Agra canal, the rest of the district is dependent for cultivation on rainfall, wells, or torrent water.

The idea of constructing sailab bunds against torrents to produce sufficient moisture in the soil as to grow and mature *Rabi* crops is an old one. As many as 32 bunds existed in the district when the Rural Sanitary Board took over charge of these works in 1923. These bunds, however, were designed in a haphazard manner under the guidance of the Civil Officers of the time. None of them had a waste weir and a very few had regulators to escape water standing against the bunds at the time of *rabi* ploughings. The result was that seldom did any bund escape from breaching or from serious damages from monsoon floods.

The Rural Sanitary Board at the beginning confined its attention to the drainage of the *jhils* which used to remain full of water the whole year round on account of breaches in bunds, as well as directly from torrents. The total area under the *jhils* was 25 sq. miles. By 1926 a drainage scheme was worked out which would have cost Rs. 16 lacs.

It struck the writer, however, that the water with which the district had been provided by nature in the shape of torrents should not be thrown away when it was badly needed for irrigation in most part of the district. He made calculations and found that all the water of the torrents could be held up by means of sailab bunds near the foot of the hills. Hence alternative schemes for drains and bunds were prepared and it was finally decided by Government to have a combined scheme of bunds and drains of small sections, because Government thought that bunds alone would not solve the problem. Bunds were started and since 1926, 16 bunds have been constructed at a cost of Rs. 1,92,000. The sites of these bunds have been shown on plate 1. As a result of this, it was found that during the past 2 years the area under Sikri and Chandeni *jhils* has become culturable. Landoha did not bring sufficient supplies during the past 2 years with the result that the Ujina *jhils* area has also been cultivated. A good deal of the areas under Qutubgarh and Khalilpur *jhils* has also been reclaimed. After the remaining 5 bunds have been constructed, there will be no fear of any area under the *jhils* remaining uncultivated. The results have been so satisfactory that the idea of constructing drains has been altogether given up. Besides reclaiming the areas of these *jhils* the scheme will irrigate 14000 acres of land from which Government will get an income of Rs. 21000 per annum as water rates. Thus the bunds have served a double purpose, *i.e.*, they avoided a costly drainage scheme and have provided a means of irrigation profitable both to the people and Government.

There are other advantages of far-reaching consequence accruing from the construction of the sailab bunds. These may be summarized as follows :—

1. The sand coming down from the torrents is prevented from spoiling cultivated land away from the hills.

2. The broken ground near the foot of the hills is levelled and reclaimed for cultivation.

3. The spring level of wells near the bund is raised thus facilitating the working of the wells.

4. The water of brackish wells in the vicinity of bunds is made sweet by percolation of water stored by the bunds.

5. The land downstream of a bund receives moisture by percolation enabling zamindars to grow *jhils* crops without any waterings.

In the scheme of bunds different torrents have been dealt with differently. Ordinary torrents of 2 to 6 sq. miles of catchment area have been dealt with individually. Smaller torrents near each other were taken collectively and a long bund built to hold the water of these torrents. Very small torrents, the water of which soaks into the soil before it reaches a *jhil* were left out. Four of the big torrents having narrow gorges and a wide basin in the hills were closed by dams at the gorges. The water that was stored above the dams was supplied to sailab bunds lower down through artificial or natural channels. Thus both the area in the hills as well as the area above the sailab bunds were

brought under cultivation. The biggest torrent the Landoha was dealt with in the following way. Its tributaries from the adjoining hills were stopped by sailab bunds separately and the main torrent was thus reduced to such dimensions that a bund could be put across it.

It may, however, be mentioned that it is not possible to have a storage reservoir scheme in the district. The soil is of such a nature that absorption losses are very high about 0·1′ per day against 0·1′ in a week in Central and Southern India. Thus with the small yields available, water dries up before it is needed for first watering in the *rabi*. A storage reservoir constructed in 1925 had to be given up on this very account and converted into a sailab bund.

Design.

A sailab bund is built at a site where spring level is low and sailab irrigation would be welcome. The alignment of the bund is on a contour where water would spread on as large an area as possible. The bunds have an upstream slope of 3:1 and outside slope sufficient to give an hydraulic gradient of 5:1. The bunds having 5:1 or flatter side slopes are most economical in maintenance. During the past 5 years no repairs were needed to such bunds. The weakest place in a bund is the site of crossing the torrent. Where the torrent bed is deep and narrow, sand or shingle must be removed to a depth of at least 5′ before the bund is built and the upstream slope should be about 10: 1.

The regulator is a small opening in the bund about 5′ × 5′ in size near the torrent bed with a cill about a foot above natural surface to allow for silting. This remains closed during floods and is opened about 10th. September to drain off water still standing against the bund so that land may dry up for rabi ploughings. It has been found by experience that a coefficient of creep of 1:15 in bed and 1:10 round wing walls is the minimum required.

The type of waste weir generally adopted is given in plate 2. This is able to pass only 1′ depth of water over the cill and is the cheapest form of construction. The discharge for which the waste weir is designed, is calculated on figures of run off given in Appendix 8 of Strange's book. These discharges are meant for storage reservoirs. In the case of sailab bunds, a co-efficient is applied which may vary from 9 per cent. to 18 per cent. according to the nature of catchment, and is the same as given in Appendix 2 of Strange's book used to give the run off and yield. The reasons why the waste weir of a sailab bund is designed to a smaller discharge are as follows :—

1. In sailab bunds absorption losses are high as the water is spread over a large area and water level falls considerably by absorption before a second flood comes.

2. The capacity of the bund at F. T. level is very large. The waste weir is designed to pass the maximum discharge with 1′ depth of

water. Freeboard is 3′. The waste weir can pass double the maximum discharge with 1·6′ depth of water leaving still a free board of 1·4′.

3. The bund is designed to hold the total yield of the catchment expected in a normal year. The waste weir comes into play hardly once in 5 years.

4. The height of the bund is generally not more than 8′. If a breach occurs, not very heavy damage is done. It would, therefore, be not worth while to spend a large amount of money on the waste weir.

In actual practice only 5 waste weirs came into play during the past 5 years. The coefficient used in the design varied from 9·2 per cent. to 18·4 per cent. In practice these coefficients were found to vary from 5 per cent. to 15 per cent. Thus the coefficients used are on the safe side. A series of observations in future will give a better idea of the coefficient to be applied.

In appendix I is given the calculation for the design of Bhond bund to serve as an example. (See plate 2). All the bunds in the district whether old or new have been redesigned, provided with waste weirs and regulators of the type mentioned in the example. It now only remains to complete the scheme which has proved so useful by the construction of five more bunds.

Malakmala Bund.

A Bund called Malakmala Bund was constructed in 1928 in Attock district for diverting the torrents of Gadgar mills through a short cut into the Indus (See plate 3). The real intention was to reclaim the Chehl waterlogged area, and to achieve this it was considered necessary to build a bund so as to divert a torrent called Namaki which passed through this Chehl area. As a number of other torrents came in the way between this and the outfall channel, these had also to be diverted by the bund. Total catchment area of these hills is 25 sq. miles, part of which is hilly and part plains having a steep slope of 1/100 near the bund. The water of all these torrents was expected to pass through an artificial waste weir of the flume type which was designed to take 1500 cusecs. After having built this bund, the Chehl drain was excavated together with a number of subsidiary drains and thus almost the whole of the waterlogged area was reclaimed.

The bund, however, breached the first year after its construction. The reason was that the torrents striking the bund headed up water before it could flow towards the waste weir. The bund was then raised and given a slope of 4′ from Namaki torrent to the waste weir site. It breached, however, again the next year. This time upstream slopes were pitched with stone and a berm provided on the upstream side. The bund breached again the third year. The design of the bund was reconsidered and it was found that the waste weir should have been designed for a discharge of 16,000 cusecs according to a conservative estimate and later on this figure was raised to 25,000 cusecs. Total amount of money spent on the bund and on compensation paid due to damages done by breaches was Rs. 4 lacs.

In order to revise the design on these figures, two alternative estimates were framed, one to raise the bund so as to increase the capacity and another to widen the waste weir and escape channel amounting to Rs. 11 lacs and Rs. 8 lacs, respectively.

In December 1930, the position was re-examined and it was thought better to give up the bund by cutting it at sites of crossings of torrents and to widen and deepen the Chehl drain so as to pass the discharge of Namaki torrent without any heading up in the area to the east of Hazro-Hatti road. This was done at a cost of Rs. 17,000 only. During the rains of 1931, two heavy floods came down the Namaki torrent and the remodelled drain passed away the flood in 4 hours in each case. No crop standing in the Chehl area was damaged. Water spread to some extent in lands above Hazro-Hatti road, but all passed away through the drain on the other side of it. A noticeable feature was that after the floods had passed the drain ceased to flow altogether. Formerly when its section was narrow, water used to stand over the ground for a few days before it was drained and the drain continued to flow with a discharge of about 10 cusecs the whole year round. This is a very important result and must be kept in view in the design of works in Hoshiarpur and Jullundur districts where the problem is to raise the spring level.

A number of useful lessons can be learnt from the failure of the bund as follows :—

1. The calculation of the discharge of a waste weir should be based either on the data collected from works in other parts of the country or on a series of observations made in the catchment.

2. A bund should not be too close to village *abadis*.

3. The result of the diversion of a torrent, on the area formerly receiving its spills, should be considered at the time of the design of the work, otherwise the effects are likely to be disastrous, for not only such an area would be deprived of fertilizing silt, but the spring level is also likely to go down considerably in the area.

4. All possible solutions of the problems involved should be considered.

5. Wherever a torrent strikes a bund with some velocity, the heading up, thus caused, should be taken into account in the design of the bund.

6. It should be remembered that a slope is required for water to flow towards the weir. This should be taken into consideration in the design of the bund.

7. A diversion bund should not be built on ground with too steep a slope.

The writer has built a number of diversion bunds and he finds that only the following conditions are suitable for the construction of such bunds.

1. A diversion bund should be far away from the hills and on flat ground so that velocity of water be not likely to erode the bund.
2. The waste weir should be a natural strip of country long enough to pass the flood discharge. An artificial regulator or waste weir should be avoided as on account of vagaries of the torrents and uncertainity of intensities of rainfall, the discharge of torrent in an abnormal year may exceed the figure on which the regulator or waste weir was designed.
3. The bund should be on a watershed as far as possible.
4. The depth of water against the bund should not be more than about 5.′

Training of Sarusti torrent.

The following was the state of affairs before the training of the torrent was done in the reach from Thanesar to the Ghaggar.

The water of this torrent had been made use of by zemindars by putting bunds across its bed and spreading it over the lands for purposes of irrigation. In time, the silt-laden water flowing over its edges in floods raised the ground on either side of the torrent bed converting it into a watershed. A high flood then made a diversion of the torrent into a drainage line. The zemindars followed this branch and put bunds across it thus creating another watershed. In this way the outfall of the torrent into the Ghaggar was completely blocked, and the water of the Sarusti spread every year in an area of about 50 sq. miles between Thanesar and the Ghaggar. Some of this area was sown with rice, but most of it remained full of reeds and long grass. Practically all communications were cut off.

In order to improve upon the conditions, the loops in the main torrent were straightened so as to give a bed slope of 1 in 3,000 (See Plate No. 4). The bed width of the remodelled torrent is 45′ and full supply depth 9′. Banks have been made on either side of the remodelled torrent bed or drain as it is now called. Two falls of 5′ and 3′ respectively have been made at R. Ds. 10,000 and 31,000, respectively, to prevent retrogression of bed levels. The drain is designed to carry the surplus supplies of the Markanda and Sarusti torrents. These torrents pour in their supplies into the Bibipur *jhil* from which the Sarusti canal is fed and after the *jhil* has been filled up to full tank level, the surplus escapes partly through a regulator which can take up to 700 cusecs with cill level 7′ below F. T. level of the *jhil*, but mainly over a long stretch of natural surface which is 1′ below the F. T. level and acts as a natural weir. The drain has been designed to carry 3,000 cusecs, but it has never run to more than 1,000 cusecs since it was constructed 4 years ago. Its bed had shown no sign of scour. The area formerly under spills is being irrigated by extending minors of the Sarusti canal and from minors taking off from the drain. Thus the water which used to spill from the torrents and

stagnate almost the whole year causing acute malaria and dislocation of traffic, is being made use of for irrigation by storing it in the Bibipur *jhil.*

The spring level in the area formerly subject to spills has gone down since the construction of the drain generally by about 6′ in wells distant one mile from the drain.

In spite of the fact that the people have benefited considerably, there have been very serious complaints from people who have been adversely affected, and since they made the most of the money formerly by growing extensive areas of rice, they can make their voice felt in responsible quarters. These people have joined hands with a few others who used to receive spills in abnormal floods and to whom it has not been possible to provide any means of irrigation now. There are other orthodox religious people who complain because their sacred tanks are in the reach of the torrent which has now been abandoned. These Pandits have been backed up by others outside the district on account of religious sentiments. It will thus be seen how important it is to consider all the vested interests involved in the beginning and provide for or settle them as far as possible.

The Sarusti torrent in its upper reaches near Jagadhri however has different problems to those described above. Here people are dependent for irrigation only on the spills of the torrents. Some of the lands, however, receive too much water and have been practically waterlogged. It is proposed to short-circuit the loops in this reach also, but no banks will be made on either side, to allow the water to spill in floods. The torrent however will need careful watching so that no obstruction is put in by zamindars, which may change the course of the stream.

Training of Dholbaha Choe.

There are a number of choes or torrents coming down the Siwalik hills westwards in Hoshiarpur district which have a very steep slope and bring down enormous quantities of sand. The Siwalik hills consist of very friable stone and sandy hills mixed with small boulders. When rain falls, the sides of hills and the beds of torrents are eroded. The velocity of the torrents is so high that even with 3′ depth, the water flows in huge waves.

As soon as a torrent emerges from the hills, it flows in a wide expanse spreading its load of sand and giving its bed the appearance of a sandy desert. On account of the steepness of the slope of a torrent, water runs off rapidly, leaving little time for it to percolate into the soil. During the last 30 years, the number of irrigation wells has increased considerably in the district with the result that the draw off from the spring level is more than replenishment from seepage and so the spring level in most part of Hoshiarpur and nearly the whole of Jullundur district has been steadily going down at the rate of about one foot per year. Things have come to such a pass that unless something be done soon, this garden of the Province will in a few years become waste land.

The problems to be tackled are first to reclaim the area under the torrent bed which has increased since 1852 from 48,206 acres to 84,853 acres and secondly to maintain the spring level and raise it as far as possible. A choe called Dholbaha has been selected to start with. The choe has a catchment area of 23·3 sq. miles and carries as much as 25,000 cusecs. The area under the bed of the torrent is 8,270 acres.

As sand comes down by the denudation of hills the remedy must be found by constructing works in the hills by selecting favourable sites for storage of water and help percolation into the soil. This suggests that reservoirs or detention basins should be built in the various branches of the choes in the hills which should hold water sufficiently long to allow as much of it as possible to percolate into the soil, but at the same time the reservoir should empty quick enough to receive the water of the next rainfall. The torrent above the reservoir will assume a flatter slope and so diminish the denudation of the hills. The reduced discharge below the dam will mean less velocity in the main torrent and so less erosion of the bed and sides of the torrent. It is also clear that in order to gain appreciable results, the dams should be built in torrents of small catchment areas. Keeping all these points in view, branch torrents having catchment areas of about $\frac{1}{2}$ sq. mile have been selected.

Two detention basins were built this year. In one branch called Jullahanwali, a rock-fill dam has been built. For plan and section of the dam see plate 6, the catchment area of the branch is $\frac{1}{2}$ sq. mile and the basin has a capacity of 0·6 m. c.ft. As the torrent runs, the dam heads up water against it, but at the same time allows some to pass through the crevices between the stones. The graph in plate 7 shows the working of the dam. It will be seen that considerable absorption takes place in the basin during the short period that water stands there. Roughly 96 % of the discharge that comes in the torrent is absorbed by the soil. It will also be seen from the curve (*vide* plate 7) that the discharge through the dam is low in the beginning, but increases rapidly as the gauge rises. This is due to the deposit of sand and jungle against the bund which blocks the passage of water.

No waste weir is needed in this case. The dam itself acts as an outlet. The torrent above the dam has however silted up by 4′ at the dam site.

In another branch choe called Bari choe, an earthen dam has been built. The catchment area of this choe is only 0·13 sq. miles. A flume outlet made of dry stones packed in wire crates has been provided in a side hill with cill 8′ above the bed of the torrent. The outlet is 5′ wide and it can pass the flood discharge of the torrent when water reaches the Full Tank level. It is expected that the basin will silt up to some extent and an allowance of 8′ has been made for this purpose.

The basin silted up this year by 3·0′. The torrent flowed on 3 occasions during the monsoon and results were as follows :—

Date of Flow.	Maximum Gauge U/s of the dam.	Period in which water dried up.
21-8-31	3·4	36 hours.
2-9-31	3·2	32 do.
4-9-31	2·3	24 do.

Thus all the water that came down the torrent was absorbed above the dam.

The observations made in the torrent give a very accurate idea of the percentage of run off expected from small catchments of different kinds of soil. In Appendix II are given calculations for the run off in Jullahanwali choe which comes to 50%.

The total rainfall during the monsoon of 1931 at Dholbaha near the foot of the hills was 23″. The total yield with 50 % run off is expected to be 1417 m. c.ft. If 96% of the total be made to percolate into the soil, about 1350 m. c.ft. of water will go down and will not only raise the spring level but also form springs and let the torrent run with a small discharge throughout the year which could be utilized for purposes of irrigation and running of mills. Besides this 8,270 acres of land under the torrent bed will be reclaimed. The price of *ghairmumkin* land in the district is Rs. 290 per acre and of *barani* land Rs. 645 per acre at a minimum. The advantages that will accrue by the reclamation of land under the torrent will thus be immense.

The sites of dams selected in the various branches of the choe are shown on Plate 5. Total cost of construction of these dams comes to about Rs. one lac. If the scheme be successful in this choe, it can be applied to other choes in the district. The following figures give areas under the torrents in the district (Hoshiarpur) .

Settle-ment 1852	Settle-ment 1884	Settle-ment 1897	Settle-ment 1913-14	As calculated roughly in 1927
48,206	80.057	94,326	98,948	84,853

The figures of 1927 are not accurate, but the above give an idea of the tendency of the torrents to bring more and more of the culturable area under their devastating influence.

It now remains to decide which of the two kinds of dams is suitable for our requirements. The rock-fill dam has the advantage that it needs no waste weir or outlet in addition, and is thus suitable in certain positions. It will also require no looking after. It has the disadvantage of being very expensive, *i.e.*, it costs 6 times as much as an earthen bund. The bed of torrent u.s. of the dam in this case is likely to silt up to a very large extent thus leaving a very small reservoir capacity. An earthen bund seems to require looking after. But experience of bunds in Gurgaon district has shown that a bund having 5:1 slopes and planted with reeds does not require any looking after. It has the advantage of low cost. It is expected that the outlet will not allow the basin to be silted up above its cill level. Percolation of water into the soil will be more in this case than in that of a rock-fill dam. On the whole it seems that earthen bunds will suit better than the rock-fill dam.

Making wats or small bunds at boundaries.

The construction of wats or small bunds at boundary of every field in a natural depression line which receives no water from hills has been tried to a large extent in Campbellpore district and found to be efficacious in holding the rain falling in a field in the field itself. The wats are only a foot high. In places where slopes are very steep, fields are stepped to hold the rain water and also to avoid ravining. By this means moisture can be retained in the field and probably this helps in maintaining the spring level. This method of holding water in fields needs to be encouraged at every place where spring level is low or falling down. It can only be useful if every zamindar has wats to his fields. The efficacy of this method is now being realized in Jullundur district where spring level is falling at the rate of 1′ per year and it would be very interesting to watch its effects on the spring level of wells and on the discharge of torrents. The immediate effect of this system is that as the fields retain moisture, the draw off from the wells becomes less. Effect of this on spring level is being carefully watched in Jullundur district where this system is being tried.

Conclusion.

It may be worth while to mention certain points to be kept in view when working out a scheme for the training of a torrent. It should be remembered that there are a number of vested interests on a torrent and although a torrent is always changing its course and some people thus gain at the expense of others, nobody complains about this. By training of a torrent however we can at best benefit only a majority of the people formerly receiving advantage from it. Those who are adversely effected will complain and put forward claims for compensation for damages. Thus the case of all vested interests should be carefully considered in the first instance. The effect on lands deprived of spills

by the training of torrents should be studied as regards spring level and fertility of silt, filling of tanks in the area and irrigation done by spills.

On the other hand many advantages can be gained by the training of a torrent. Water running to waste or causing waterlogging can be made use of for irrigation, waterlogged areas can be improved, sand can be prevented from spoiling lands, beds of torrents can be reclaimed for cultivation, spring level of neighbouring wells raised, brackish wells can be made sweet, denudation of hills or erosion of land avoided, *abadis* can be protected and sufficient head can be created for generating power.

The scheme should therefore be considered in a comprehensive manner and maximum advantages obtained by the training. This can only be done if the engineer has had experience of similar works and has seen a good many of such works in and outside the country. No hasty action should be taken and if the results cannot be foretold, the scheme should be tried in bits as an experiment. A certain amount of propaganda is necessary to make the scheme successful. Active sympathies of the zemindars affected and of the revenue officers should be secured and very good results can be obtained by the collaboration of the zemindars. The engineer has to make the best use of his knowledge to achieve good results out of the extremely complex problems arising in the training of torrents.

Appendix I.

CALCULATIONS FOR THE DESIGN OF BHOND BUND AND WASTE WEIR.

Catchment area 2·56 sq. miles.

Rainfall during monsoon 23″.

Average run off assumed 13·8% *vide* Appendix II of Strange's book " India Storage Reservoirs with Earthen Dams."

Yield of the torrent is thus 17 millions c.ft.

Refers to capacity and area curve

17 m. c.ft. will fill the reservoir up to R. L. 710·0 and this is taken as the Full Tank level.

Top of bund is 713·0.

Waste Weir.

Assume intensity of run off at 2·65″ per hour (See Appendix 8 of Strange's book.)

As this is a sailab bund and not a Storage reservoir, apply a further coefficient of 13·8% Appendix II of Strange's book (I).

Flood discharge to be expected :—

$$\frac{2{\cdot}56 \times 5280 \times 5280}{60 \times 60} \times \frac{2{\cdot}65}{12} \times \frac{13{\cdot}8}{100} = 604 \text{ cusecs.}$$

Discharge of waste weir is calculated by the formula $2.8\ L.H.^{3/2}$ Keeping height of water above cill=1′,

length of waste weir $= \frac{604}{2.8} = 216'$.

Appendix II.

JULLAHANWALI BRANCH OF DHOLBAHA CHOE.

OBSERVATIONS FOR RUN FROM THE HILLS :—

Date of observation	.. 30-8-31.
Rainfall between 1-50 and 4-0 in the catchment	.. 2·5″
Maximum intensity of rainfall observed ..	.. 3″ per hour.
Maximum discharge observed in the torrent	.. 498 cusecs.
Period of rainfall	.. 1 hr. 50 mts.
Total yield as calculated from the curves of discharge	.. 1·44 m. c.ft.
Catchment area of the Choe	.. $\frac{1}{2}$ sq. mile.

If X be the percentage of run off from the hills :—

$$\frac{1}{2} \times \frac{5280 \times 5280 \times 5}{2 \times 12} \times X = 1,44,000$$

$\therefore$ X=50% which is the average run off during the period of rainfall.

Basing our calculations on the maximum intensity of rainfall and maximum discharge we have

$$\frac{1}{2} \times \frac{3}{12} \times \frac{5280 \cdot 5280}{60 \times 60} \times X = 498 \text{ cusecs.}$$

$\therefore$ X=51% which is the maximum run off during the period.

PLAN

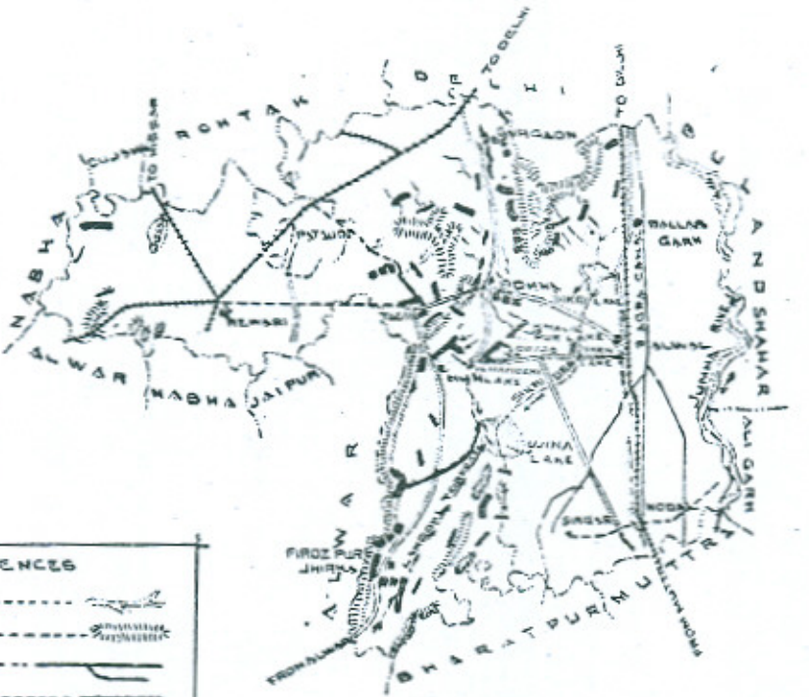
SHOWING

TORRENTS AND SAILABA BUNDS

IN GURGAON DISTRICT

SCALE 1 INCH MILES

PLATE No 2



REFERENCES

RIVER

HILLS

CANAL

RAILWAY LINE

LAKE OR DEPRESSION

BUNDS OLD

BUNDS NEW

BUNDS UNDER PROPOSAL

PACCA ROAD

KATCHA ROAD

DRAIN UNDER PROPOSAL

EXECUTIVE ENGINEER

RURAL SANITARY DIVISION

JULLUNDUR

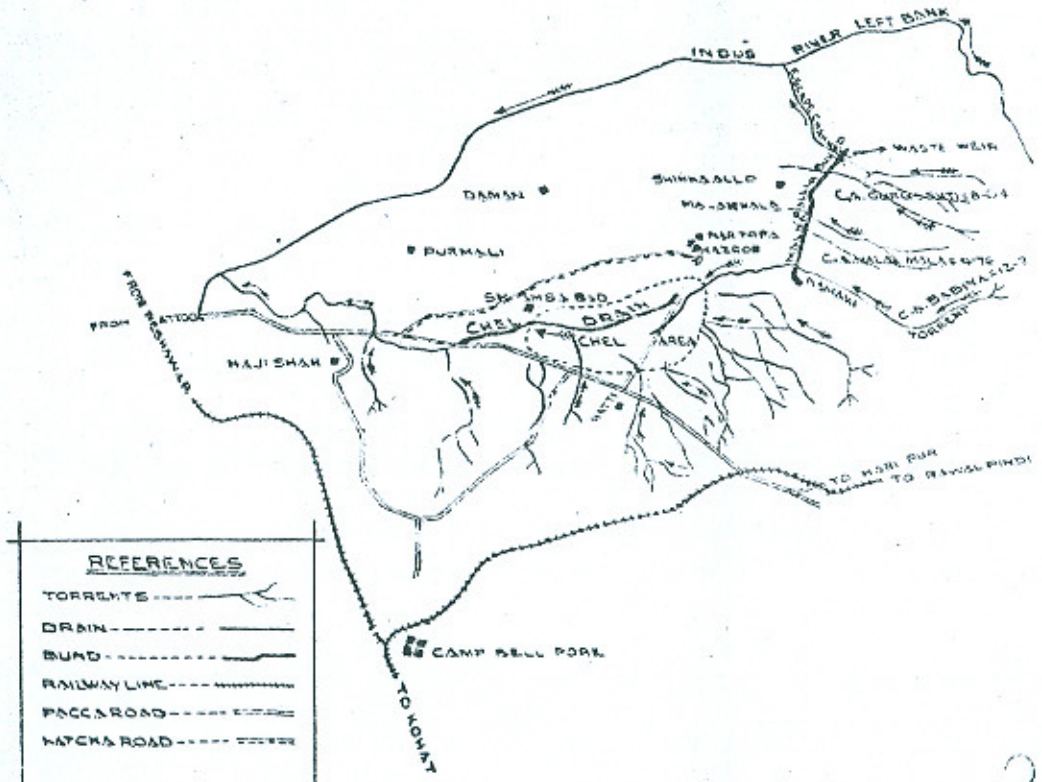
PLATE No 3

PLAN

SHOWING

MALAK MALA BUND AND CHEL AREA

SCALE 1 = 4 MILE



REFERENCES

TORRENTS

DRAIN

BUND

RAILWAY LINE

PACCA ROAD

KATCHA ROAD

Raj Parmar
13/1/1941
EXECUTIVE ENGINEER
RURAL SANITARY DIVISION
JULLUNDUR

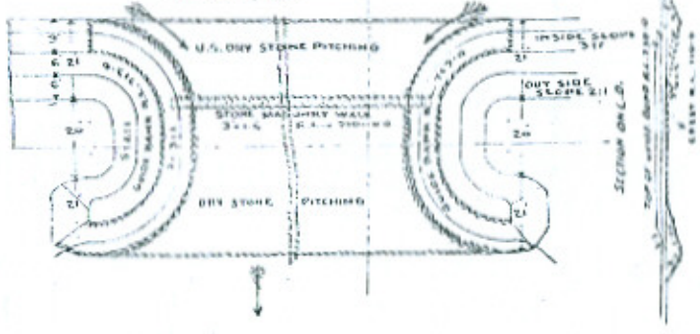
PLATE NO. 2.

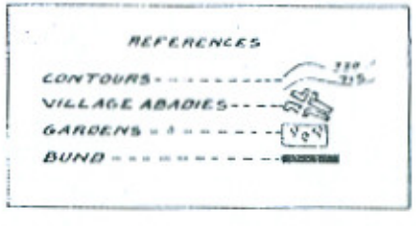
INDEX PLAN FOR BHOND BUND

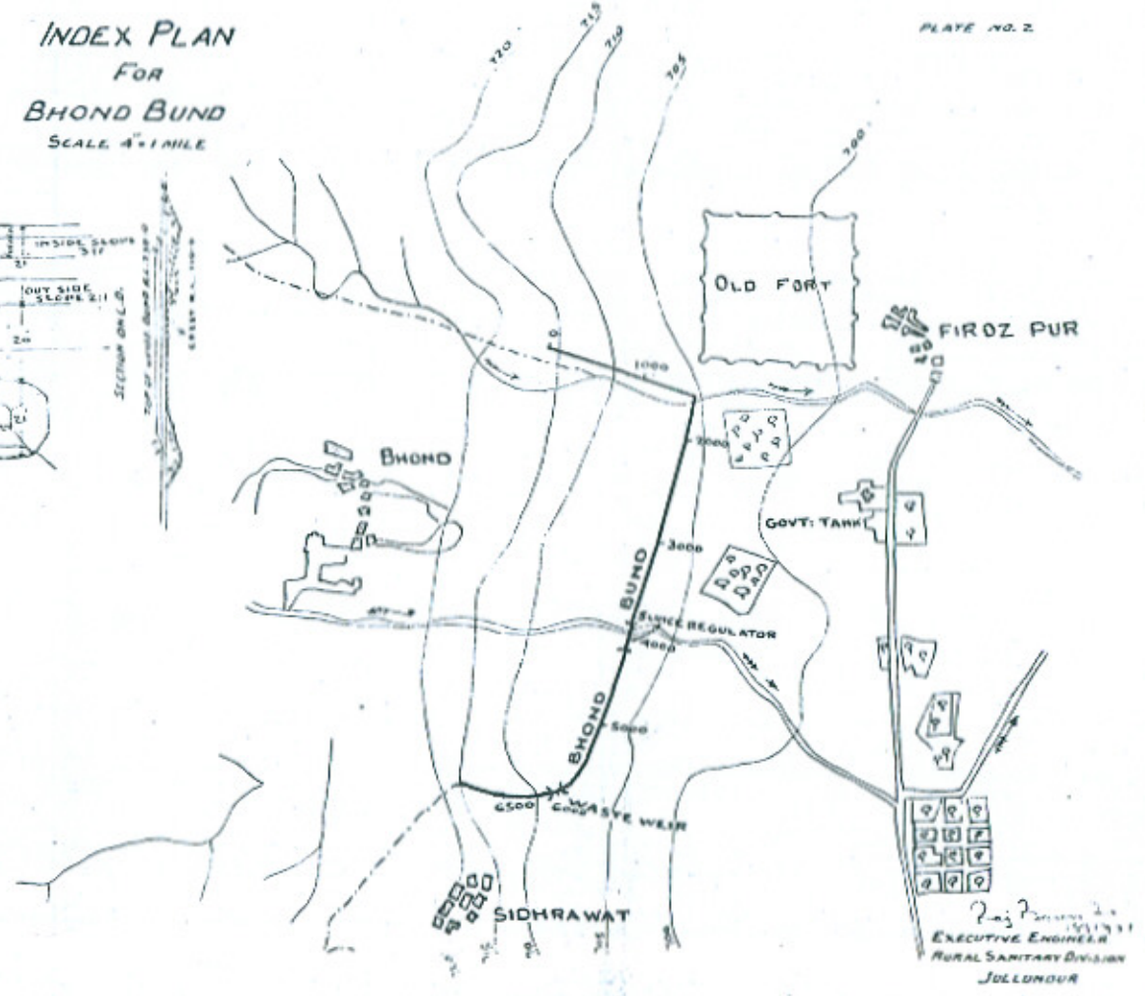
SCALE 4" = 1 MILE

PLAN OF WASTE WEIR ON BHOND BUND

SCALE = 1/200







EXECUTIVE ENGINEER
RURAL SANITARY DIVISION
JULLUNDUR

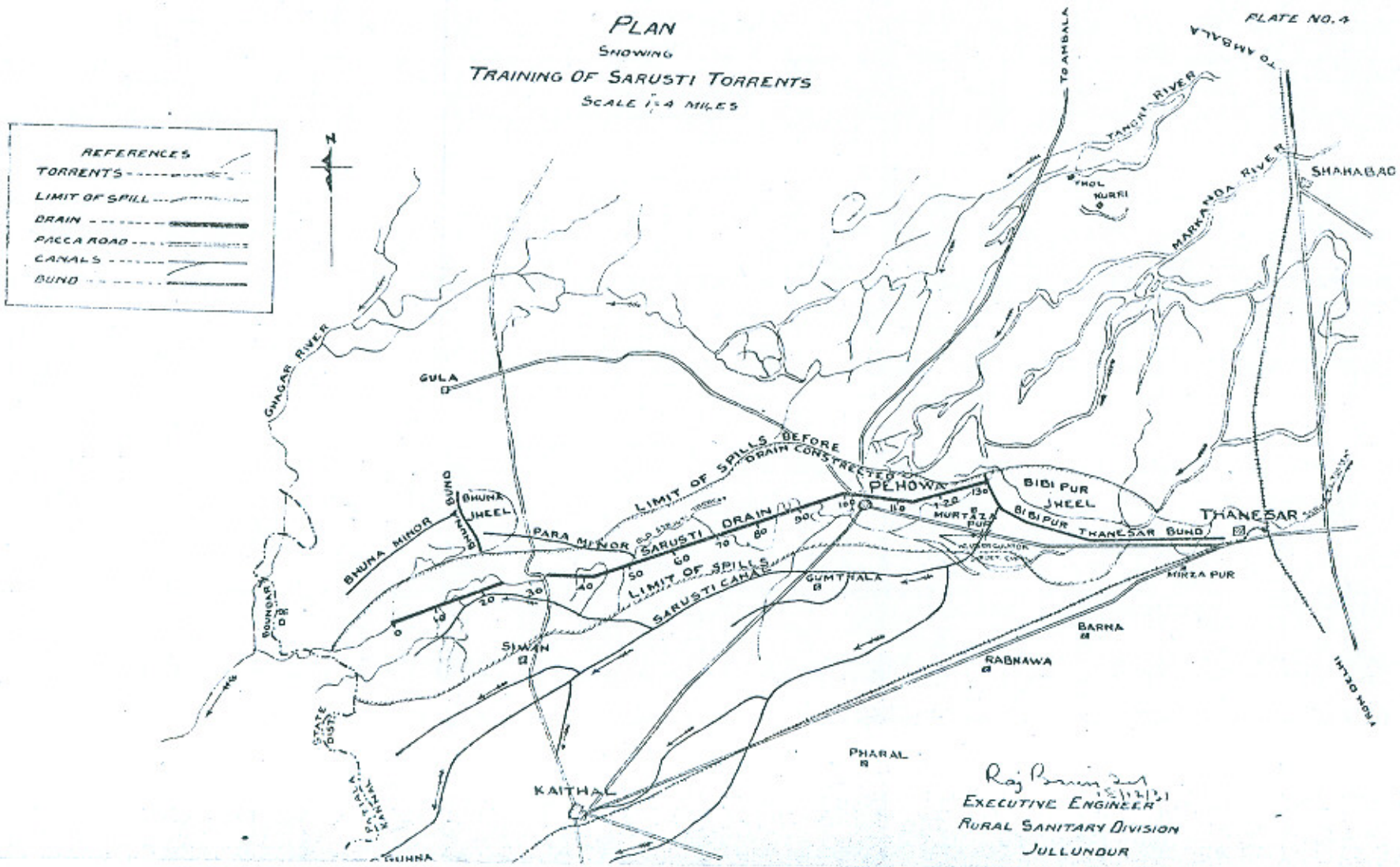
PLATE NO. 4

PLAN

SHOWING

TRAINING OF SARUSTI TORRENTS

SCALE 1"=4 MILES



Raj Paramjit Singh
EXECUTIVE ENGINEER
RURAL SANITARY DIVISION
JULLUNDUR

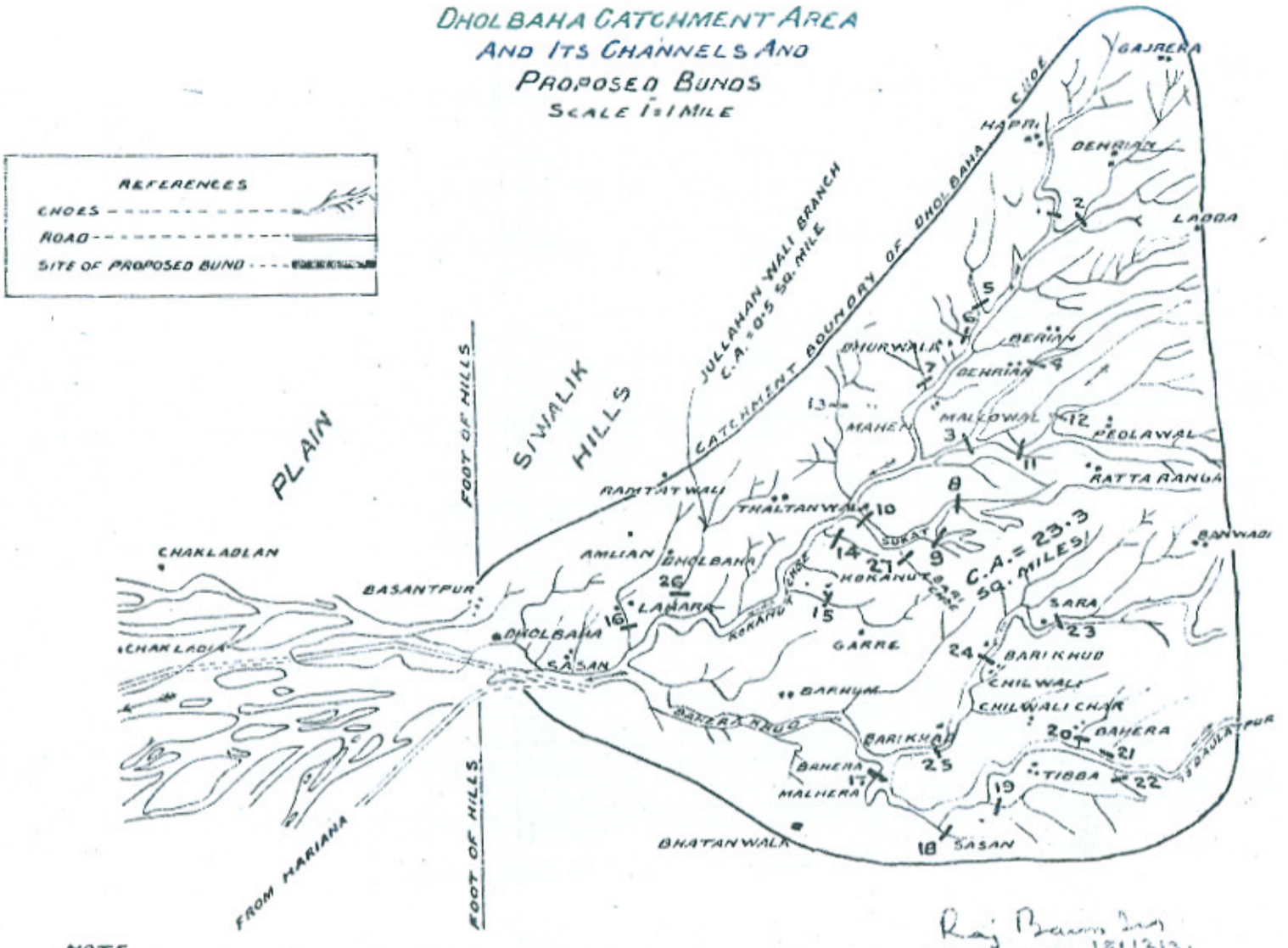
PLATE NO. 5

INDEX PLAN

SHOWING

DHOLBAHA CATCHMENT AREA AND ITS CHANNELS AND PROPOSED BUNDS

SCALE 1=1 MILE



NOTE

NUMBERS 1 TO 25 REPRESENT PROPOSED DAMS

Dg 26,27 Dg DAM CONSTRUCTED

Raj Bahadur Singh 18/12/31

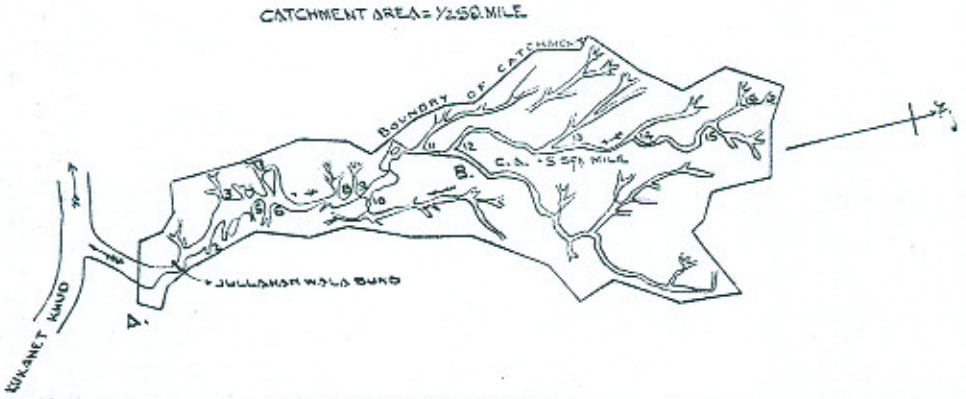
EXECUTIVE ENGINEER

RURAL SANITARY DIVISION

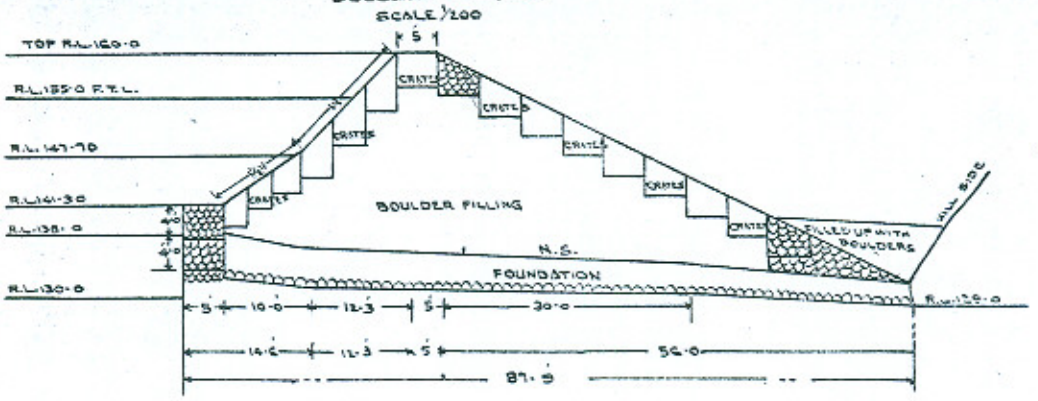
JULLUNDUR

PLATE No 6

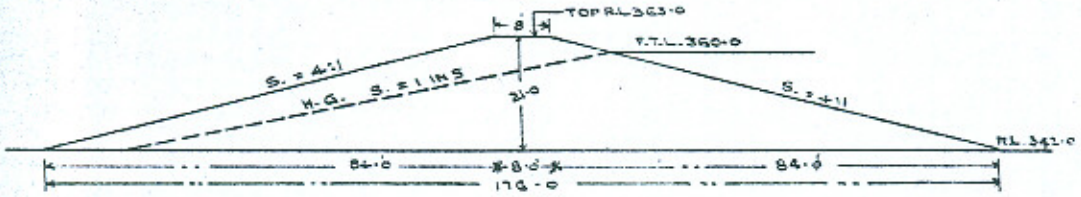
PLAN
SHOWING
CATCHMENT AREA AND SITE OF JULLAHANWALA DAM
SCALE 1/2,000



TYPE CROSS SECTION
OF
JULLAHAN WALA DAM
SCALE 1/200



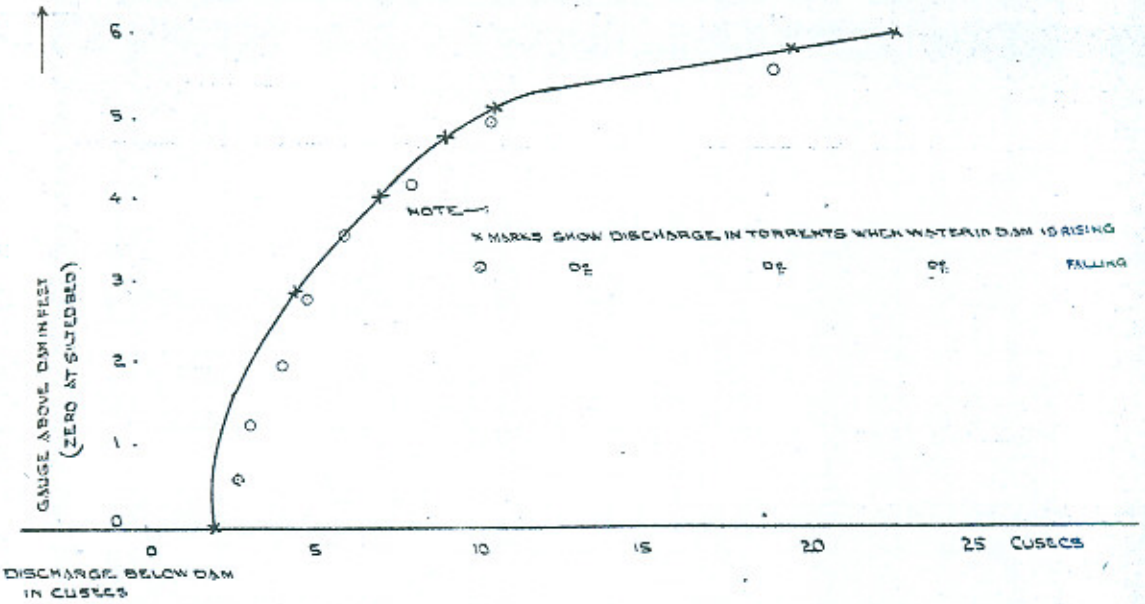
TYPE CROSS SECTION
OF
BUND IN BARI CHOE
BRANCH OF SUKAT AND DHOLBAHA
SCALE 1/300



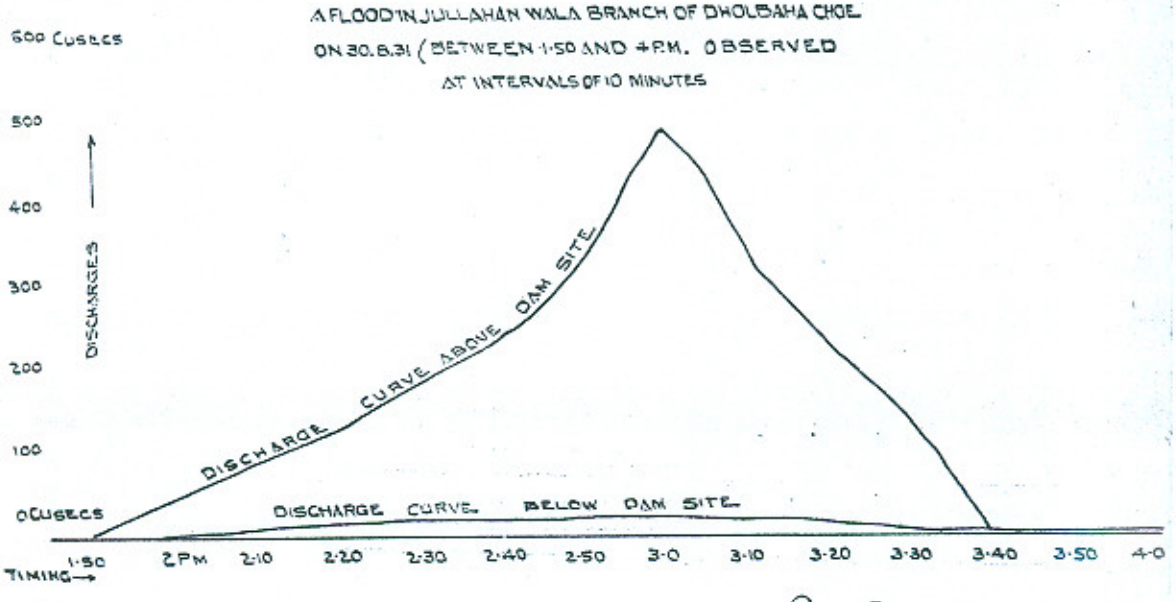
Raj Parmanand
EXECUTIVE ENGINEER 15/11/51
RURAL SANITARY DIVISION
JULLUNDUR

PLATE NO.7

CURVE SHOWING DISCHARGE IN JULLAHAN WALA BRANCH OF DHOLBAHA CHOE BELOW DAM CORRESPONDING TO DEPTHS OF WATER ABOVE THE DAM



DISCHARGE OBSERVATIONS OF A FLOOD IN JULLAHAN WALA BRANCH OF DHOLBAHA CHOE ON 30.8.31 (BETWEEN 1-50 AND 4 P.M. OBSERVED AT INTERVALS OF 10 MINUTES



Roy Brown Esq
18/12/31
EXECUTIVE ENGINEER
RURAL SANITARY DIVISION
JULLUNDUR

L. RAJBANSI LAL introduced his paper by remarking that the training of torrents comes as a side line to many engineers in the Punjab. The Rural Sanitary Engineers, however, have been dealing exclusively with torrents for several years past. They committed some mistakes in the beginning, but as their experience increased, not only were such mistakes avoided, but the problems were considered in a more comprehensive manner. An account of their experience will, it is hoped, be found valuable to those dealing with torrents.

The Gurgaon Bunds Project worked out by the writer is nearing completion. The bunds have taught us many lessons and the experience so gained was helpful in solving problems in other parts of the province. It is a pity, however, that the various observations started on the bunds have been cut short owing to the proposed transfer of the bunds to the Civil Department.

The training works of the Sarusti Torrent and of the Malakmala Torrent have been completed. The main problem before us, at present in that of raising the spring level in Jullundur and in part of Hoshiarpur district. The spring level in these tracts has been falling rapidly and it is feared that unless something be done immediately to improve the situation, it will become impossible for zemindars to run their wells in the near future. To effect this, it has been proposed to hold up the water of the various torrents which run down the Siwalik hills, in or near the hills and so encourage percolation of water into the soil. These torrents flow with immense velocity and carry large discharges. The torrents north of Hoshiarpur town fall into a Nullah called the Western Bein, and those south of it into another Nullah called the Eastern Bein. The two sets of torrents differ in their characteristics and problems. Those falling into Western Bein bring more sand and flow in larger widths. The tract they traverse may be divided into three tracts (A) near the hills where spring level is low and falling, (B) the central portion where spring level is normal, (C) the tail portion of *chambs* or marshes.

Dholbaha is one of the Choes which flows in this tract. By dealing with it and other Choes in the tract, in the manner explained in this paper, we will not only be raising the spring level in tract A, but the holding of water in tract A means withholding it from tract C and reclamation of the latter.

The Choes which fall into the Eastern Bein bring less sand and flow in undulating ground. It is proposed to hold the water of these Choes in the plains at suitable sites and thus encourage percolation into the soil. Rain-water falling in the catchment area on either side of the Bein is proposed to be held up in each field by raising its *vats*. This work has already been started with good results. An effect of these would be that the Bein which at present runs with as much as 50,000 cusecs for a few days at a time, will run with a small discharge for the most part of the year. Regulators could then be built in the Bein at suitable sites to flood lands where spring level would still be low or to run canals for irrigating such areas.

The problems are of great interest to an engineer and of the utmost importance to the cultivators and to Government.

L. ISHAR DAS pointed out that the conditions of floods in torrents described in the paper were also found in some districts of the North-West Frontier Province. The prosperity of the majority of the peasants depended on the flood waters and their proper control. Bunds for the control of floods were nominally in the hands of the civil officals, practically they were left in the hands of the zemindars. Neither the civil officials or the zemindars had the engineer's insight into the matter. In the majority of cases the bunds were made very weak and waste weirs were unheard of and the sites were not always fixed in conformity with the engineer's ideas.

The result was exceedingly unsatisfactory. The speaker has seen many bunds erected and several washed away and it was his experience that several of these bunds were washed away with a single flood in one or two days and the zemindars were left stranded to depend upon rain for their crops and livelihood. He was aware of villages which were once prosperous but were now deserted places. It would be desirable that a valuable paper like this with the discussion thereon was brought to the notice of the officials and the zemindars so that after careful study the engineer's aid might be sought and better results achieved.

MIAN IQBAL HUSSAIN remarked, that the author mentioned that by 1928 a drainage scheme was worked out for Gurgaon District which would have cost Rs. 16 lakhs. The speaker happened to be in charge of this work, and he could not recollect if such a scheme was ever put forward. In fact they could not prepare a proper scheme and Mr. Scott, and the speaker, preferred not to mince matters and would never have a agreed to interfere with the drainage lines as they knew how much the country had suffered at other places through this short-sighted policy of bunding drains to get over temporary difficulties.

Therefore if the Rural Sanitary Board is going to adopt the policy as enunciated by the Author, that constructing drains should be altogether given up, the country must stand to suffer in the course of time.

The Author could comfortably deal with the tributaries of Landoha stream in its submontane tract, but he must not interfere with the main stream, whereas he recommends putting a bund across it.

During continuous dry monsoon periods, the area round the bund will go on silting, and never afford a section for abnormal floods to pass, resulting into general havoc as occurs usually in such cases. The losses to the zemindars at the time of a big flood will outweigh the benefits derived in the previous years.

On page 3, the Author refers to a storage reservoir constructed in 1925. If he means the Sohna Bund, he should know, that this was

possibly one of the oldest bunds existing in the locality, and no additions or alteration were made to it, as during the month of November we had to escape a sufficient quantity of water to allow Sailaba cultivation in the reservoir area. H. E. the Governor desired us to find a use for this water and a small flow irrigation scheme was worked out and executed, but the zemindars declined to take this water, because the period when we wanted them to take water did not suit them also they were not prepared to pay an extra water rate. As we were not prepared to sacrifice the Sailaba irrigation within the reservoir area the scheme fell through. This caused us to drop a good few other flow irrigation schemes for which the district had been howling for some time.

The Author is incorrect in saying that the real intention of the Malakmala Bund was to reclaim the Chel waterlogged area. The object was really to divert the flow of Namaki Kass from Hazro, where it had been doing a tremendous amount of damage. During the construction period, this Kass in the monsoon season flowed towards Hazro and Shah Dher part of this town suffered heavily, and two lives were lost.

What has been done now, is that this Kass Namaki, whose catchment area is about 12 square miles, is made to flow towards Hazro and lead to the Chel, which clearly means accentuating the bad conditions at Hazro.

About the discharges at the Malakmala Bund it must make every one wonder how to reconcile the figures 1,500, 16,000 and 25,000 cusecs. The Author should give details of all this, as certainly it must reflect on the considered opinion of the experts, who first sanctioned this scheme after very careful consideration. At that time 4,000 cusecs was considered too high.

If, for argument's sake, we may accept the figure of 25,000 cusecs, then as the catchment area of Namaki is about half of 25 square miles, we should expect 12,500 cusecs to pass through Hazro, and a small Chel drain of 8 ft. bed width can never possibly pass this amount, resulting in prolongation of the time of discharge and increased absorption in our already waterlogged tract.

The Author has also not explained why the bund breached. It is a fact that under the severest conditions the reservoir level above this bund was $2\frac{1}{2}$ ft. below its top, before any breach occurred. The bund was constructed allowing 10 ft. top width and H. G. 1 to 6 with its face armoured with stone pitching. My enquiries always proved that the bund suffered from the want of a local capable officer in charge.

The speaker should be obliged to the Author for the suggestions he makes for storage in the hilly tract of the Dholbaha Choe by detention bunds, all the same he fails to understand how water stored in the hills situated about 2,000 ft. above the average ground level is going to supplement the subsoil water reservoir in Jullundur.

An absorption loss of 96 per cent. as mentioned by the Author in the detention basins seems to the speaker to be a very high figure. The Author will certainly be well advised if he makes these observations carefully again, and the speaker is sure that this figure of absorption drop to less than 10 per cent. If the Author is right in his experiments, then the basins are not detention ones and water is not lost through absorption, but there is direct percolation.

L. CHAJU RAM GUPTA remarked that he used to roam about on a bund mentioned by the Author on page 2, when a student of the Primary class, and may therefore pretend to know something about them. The fact is that the local villagers knew the utility of these bunds as if by instinct and if their finances permitted, would resort to them, even as private enterprises. The Rural Sanitary Board only extended these operations on a large scale. If any drainage scheme for drainage off the jheels or " dahars " as they are locally called was contemplated, it was really unsound from a financial as well as from a technical point of view. The speaker thought that it is self-evident that holding up rain-water for which the villagers pine so much, at higher levels is more useful than the drains lower down, even though they deprive the lands of the jheel of their moisture. The jheels generally dried up for rabi sowings after the basins were filled by torrents in the rainy season. As regards the point that the bunds have reclaimed a lot of land, the speaker would say it is not a question of reclamation of any bad land but only a point of drying of water in the " dahars," and this depended on the amount and time of rainfall.

As for the design and strength of the bunds the case is very simple. Those recently constructed have not been tested because in the last two years, the rainfall has been much below normal. The " dahar " would have been cultivated as well without the bunds, because the small volume of water would have been dried up in time for rabi sowings. On similiar grounds it cannot be said that the particular design was responsible for requiring no repairs.

In the matter of advantages enumerated by the Author on page 2, the speaker would say that advantage No. 1 is not general. In a good many cases the torrent water brought fertilising silt with it and improved the quality of land. The author himself recognises this fact when mentioning advantages of his proposed bunds in Hoshiarpur on page 5, sub-para. 3.

The advantage No. 5 leaves the point of waterlogging the low areas where subsoil water table would rise up, out of account. This appears a disadvantage rather than an advantage.

MR. COLYER remarked that the paper was of great interest to him as he was in charge of this circle for six months and as one of the breaches of the Malakmala Bund had occurred while he was there. The Author had touched upon the breaches of this bund very lightly. This was.

perhaps because he had not gone carefully into the papers and the reports that were made upon the third and last breach.

The speaker knew nothing about the first breach. About the second breach he knew something, but he knew quite a lot about the third and last breach. There had been some difference of opinion as to the cause of this breach. By some it had been attributied to erosion of the bund. The speaker investigated the matter at site and had ditches cut along the back-slope and kept filled with water for about a week. Distinct cup-cracks, due to sliding, resulted. This together with other evidence regarding bulging of pitching and soakage by previous rain convinced him that the breach was a result of the flattening of the angle of repose of the soil. He mentioned this as an illustration of the far too general neglect, in the Punjab, of the theory of the angle of repose. He described his experience of a somewhat similar case on the Upper Swat Canal. There was a breach in a heavy filling-reach of the canal and some of the engineers put forward a theory that it was due to the chemical composition of the soil. This was discounted by the fact that after extremely careful reconstruction the bank partially failed by the formation of cup-cracks, when it had only three feet of water against it. These cracks were clearly the result of sliding owing to the flatter angle of repose of the soil when wet.

The speaker was very interested to find his own idea tallied with that of the Author that the slopes of these bunds in the various parts of the Punjab should not be steeper then 3 to 1. He opined that in the Punjab the theory and scientific design of earthwork did not generally receive the attention which they deserved.

Passing on to the use of Strange's appendix, No. II, by the Author, he remarked that this was a wrong method. He regretted that he could not back this statement with more detailed facts but he remembered very clearly that that appendix No. II was for an entirely different purpose, and was not applicable to the designing mentioned in the paper. It was clearly unscientific to use a wrong method and then apply enormous co-efficients to bring it into line with facts.

He further drew attention to the pabbi-bunds in the Jhelum district which consisted of a series of bunds in tributary nallahs with spill-ways cut in the virgin soil and delivering into the adjacent tributary. They were very inexpensive, and might very well be copies for reclamation of scoriated tracts like the Hoshiarpur Choa area.

Sir Bernard Darley said that he had spent about 10 years of his service on the construction of bunds both earthen and masonry. The section of earthen bunds, as Mr. Colyer had pointed out, was very important. It was very essential that the upstream slope should be a very flat one. He remembered one case in which a dam burst; it was about 60 feet high and at once the whole upstream face of the dam slipped in the

reservoir. He pointed out that the downstream slope wasalso important. In the Central Province the usual practice was to make the upstream slope of 3 to1 and the downstream slope of only 2 to1. But there a very expensive downstream stone toe was given. Unless this is done there will always be sloughing at the toe with such a steep downstream slope. In the United Provinces for high dams they gave a 4 to 1 hydraulic gradient with a depth of about 8' of earth above it and a very small stone toe. A bund might have a downstream slope of 2 to 1 for the top section before running parallel to the 4 to 1 gradient.

The most fruitful source of failure was due to settlement cracks and from personal experience the speaker could say that, however well earth work might be done a dam might not stand if the earthwork was laid dry. A dam might hold for months and then one day the central dry core might settle as water percolated into it. If the top earthwork had been carefully done it might not settle with the rest and a cave would be formed which would develop into a hole through the dam. He mentioned two cases where dams about 60 feet high, very carefully constructed, had failed on this account. He emphasised the point that settlement must be very carefully guarded against. It was a very good thing to water thoroughly and so settle fully a central core. In the case of hill torrents water is generally not available and then a risk must be taken.

He then remarked that flood absorption lakes often silted up very quickly in the hills and enquired if afforestation had been tried as a means to absorbing floods. The point had not been mentioned in the paper. The rainfall in this tract Jullundur and Hoshiarpur District, was 23 " and therefore it should be possible to grow grass at least. He remarked that it was not necessary that trees should be grown. In his opinion small shrubs and grass were better for this purpose than big trees and so all that was necessary was to prohibit grazing.

Mr. Mithal thanked the Author for putting many useful and very cheap methods of control of floods in torrents before the younger section of the engineers.

The speaker was in charge of the Gurgaon Sailab bund, but the Irrigation Branch was severing its control by closing the Sub-Division, therefore a great danger existed of all the good work done during the last decade, being lost to the zemindars.

The bunds were in good condition and no alteration might be needed for a few years. But the final result would be that there would be breaches and cuts and the conditions would fall back to what they were when the work was taken over by the Irrigation Branch. The areas of jheels which had been reclaimed would again begin to breed the malaria carrying mosquitoes, the fertile parts of land would be run over by sand depositing torrents and a tremendous amount of money would again have to be spent if the bunds were to be of any future use.

Apart from the uses detailed by the Author, these bunds were very useful in as much as they raised the subsoil level below the bund and rich

crops could be raised by the zemindars without even initially watering the fields.

The rain was the only saviour of the barren Gurgaon district. This year the winter rain failed, crops were destroyed. In the midst of this catastrophe the only green patches of crops were on the well irrigated land or on the land upstream and downstream of the bunds. It would be well if the famine relief which had become an annual feature of Gurgaon district be given to the zemindars in the shape of more and more Sailab bunds, but the relief would be but temporary, and of little use if the money is spent without looking to the technique of the design.

With regard to Mr. Iqbal Hussain's remarks the AUTHOR replied that an estimate for part of the drainage scheme had been sanctioned and estimates for the rest were to follow when he took charge of the works. On the suggestion of the author it was decided to substitute bunds near the hills for this drainage scheme. These bunds have proved quite successful. There are about 32 bunds in the district more than 20 years old and nowhere has the difficulty of silting arisen so far. When the tributaries of a stream are dealt with separately, the discharge of the main streams became so low that it can also be dealt with similarly.

The Sohna Bund existed already, but Mr. Iqbal Hussain made the regulator and a channel with beautiful flume outlets for distributing the stored supply. This had to be abandoned because the absorption losses were so high that no water was left in the tank even in the beginning of November. The zemindars to whom the supply was meant to be given did not want it, but it could be delivered lower down where the people wanted water.

As to the Malakmala Bund, the object as ascertained from files was to reclaim the Chel waterlogged area. If the object of the bund was simply to save Hazro town, it could have been achieved by a small bund costing about Rs. 500 in the Namaki torrent. Anybody who knows anything about run offs, would say that 1,500 is not even 1-10th of the discharge expected in such a large catchment area with so much rainfall. With the present arrangement water spreads on a large area and then is escaped through Chel Drain which empties it in about four hours.

As to the Dholbaha Choe, the figures are of actual observation at site and could not possibly be wrong.

Mr. Colver gave very good advice regarding slopes of bund and this has been followed in the design of bund in Gurgaon District. As to designed discharge of waste weirs, the co-efficient applied was arbitrary. Some co-efficient must be applied and it was found from observation that these co-efficients were not far out.

In the Dholbaha Scheme afforestation was being tried. Nobody is allowed to graze goats and the Author thinks this will help in afforestation.