
SECOND INTERIM REPORT
OF THE
ORISSA FLOOD ADVISORY COMMITTEE

January 1940.

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* To be printed in a separate volume.

Second Interim Report of the Orissa Flood Advisory Committee, January 1940.

SECTION I.

BRIEF RETROSPECT.

This Committee was constituted in 1938 and the first meeting was convened in August of that year, when a preliminary report was drawn up. The second meeting was held in January 1939 and an interim report was issued. In these reports the general policy to be adopted for the protection of the flood-affected areas was indicated in broad outline and detailed suggestions made for carrying out surveys and investigations and for collecting hydraulic and other data required for formulating definite proposals. Certain remedial measures were also considered for some special areas and recommendations made for further detailed investigations.

2. The Executive Engineer, Floods and Drainage Division has prepared a detailed note on the action taken on the Committee's recommendations and has reviewed the data collected in the flood season of 1939 for certain areas badly affected by the floods, for the consideration of the Committee. (Appendix I.)

The data collected has been of much value. This is practically the first flood season during which reliable data has been collected in a systematic and scientific manner, though the methods have to be perfected as experience is gained, and more time is required before complete data can be made available, earlier data being vitiated by unreliable reduced levels. The information now before us has enabled us to make more specific recommendations than we were able to do previously; and these, if carried out, will in our opinion avert much of the damage now caused by floods in the areas referred to.

3. Before proceeding further, it is necessary to refer to notes on the flood problems in Orissa by Sir M. Visvesvaraya, K.C.I.E., at whose suggestion this Committee was constituted.

In the year 1937, Sir M. Visvesvaraya prepared a note on the flood problem in Orissa, having been supplied with literature dealing with the problem. Later, at the invitation of the

Hon'ble Sri Nityananda Kanungo, the then Minister for Public Works, he visited the delta in April 1939 in order to acquaint himself with the physical features of the area and the conditions under which floods and destructive inundations occurred. He spent ten days visiting various parts of the delta and prepared a note based on the information gathered during that visit.

The Committee have given careful consideration to the various views and suggestions expressed by Sir M. Visvesvaraya, particularly as regards the preparation of a comprehensive plan embodying the following :—

- (1) The total approximate cost of all works proposed.
- (2) The area, population and magnitude of the interests to be protected, individually and collectively.
- (3) The effect the execution of the works will have in protecting existing revenues and where possible increasing the revenues of the future.
- (4) Government's own resources and inclination to finance the proposed works.

The Committee feel that it will take several more years of investigation to prepare such a plan for the entire area, but that it is possible even at this stage to select certain proposals which are outstanding and are necessary to protect particular areas which at present are badly in need of relief. A list of such works has consequently been prepared and has been arranged in what the Committee consider the order of importance. (Appendix II.) This list can be further added to as the work of investigation proceeds.

SECTION II.

INSPECTIONS.

4. We have, during this inspection visited certain badly affected areas in the Puri and Cuttack districts. The Collector of Puri district kindly met us and acquainted us with the situation in certain areas which he considered were badly in need of protection.

The places and areas covered during our tour were—

- (1) Sur Lake Sea Cut.
- (2) Bhargovi river at the head of the proposed cut from Gobakund to the Sur Lake.

- (3) Dhanua and lower Kusbhadra and part of the Pathar Buha.
- (4) Lower Daya area from Pipli to Kanas and thence down to Monaguni junction and Makra river, which bifurcates from the Daya $9\frac{1}{2}$ miles above the Chilka Lake.
- (5) Hansua river from the place where it branches off from the Brahmini.
- (6) Brahmini river down to its junction with the Baitarini and up to Chandbali Port.

Our colleague, Mr. C. C. Inglis, made a special inspection of the Mahanadi above and below Naraj with a view to design the models for experiments recommended in paragraph 47 of our Interim Report.

SECTION III.

CONDITIONS IN SOME FLOOD-AFFECTED AREAS WITH PROPOSED MEASURES FOR PROTECTION.

5. From the report of the Executive Engineer, Floods and Drainage Division (Appendix III), on the flood-affected areas and from the maps accompanying, it will be seen that a large tract which suffers frequent damage is situated in the Puri district. This comprises (1) the Dhanua basin between the rivers Bhargovi and Kusbhadra, (2) the basin of the Kadua and Prachi between Kusbhadra and Debi rivers south of Bananalipur, and (3) the Daya area.

The areas affected in the Cuttack district are situated between the Kimira and the Brahmini and between the Brahmini and the Kharsua. Reference is invited to the Executive Engineer's report for a full description of the sources of the floods and the nature of damage caused. We shall only briefly indicate them here and proceed to deal with the remedial measures that we consider necessary at the present stage of our investigations.

(1) THE DHANUA BASIN BOUNDED BY THE BHARGOVI-KUSBHADRA RIVERS.

6. The two sources of flood in the Dhanua basin are the Jogisahi escape from the Kusbhadra and the Achhutpur escape from the Bhargovi. The discharge of the Jogisahi escape is now taken as a fixed quantity, but that of the Achhutpur escape

will decrease as the proposed Bhargoai-Sur Lake connecting channel referred to in paragraph 38 of our Interim Report of 1939 and dealt with in more details in this report, improves the river above and reduces flood levels.

Conditions in the Dhanua basin have been aggravated by the fact that the Jogisahi escape generally breached in every high flood and so passed excess flood water into this area. Now that the escape is being redesigned and reconstructed, considerable reduction of flood water from this source is expected.

7. The flood entering the Dhanua basin passes off in three ways: to the Kusbhadra river and thence to the sea; into the Kusbhadra and by spill over the opposite bank into the Kadua basin; and largely by breaches in the Dhanua and Kandaria embankments to the Dal Nadi and thence to the Sur Lake. A small amount of flood also enters the Sur Lake by the Bengai river.

At present the level of the Sur Lake is the controlling factor in the flooding of the Dhanua area. With the proposed lowering of the Sur Lake levels by the improvement of the cut to the sea dealt with in paragraph 9, considerable relief will be afforded by linking the Dhanua with the Dal Nadi by means of a direct channel from the Dhanua right embankment at the village of Siaro, southwards to the Dal Nadi at Tarhana. This channel should be double-embanked with a width between embankments of about 600 feet. The existing breaches in the Dhanua and Kandaria right embankments should be closed.

From the data before us we anticipate that the period of flooding in the lower Dhanua area will then be sufficiently reduced so as to safeguard the paddy crop in the greater part of this area.

The above proposal is in accordance with our recommendations in paragraph 41 of our Interim Report of January 1939.

8. The 1928 Flood Committee, in paragraph 16 of their report, stated that the rivers of the Mahanadi delta at a distance of 25 miles from Cuttack could only carry within their natural banks a discharge equal to approximately half the maximum flood discharge entering at the head of the delta. This information was extracted from Captain Harris' Report II of 1858 but present day calculations confirm this statement. From this it follows that the policy of closing breaches and constructing high level escapes must synchronise with the development of the rivers lower down to make them capable of carrying the consequent increased discharge with approximately the same water level.

It is of great importance, therefore to determine the rate at which any particular river can be developed. The Bhargovi, which is the only river double-embanked throughout its length, is specially suitable for treatment, because it flows several feet higher than the Sur Lake; and if an escape were constructed near Gobakund, and a channel constructed from there to the Sur Lake, it should be possible to develop the Bhargovi fairly rapidly. This is obviously the only river in the Daya-Kusbhadra area which can be developed so as to carry silt from the Kuakhai right through to the sea and at the same time drain off the excess discharge which is causing so much flooding in that area.

Designs should be prepared for the works required to give effect to these proposals, which will be considered by the Committee as soon as they are ready.

9. An equally important work in this region is the development of the cut from the Sur Lake to the sea. We inspected this cut and we found that the floods of 1939, assisted by the deepening of the central portion of the cut done prior to the floods, as recommended by us in paragraph 40 of our Interim Report of January 1939, have caused considerable scour of the bed, though not to the ultimate dimensions required. The head of the scour has now however approached sufficiently near to the position of the proposed masonry sill to warrant its construction at an early date.

This sill should be in line with the Puri-Balighai road and should be built for the full 400 feet width of the original cut, with crest at R.L. 7'00. To ensure proper development of the cut, some excavation of the present high berm both upstream and downstream of the sill is necessary. On the upper or lake side, the middle 200 feet of the existing 400 feet width should be taken down to R.L. 7'0 at the sill, rising to R.L. 8'0 at the head of the cut and projected at this level into the Lake. The remaining upstream part of the original 400 feet width should be excavated down to R.L. 10'0 at the lake, sloping to R.L. 9'0 at the sill. On the downstream side of the sill, the 200 feet central width should be cut to R.L. 7'0 for a length of 200 feet, and the flanks excavated so as to converge from the full width at R.L. 9'0 at the sill, to the central cut width in a distance of 200 feet, at R.L. 7'0. The scoured channel further down should be cleared for a length of 300 feet tapering down from 200 feet width to 100 feet, with the bed not higher than R.L. 7'0.

10. It is calculated that this drowned sill with a co-efficient of 2'8 and a depth of 6'7 feet over the crest, will pass 50 cubic

feet per second per foot run, which will give a discharge of 20,000 cusecs. The sill level of R. L. 7'00 is reckoned as being sufficient to reduce the maximum flood level of the Sur Lake from R. L. 17'50 to R. L. 15'00 with influx conditions as indicated in paragraph 7 above. The Sur Lake embankments which are now overtopped from about R. L. 17'00 would then be safe with the lower maximum flood level which would also accelerate run-off from the Dhanua flooded area as previously mentioned.

As regards the minimum level to be maintained in the lake after the monsoon season, it is found that under present conditions the water level of the Sur Lake is about R. L. 10'00 in the middle of January and about R. L. 8'00 by the middle of April and *dalua* cultivation is regulated according to these conditions. In order to satisfy these irrigation requirements it would be advisable to have some means of control on the sill, such that the lake level could be maintained and regulated as required. This could be done by a sand bag dam while the cut is developing, and later by installing falling shutters as a permanent measure.

So far as the retrogression of the bed of the cut is concerned, if the foundation of the sill is taken down to 2 feet below M. S. L., the sill should be safe and it would prevent any scour extending towards the lake to an undesirable extent. There will be no danger of salt water incursion from the sea up the cut into the lake, because the usual sand bar will continue to form across the mouth after the monsoon period, while during the monsoon, fresh water will be flowing in the cut. Even in the absence of a sand bar the sill level of R. L. 7'00 will be sufficiently high to keep out salt tides, as will be seen from the Note on Tides by the Executive Engineer, Floods and Drainage Division (Appendix IV).

11. Interference with communications which will occur when the cut develops has also to be considered. At the end of the monsoon, when the shutters are raised, traffic should be enabled to pass across the bed of the cut below, as at present, by means of a temporary road-way, or preferably over the sill itself, which could be designed of sufficient width for this purpose. During the monsoon a ferry service will be necessary and should be maintained.

The development of the sea cut with its controlling sill at the head will have no effect on the Puri water-supply as may be apprehended.

(2) THE KADUA-PRACHI BASIN BOUNDED BY THE KUSBHADRA AND DEBI RIVERS.

12. The Kadua area is affected mostly by the flood spill of the Kusbhadra river which flows over its left bank in many places from Bantugram to the sand hills. The average annual flood damage in the Kadua area is calculated at Rs. 61,000 of which about Rs. 43,000 may be attributed to Kusbhadra flood spills [Appendix III (2)].

The Committee have inspected part of this area and examined the data available. It would seem that the only possibility of flood relief in this area is to extend the embankments so as to make the Kusbhadra river double-embanked as far as the coastal sand hills near Alanda. The existing right and left embankments should be raised and strengthened where necessary. Designs and estimates may be prepared for the purpose, making due provision for the supply of sufficient water for irrigation by sluices or escapes and for drainage.

13. The investigations recommended in paragraph 43 of our Interim Report of January 1939 and those since made, confirm that the western loop of the Kusbhadra should be improved so as to act as the main channel and the eastern loop closed, provision being made for supplying water for irrigation if found necessary. Details of this scheme may be formulated and placed before the Committee for final decision.

14. The Katjuri-Debi river from the Katjuri-Surua confluence to the sea does considerable damage by flooding, due in the upper reaches to the bad condition of the right embankment, and lower down to the river splitting up into numerous channels with general and concentrated spill over the Cuttack-Madhab-Astrang Road into the Prachi area.

In accordance with paragraph 36 of our Interim Report of January 1939, data has been collected for the Prachi-Kadua area, but the necessary investigation of the upper and middle Debi river areas is still to be done; and until a thorough investigation of the whole of this area has been completed, a comprehensive scheme cannot be formulated. This investigation is essential as we consider it necessary eventually to confine the river flow to a single channel.

The general aim of the comprehensive scheme should be to prevent the rivers splitting up into a number of smaller river courses and to help them to regain their regime as far as possible. For this purpose the investigations should proceed somewhat on the following lines:

The rivers should be divided into four or five convenient reaches. In each reach the quantities of flood that may be passed with safety (1) between natural banks, (2) on the berms beyond the banks but between flood embankments spaced sufficiently far apart and (3) over high level escapes, without causing injury to the crops or damaging the lands, have all to be determined.

The approximate cost of the works involved, as compared with the value of protection that would be afforded by the works, has also to be ascertained.

In the meantime proposals with estimates may be prepared for connecting the embankments I-B and II-B and closing the breaches in the latter as proposed in paragraph 36 of our Interim Report. The proposal should include also an extension of the embankment up to the village of Madhab allowing sufficient spill-way at the Puranabetanda 'ghai'.

The Government embankment on the right of the Katjuri-Debi river ends at Gobindpur and thereafter continues as a private embankment to the mouth of the Tel drainage. We recommend that this important embankment which is not maintained satisfactorily at present be taken over by Government, the Manikunda breach being closed.

The possibility of developing the Prachi as a channel for irrigation purposes may be investigated.

(3) THE DAYA RIVER AREA.

15. We have examined the flooding on the right banks of the Kuakhai-Bhargovi-Daya rivers and consider that no permanent measures can be recommended to improve conditions unless the Bhargovi river develops, as a result of the improvements suggested elsewhere in this report (paragraph 8). There are two sources of flood in the middle Daya, namely, the Daya river itself and the large flood-spill received from the Kuakhai river through the Mancheswar gap 9 miles above [Appendix III (3)].

In accordance with the recommendation in paragraph 46 of our Interim Report of January 1939, the two breaches in the flanking embankment of the Mancheswar gap caused by the floods of 1937 were closed and raised to a level 2 feet lower than the existing embankment to act as breaching sections. One of the sections gave way in the 1939 floods and we now recommend that this section be left open or its equivalent waterway be provided in extension of the existing gap.

Under present conditions we do not consider it advisable to alter the distribution of floods in this area, or effect any change in the existing escapes in the Daya left embankment.

16. In the lower Daya area some improvements are desirable. In order to prevent further deterioration of the Daya river below Tirinul, the breach at that place may be closed and a high level escape provided. The maintenance of the lower Daya left embankment was discontinued on the recommendation of the 1928 Flood Committee. Since making our recommendation in our Interim Report, investigations show that to leave things alone would, for many years to come, expose this area to severe and avoidable flooding and alleviation is necessary and cannot wait until the improvements contemplated in our previous report become effective. The left embankment may therefore be maintained throughout its former length.

There would also be no objection to the construction of a flood embankment on the right of the Makra river extending almost straight from the end of the Monaguni right embankment at the gap, to the Adal bund at Sahupara.

In connection with floods in the adjoining Brahmagiri area, it is considered advisable that the embankment at present linking the Bhargovi left embankment at Kajuria with the Nuna or salt embankment on the margin of the Chilka Lake, be properly maintained, making due provision for irrigation sluices.

(4) KIMIRIA-BRAHMINI AREA.

17. Details of flooding conditions in this area are given in Appendix III (4). The land between the Kimiria and Brahmini rivers is typical of many such areas in the Orissa delta. The land near the river banks is high and the interior is low and traversed by many drainage channels which are fed by spills from the rivers bounding the area.

In this case there are three important spills which flood the lower central area for a considerable time and cause frequent crop damage. This particular area should form the subject of a separate enquiry. The general flooding conditions are now known after the observations taken during the 1939 floods, and further detailed investigation should now be made and plans for control and relief prepared so as to determine the economic advantages gained, as against the cost.

Protective measures would probably take the shape of marginal embankments and controlled spill-ways, the embankments being spaced about 2,000 feet apart.

(5) THE BRAHMINI-KHARSUA AREA.

18. We have devoted some special attention to the area between the Brahmini and the Kharsua rivers. We paid a visit to it during our tour in January 1939 and we have inspected part of this area again this month.

An account of flood conditions in this area is given in Appendix III (5). The land between the Kharsua and Brahmini is affected to a considerable extent by bad flooding.

Now that the Janardhan 'ghai' and other considerable spills from the upper Brahmini have been stopped, the Jabra spill-way only being retained, flooding of this area is mostly from the Kharsua, through the Tanti and Similia 'ghais' which are controlled escapes, and the Rautra 'ghai' and the Kani Nadi further downstream.

19. It has been calculated that in 1939 the volume of flood that passed over the land between the rivers above the Aul embankment is about 103,000 cusecs, or three times that passing down the Kharsua river proper below Singhpur, which was only about 32,000 cusecs. About 70,000 cusecs flowed through the Aul area, the major part of which re-entered the Kharsua. The distribution of the flood water in this area is shown in the statement accompanying Appendix III (5).

The badly affected area is the wide strip of low land between the two rivers including that within the Aul ring bund. The area is so large and extends for such a long distance that a comprehensive scheme for the whole tract is necessary. This would amount to controlling the Kharsua river from its upper reach to beyond Aul, and not merely at the lower end.

20. The problem confronting us here was dealt with in considerable detail by the Orissa Flood Committee of 1928 in Chapter X of their Report. That Committee came to the conclusion that the excessive flooding which occurs in the area was due almost entirely to the obstructions to the free flow of flood water, which in their opinion were the Gajaria, Uttikan and Damerpur embankments, and also the Aul ring bund to a partial extent. They considered that such flooding could be largely prevented by the removal of the above obstructions.

Estimating that the heading up which occurred owing to these embankments was certainly 5 feet and possibly considerably more, they recommended their entire removal.

In 1939 we examined the flood levels on which the 1928 Committee based their opinion regarding the heading up of floods, but those levels did not indicate any such heading up. Though we believed that these embankments could have hardly any such effect as surmised by the 1928 Committee, we stated that the data then available was insufficient to enable a final decision being arrived at and consequently recommended that further contemplation of the removal of these embankments should be deferred until data was available.

Except the Aul ring bund which is not being maintained and which is breached in several places, thus allowing flow of floods through the Aul area, the other embankments are in fair condition. They protect an area of 32,610 acres and support a large population. The results of the investigations conducted during the floods of 1939 have been gone into with care and we are in a position to state that the excessive flooding in this area cannot be attributed to the existence of these embankments, but to spills from the Kharsua as explained above.

Flood levels have been taken along the Brahmini and Kharsua rivers during the 1939 floods from Jenapur to where they meet again, and beyond as far as Dhamra. These flood levels show a continuous slope and in no place is there any appreciable heading up.

We, therefore, recommend that the question of the removal of the embankments referred to be dropped.

Other measures necessary to protect this large area have to be more fully investigated, and the costs balanced against the probable benefits.

In the meantime we do not advise any further action beyond the recommendation contained in paragraph 30 of our Interim Report, namely, that the Rautra 'ghai' should be closed and an escape constructed nearby. The existing embankments should, of course, be maintained in good condition.

21. The 1928 Committee considered that the best way to afford relief to this area would be to develop the Hansua creek, thus providing the shortest possible course to the sea, which would be considerably less than half the length of its present course via the Dhamra estuary. They inspected this creek and it

appeared to them to be a suitable channel for the above purpose, though it was in danger of being starved for lack of an adequate discharge.

During our tour in January 1939 we inspected the head of this creek with reference to the opinion expressed by the 1928 Committee and remarked as follows in our Interim Report :—

“ We agree that it could be developed, but, if allowed to develop too much it would get out of control and might have most injurious effects on the Dhamra estuary and the Chandbali Port and it is impossible to see what these effects would be without the necessary data.”

We inspected the creek during our present tour and found that, far from being starved, the creek was showing definite signs of development. The berms were slipping in and the marginal embankments in many places had been retired owing to the creek enlarging itself.

This development is taking place more rapidly in the lower half of the channel, where the bed has scoured to a depth of 19 feet below M. S. L. and meander cutting is active. This action is rapid because the meanders are lengthening due to cutting both from upstream and downstream.

At the upper (Brahmini) end of the creek, action though marked, is not so severe as further downstream, but the Brahmini is cutting towards the creek and scour across the neck has already begun, vide map accompanying Appendix III (5). As this develops, entry conditions will improve, which combined with the development from the sea upwards will accelerate the process throughout the length of the creek.

These developments will have to be watched and considered as part of the comprehensive scheme for improvement in the Brahmini-Kharsua area.

SECTION IV.

FINANCIAL POLICY AND PROGRAMME.

22. We now come to the consideration of the policy to be followed in finding funds for carrying out the protection works. The proposals made here are with a view to enable Government to undertake the works according to the programme indicated before the conditions on which the designs are based undergo changes, which may necessitate fresh investigations and redesigning.

Sir M. Visvesvaraya has in both of his notes stressed the importance of giving full consideration to the protective and

economic value to the area affected of every scheme proposed, and states that, if Government are convinced of the benefits of such a scheme, they would be justified in levying a cess. We fully endorse this view. A cess of the kind at, say one anna in the rupee of assessment would enable Government to maintain the works after they are carried out. But to find the capital outlay required for original construction, we propose a levy in proportion to the unearned increment in the value of the lands benefited by the works. Supposing that as a result of the improvements brought about by protective measures, the value of the lands in the area increased by Rs. 100 per acre, the Government may well claim that the raiyats should contribute towards the cost of construction of a proportion of this increase in value, which may be fixed from one-third to one-fourth according to the conditions in each case. Whenever Government may consider it desirable to undertake a work of this kind, they may notify beforehand that, if two-thirds of the people affected by the works in any area agree to give the contribution fixed, they would proceed with the work. Statutory powers should be acquired for compelling the remaining one-third of the land owners to contribute at the rate fixed, and if necessary for levy of the cess also.

In order to lighten this burden, the payment of contribution may be spread over a term of years extending from 5 to 10 according to the heaviness of the levy and the ability of the people affected in each area to pay.

23. Appendix II is a programme of the works which we have recommended at present with approximate costs; wherever possible the area to be protected and the valuation of damages caused have been given in the statement against each work. The works have been divided into two classes, major and minor, and under the former, measures of a permanent character are grouped. We recommend that a definite allotment be made year by year for carrying out the works in a systematic manner.

SECTION V.

SUMMARY.

24. The following is a summary of the recommendations on which action has to be taken :—

- (1) Opening a channel from the Dhanua right embankment at Siaro village to the Dal Nadi at Tarhana so as to drain the Dhanua into the Sur Lake.

- (2) Preparation of designs for an escape on the Bhargovi left bank at Gobakund village and a channel therefrom to the Sur Lake.
- (3) Constructing a masonry sill and connected works in the bed of the cut from the Sur Lake to the sea.
- (4) (a) Preparing designs and estimating the cost of raising and strengthening the Kusbhadra embankments where necessary and extending them as far as the coastal sand hills at Alanda village; and
 (b) closing the eastern loop of the Kusbhadra.
- (5) (a) Investigations to be made for a comprehensive scheme for confining the Katjuri-Debi river flow to a single channel.
 (b) The right embankment of this river from beyond Gobindpur to be taken over by Government and maintained satisfactorily, the Manikunda breach being closed.
 (c) The embankment connecting IB and IIB to be extended to the village of Madhab.
- (6) (a) Closing of the breach at Tirmul village on the Daya river and providing a high level escape.
 (b) Restoration of the lower Daya left embankment.
 (c) Linking the Bhargovi left embankment with the Nuna salt embankment at the Chilka Lake.
- (7) Detailed investigations to be made for providing marginal embankments and controlled spillways in the Kimiria-Brahmini area.
- (8) (a) The question of removing the Gajaria, Damerpur and Uttikan embankments to be dropped.
 (b) Preparing a comprehensive scheme on the lines indicated for treating the full reach of the Brahmini and Kharsua rivers from Jenapur downwards, existing embankments being maintained in good condition.
- (c) Watching the development of the Hansua creek.
- (9) Acquiring statutory powers for levy of contribution and flood protection cess.

We consider that the data so far placed before us shows that satisfactory local and permanent measures to improve conditions in the delta are feasible. The investigations now being conducted should be proceeded with steadily without interruption until permanent measures for dealing with the problem are evolved, in accordance with our recommendations in this and our previous reports.

M. G. RANGAIYA.

C. C. INGLIS.

A. VIPAN.

The 30th January 1940.

APPENDIX I.

Report of progress of work and actions taken on the Orissa Flood Advisory Committee Interim Report I of 1939.

I. INVESTIGATIONS

(i) *Levelling, surveying and contouring of the flood-affected areas.*

1. A plan has been drawn up showing the lines of levels to be taken and the progress up-to-date. This shows that 564 miles of levelling on primary levelling lines and 190 miles on secondary lines have been drawn up-to-date. It was found impossible to take levels in most of the secondary lines during the monsoon season and up to mid December as the land was flooded and covered with rice. Attempts were made but proved a waste of time, so levelling during the monsoon was confined to higher lines as embankments or roads. These embankment level lines were also more urgently required for connecting cross sections and flood levels of 1939 (para. 16).

2. Representative ground levels and flood levels have been shown on special maps and contours will be drawn when more detail is to hand (para. 23).

3. A whole series of cross sections has been taken at the head of the Brahmini and Pattia as may be required for building a model and this data can be extended and added to as is required for a model experiment if this is required (para. 32).

4. Levels and sections have been taken of the proposed Bhargovi-Sur Lake Cut and also in the Sur Lake. The Sur Lake Cut cross sections have all been re-taken showing the 1939 flood scour (para. 38).

5. It was not found possible to do the full survey of the rivers Mahanadi, Katjuri, Berupa, Kuakhai and Surua before 1939 flood; and as the situation is now considerably altered after 1939 floods, the whole survey will have to be undertaken now from the start all as required for a model experiment (para. 47).

6. *Construction of bench marks.*—Temporary bench marks have been made on pucca structures wherever possible and the construction of permanent bench marks will now be pushed on (para. 16).

(ii) *River Maps and Sections.*

7. *Plans of rivers.*—These were very carefully drawn up but great difficulty is felt in many cases in the exact interpretation of alterations as older surveys are not very exact and are projected differently. Sufficiently exact superimposition has however been done as to show the chief alterations in the courses (para. 17).

8. *Longitudinal section of rivers.*—Cross sections have been taken on all rivers in the delta and longitudinal sections deduced except for the central Debi and Mahanadi group and a few on the Baitarani. 1939 flood levels have been taken and shown throughout at short intervals. Natural bank and embankment levels, average and deepest bed levels and cross sectional area have all been plotted (paras. 19, 21 and 22).

9. Sections of both loops of the Kusbhadra are ready for inspection. Report has been made on the Kusbhadra spills and action taken where necessary (para. 43).

10. *Meander Calculation.*—This has been done as required in paragraph 18.

(iii) *River gaugings and flood observations.*

11. Three automatic gauges were received at the end of the monsoon season and so could not be installed for the floods of 1939. Location for these have been surveyed and they will be fixed for use in the 1940 flood season. Ordinary gauges were fixed at these sites instead. Nineteen numbers new river gauges were fixed which now give comprehensive river flood data. Gauges are read at all spill-ways (para. 22).

12. Sonic sounding apparatus was found to be too dear for the present consideration, so cross sections were taken as opportunity offered (para. 22).

13. Velocity observations have been made by current meters and other methods at chosen discharge sites during 1939 floods and recorded. Discharges for various depths of flow have been recorded from which curves of discharge can be drawn. Wherever possible velocity by float observations have been checked by special local flood slope observations between special gauges and also in important cases by current meter observations (para. 24).

14. The Hansua head special observations were taken of tides and discharges before and during the monsoon. Further simultaneous tidal observation was taken in December of all the gauges at the Hansua head, Rajnagar, Damerpur, Albia, Aul and on the lower Brahmini near the Patsala off-take to show the range of tide and interactions at these places. River water samples were taken and the salinity noted. The Dionic water testing machine was received in the middle of the flood season when the water was all fresh to the sea (para. 25).

15. As noted under paragraph 24 discharges have been observed for various gauge readings near anicuts. The position and formation of standing waves on the anicuts and the variations and nature of flow have been noted for examination with the proposed discharge tables as required (para. 26).

16. Gauge readings, high flood levels and velocity observations and cross sections of rivers have been taken in the lower Kharsua-Brahmini-Hansua area during the floods of 1939 which were fairly high, so some

data is now available for examination and some conclusions have already been drawn for placing before the Committee (para. 29).

17. Cross sections and flood levels of the Katjuri loop have been taken and discharges of the Katjuri and Surua channels during the floods. This data can be studied (para. 37).

18. Observations have been made throughout the 1939 flood season in the Bhargovi-Kusbhadra-Dhanua-Sur Lake area, discharge observations of the Sur Lake Cut have been made throughout the flood season and deductions made for putting before the Committee (para. 38).

19. Flood conditions in the middle and lower Daya have been studied throughout 1939 (para. 39).

20. From the observation of the 1939 floods in the Brahmini, hydrographs have been prepared which show little trace of heading up. No further reliable series of Brahmini bed levels at the head are to hand to prove the gradual rising of the bed but the growth of new islands in the last ten years is observed (para. 32).

21. Discharge and silt observations of the rivers Mahanadi, Katjuri, Berupa, Kuakhai and Surua have been taken throughout the 1939 flood season (para. 47).

22. Investigation of Kakatpur area has been done, observation taken through the 1939 floods and a comprehensive report submitted with recommendation for relief (para. 36).

II. WORKS.

23. *Jabra escape*.—The Jabra escape has been raised, as recommended, to R. L. 66.0 (para. 33).

24. *Surua right embankment*.—The Surua right embankment has been strengthened and retired where necessary (para. 37).

25. *Jogisahi escape*.—The Jogisahi escape which was temporarily repaired before 1939 floods again breached badly. The escape has been redesigned and the work of reconstruction is started (para. 44).

26. Both breaches in the Jagannath road above Balianta have been closed as it was not found possible to construct an escape here in time (para. 45).

27. The situation in Pipli-Nimapara road is as before and the breached sections have been left open for the present (para. 45).

28. The breaches in the flanking embankment of the Mancheswar gap were closed as recommended and in the high flood of 1939 one of the breaching sections was scoured away. In connection with the construction of an all weather road from Cuttack to Fari this case is being put before the Committee (para. 45).

29. The Brahmini anicut is being removed as soon as exposed. A further 200 ft. has been exposed by the 1939 floods and steps are being taken to remove it (para. 32).

30. Alignment for a retired embankment and escape at Rautra Ghai have been fixed and the earthwork estimate prepared. Borings have been taken and physical details are known. The design of the escape was delayed until the design of Jogisahi escape would be approved, as this is being adapted for type designs. This design has just now been approved and the design of Rautra escape will now be taken up (para 30).

31. Estimates have been prepared by the Mahanadi Division under our guidance, for repairs to embankments 2 B and the proposed new embankment from Hasanpur to Lataharan (para. 36).

32. The flood data of the middle and lower Daya, with relief proposals, are put up (para. 39).

33. As mentioned under para. 33 details of the Sur Lake Cut conditions and working are being put up for examination (para. 40).

34. The flood situation in the Dhanua basin has been carefully studied and data and proposals are ready (para. 41).

35. The mouth of the Kusbhadra river was in good condition in 1939 so no action was necessary (para. 42).

General.—In general it may be said that for the first time a series of reliable flood observations have been made throughout a season of high floods in the Mahanadi and Brahmini deltas, and the distribution and behaviour of these floods recorded. A considerable part of the necessary network of reliable levels has been done and sections and flood levels of rivers have been taken. From the data now available certain deductions can be drawn on which action may be possible and a good beginning has been made towards the proper study of floods in Orissa as required by the Orissa Flood Advisory Committee.

J. SHAW,

*Executive Engineer, Floods and Drainage Division and
Secretary, Orissa Flood Advisory Committee.*

APPENDIX II.

List of Works.

Name of work.	Concerning flood-affected area.	Approximate annual flood damage (crops and houses).		Approximate cost of work.	Probable reduction in average flood damage as a result of construction of work in col. 1.	
		Original loss in rupees.	Possible net loss of income after recoupment by extra <i>rahi</i> crop or foreign labour in rupees.		Proportion of total original loss.	Value.
1	2	3	4	5	6	7
MAJOR.				Rs.		Rs.
1. Improvement of the Sur Lake Cut	Dhanua basin ...	2,00,558	1,10,007	88,000	$\frac{3}{8}$	75,210
2. Escape at Rautra Ghai	Kharsua-Brahmini area.	1,75,000	96,800	74,000	$\frac{1}{8}$	21,875
3. Direct channel linking the Dhanua with the Dal Nadi double-embanked and closing the breaches in the Dhanua and Kandaria right embankments.	Dhanua basin ...	2,00,558	1,10,007	45,000	$\frac{3}{8}$	75,210
4. Formation of a connecting embankment between 1 B and 2 B and closing the breaches in embankment 2 B and extending the embankment to Madhab.	Kadua-Prachi ...	1,18,000	64,900	1,40,000	$\frac{1}{5}$	22,600

Name of work.	Concerning flood-affected area.	Approximate annual flood damage (crops and houses).		Approximate cost of work.	Probable reduction in average flood damage as a result of construction of work in col. 1.	
		Original loss in rupees.	Possible net less of income after recoupment by extra <i>rabi</i> crop or foreign labour in rupees.		Proportion of total original loss.	Value.
1	2	3	4	5	6	7
MINOR.				Rs.		Rs.
1. Restoration of the Daya left embankment (29th to 33½ miles).	Daya area ...	1,52,687	88,978	26,500	$\frac{1}{5}$	90,583
2. Extension of embankment on the right of the Katjuri-Debi river from Gobindpur to the mouth of the Tel drainage and closing the Manikunda breach.	Surua-Debi west to Prachi.	2,08,880	1,14,900	35,500 or 26,000, if land free.	$\frac{1}{8}$	26,110
3. Restoration of the embankment linking the Bhargovi left embankment with the Nuna embankment and construct on of irrigation sluices.	Daya area ...	1,52,687	83,978	19,500	$\frac{1}{15}$	10,179
4. Provision of an escape in place of the breach at Tirimul.	Daya area ...	1,52,687	83,978	5,750	$\frac{1}{20}$	7,634

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APPENDIX III (1).

The Dhanua Basin between the Rivers Bhargovi and Kusbhadra.

The report on this area is considered under the following headings:—

General Topography.	Flooding.
Rivers.	Flood Damage.
History.	Flood Hydraulics.

A map, section and charts are attached illustrating this report.

GENERAL TOPOGRAPHY.

The area under report lies in Puri district to the north-east of Puri and is that land bounded on the west by the Bhargovi river, the Kanchi river and the railway line near Puri; on the east by the Kusbhadra river; and on the south by the Bay of Bengal.

Following the usual deltaic land formation the land is higher near the Bhargovi and Kusbhadra river banks and slopes gradually inland to the Dhanua river which is the interior drainage and follows for the most part the lowest land formation. The general contour lines in the map indicate the slope of the land. A 2-mile wide strip of sand dunes extends along the sea coast at a generally higher level than the immediate hinterland. The lowest formation is the Sur Lake an extensive permanent sheet of water about 4 miles long by $2\frac{1}{4}$ miles wide, lying just north of the sand dune area and about 4 miles north-east of Puri town. The next lowest area is that north of the Sur Lake between the Bhargovi and the Dhanua rivers. The area is well populated and is nearly all cultivated, the crop being largely rice.

RIVERS.

The area in question is part of the southern portion of the Mahanadi delta under the Kuakhai river system.

Bhargovi river.—The Bhargovi river which forms the west boundary of the area takes off from the Kuakhai river and passes south to within about 5 miles of Puri town after which it proceeds west and finally north-west to the Chilka Lake. This river is double embanked throughout and does not contribute flood to the area under report except through Achutpur escape on its left bank about 5 miles from the head, and by the Kanchi river which takes off near the river bend north of Puri and flows into the Sur Lake and Samang Pat. The Bhargovi has a wide sandy bed near its head but lower down gradually assumes a narrower troughlike formation. As the tidal range in the north shore of the Chilka Lake is very small the Bhargovi cannot be considered as tidal.

Kanchi river.—The Kanchi river takes off from the Bhargovi about 29 miles from the head of the Bhargovi and at an acute reverse angle to the Bhargovi. About $1\frac{1}{2}$ miles from its head the Dhauria river takes off from the Kanchi passing in a south-west direction into the Samang Pat which is a large low lying seasonally flooded area measuring about 3 miles by 2 miles lying north of Puri town. The Kanchi river flows into the Sur Lake and is double embanked to within about 2 miles of its low flood outfall into the Sur Lake. The river is a deep and narrow trough which deteriorates in section after the Dhauria takes off and is much reduced after entering the open lands bordering the Sur Lake. This river carries flood water from the Bhargovi to the Sur Lake but later in the season when the Sur Lake is at a high flood level and the Bhargovi river falls, the current is reversed and Sur Lake water passes back slowly to the Bhargovi.

Atharnalla.—As previously described, the Dhauria river coming from the Kanchi river fills the Samang Pat with flood water, most of this flood water passes off to the Chilka Lake mouth by the Sunamuhi river flowing west, but the Atharnalla is a shallow drainage which connects the Samang Pat on the west with the Sur Lake on the east and flows in either direction according to the respective flood heights of the two lakes. It is a definite channel from the Samang Pat as far as $1\frac{1}{2}$ miles east of the railway line, then gets lost in the flood-exposed fields bordering the Sur Lake. It is bridged by the Jagannath road and the Bengal-Nagpur Railway just north of Puri.

Sur Lake Sea Cut.—This is an artificial cut from the Sur Lake at Beldal through the casuarina plantation and high coastal sand dunes to the sea. It was made for flood relief purposes in 1932 and is 400 feet wide. It only works during flood time and thereafter the mouth is closed by a sand bar. It is developing gradually as it is exposed to the scour of floods and during its working period is tidal to within $\frac{1}{2}$ mile of the Sur Lake.

Kusbhadra river.—The Kusbhadra river forms the east boundary of the area and is the first branch of the Kuakhai river. It is double embanked for $12\frac{1}{2}$ miles from its head as far as Banamalipur and thereafter the right embankment extends another $11\frac{1}{2}$ miles to below Nimapara. During maximum floods it takes about 62,100 cusecs at its head escapes, 28,600 cusecs into the Dhanua basin through Jogisahi escape on its right bank about $2\frac{1}{2}$ miles from its head, 7,000 cusecs to the Prachi area through Ramchandrapur escape on its left bank one mile further downstream. The remaining flood volume passes down the river and over the left bank at many places into the Prachi and Kadua area. Further down the river forms two loops, and into the larger western loop the Dhanua drainage with the flood water from the Achutpur escape on the Bhargovi and the Jogisahi escape on the Kusbhadra enters and spills into and over the Kusbhadra. Thereafter the river takes a winding course and passes through the sand-hills into the Bay of Bengal with the usual deflected sand-barred mouth. The tidal range extends as far as Bcdpur 15 miles from the mouth.

Dhanua river.—The Dhanua main interior drainage of this area and with its minor additions, the Kandharia on the west and the Monaguni on the east, flows to the Kusbhadra. Another small high level drainage, the Bengai, flows south into the Sur Lake.

Dal Nadi.—The Dal Nadi is a small channel linking the Sur Lake into the Kusbhadra. It used to flow in either direction according to whether the Kusbhadra or Sur Lake were higher although now-a-days with the open breaches on the Dhanua embankment it flows mostly to the Sur Lake in the small length of that end west of Tarhana and to the Kusbhadra in its east portion. It is double embanked for most of its length.

HISTORY.

From old records it is seen that the Dhanua basin has always been badly affected by big floods in the Bhargovi and Kusbhadra rivers. The Bhargovi and upper Kusbhadra embankment system seems old and later on the extension of the embankment system on the Kusbhadra right bank to below Nimapara reduced flooding to some extent. All the river embankments breach in big floods, and in 1902, the Superintending Engineer, Mr. Inglis, introduced the system of flood escapes in the embankment under which the continually occurring breaches at Jogisahi and Achutpur were reduced in size and formed into revetted flood escapes. This was done as it was realised that the embankment system was incapable of confining a big flood without raising the embankments to a much greater height than existed and beyond the practical limits. The Achutpur and Jogisahi escapes were constructed from 1905 to 1909.

Previous suggestions had been made to turn part of the Bhargovi into the Sur Lake but this was not done as it was feared that Puri town communication would be too badly affected and a sea cut would not function well.

The system of embankments in the interior is purely recent as also some of the ring embankments bordering the Sur Lake.

In 1921 this area was surveyed roughly and flood conditions reported as in Stevenson's report on the Contour Survey and Flooding of the Coastal Districts of Orissa. The only scheme of relief of any importance was a cut from the Sur Lake to the sea but this was turned down. A new mouth for the Kusbhadra was cut through the obstructing sandbar in 1926 but this filled up again in the next flood season.

The 1928 Flood Committee studied this area and recommended the construction of a cut from the Sur Lake to the sea to be undertaken before any other improvements could be considered. This cut was completed in 1932 and has been functioning since.

In 1938 as recommended by the Orissa Flood Advisory Committee, the Sur Lake Sea Cut was deepened from its head to the scoured portion for a width of 200 feet and a depth of $1\frac{1}{2}$ feet. This made the cut work earlier and encouraged bed scour which had practically ceased.

FLOODING.

As indicated previously, flooding in the Dhanua area is caused by the flow from the Achutpur and Jogisahi flood escapes. When the Sur Lake is filled to its maximum the northern embankments of the lake are sometimes breached and flooding takes place from the Lake over the lands on the north.

The general direction of flooding is shown by arrows on the accompanying map as also the extent of flooding.

The Dhanua river passes the first of the floods; then as the flood level rises the other drainage channels come into use until the whole central area is flooded in a big flood.

The Bengai drainage, which is now too old and high to be an effective drainage channel, passes a certain amount of high spill slowly into the Sur Lake on the north. The flow is never reversed. The area west of the Bengai, which is partly protected by higher lands and some length of embankment, receives only high spill water and remains water-logged until the Sur Lake levels become lower, after which drainage takes place by Murarapara sluice and by temporary cut made in the Sur Lake embankment.

The vast amount of the interior flood is held up by the Kandharia-Dhanua right embankment and directed east into the Kusbhadra. Large breaches and cuts exist in this embankment however and about 5/8th of the flood volume passes south to enter the Dal Nadi at the exposed bend at Tarhana and flow in both directions to the Kusbhadra and the Sur Lake. The Barana embankment which prevents direct access to the Sur Lake is also frequently overtopped and breached. The distribution of the run-off here depends on the level of the Sur Lake which rises as the flood season advances but the bulk of the water passes to the Sur Lake. The area between the Dhanua and the Dal is also drained by the Balia Nadi, a small drainage which joins the Kusbhadra at the Dhanua outfall.

Between Gop and the Dhanua outfall the Dhanua basin floods pass over and through the roadway and into the Kusbhadra river which again overflows and passes the flood water east into the Kadua area and the land to the south.

The level and extent of the Sur Lake increase with the floods and in a high flood the lake is limited by the embankments on the north and east, the road on the south and extends westwards over the fields to the Kanchi embankments and over a wide area of land to the Atharnalla. The inflow is from the Kanchi and Dal with a small amount from the Bengai and the outflow is by the Atharnalla to the Samang Pat and by the cut to the sea.

FLOOD DAMAGE.

A statement of the average flood damage experienced in the last 20 years in this area is attached.

Round the Sur Lake, provided the surrounding embankments do not breach, flood damage is small and is confined to the exposed lands on the west. The unprotected low lands round the Sur Lake generally grow "Dalua" or spring rice after the flood season is over. The chief damage occurs when any of the surrounding embankments breach as the ring bund areas are then water-logged until the Lake level is sufficiently low to drain them dry again. When the old Bengai embankments north of the Lake breach then the large expanse of partially-flooded low land on the north is inundated to a greater extent and depth and severe prolonged damage ensues.

North of the Sardeipur-Balipatna road general flood damage cannot be said to be severe as although the flooding is fairly general, the water passes off quickly and stagnation does not occur. There is no complaint of the cross drainage roads holding up the water to a damaging extent. Some damage is caused in the lower areas and near the field channels by the force of the water. When Jogisahi escape breaches then sand is brought in and causes flood damage nearby but when the escape does not breach little damaging sand enters.

Between the Sardeipur-Balipatna road and the Pipli-Nimapara road the Dhanua has taken definite form as a channel and the Achutpur escape flood enters. The land is also lower near the Dhanua and flooding more extensive. The worst damage occurs in the central strip about one mile wide on either side of the Dhanua and along the field drainages. Damage in the rest of the flooded areas is not serious. The Pipli-Nimapara road formerly was a source of trouble but since the large breaches in the 10th mile have been left open at field level, the damage caused by the heading up of water by this road is not great. A certain amount of sand is brought in by the Achutpur escape and much damage was done by the breach and escapes in early days but now-a-days there is little damage from this cause.

The area from the Pipli-Nimapara road to the Sur Lake is the worst flood-affected area. The lands near the Dhanua and to the east suffer most as also the low lands on the south-west whose only drainage on that is the Sur Lake. There are several isolated privately protected areas such as the Dobhar and the Arisanda ring bund areas but these embankments rarely keep out a big flood.

The area between the Dhanua and Dal is low lying and deeply flooded and the ring bund areas around, such as the Baruna and Uruali embankment are frequently breached in high floods and much damage done.

Damage in the Gop-Kusbhadra-Dhanua area is not excessive as although flooded the land is fairly high and stagnation does not take place.

South-west of the Dal Nadi little or no damage occurs but the low lands on the south-east suffer considerably. The lands south of the Kusbhadra loops are also affected badly in high floods.

FLOOD HYDRAULICS.

Flooding conditions depend on the floods in the Bhargovi and Kusbhadra rivers and the interplay of these rivers with the Samang Pat and Sur Lake.

In the 1939 high flood the Kusbhadra carried 52,600 cusecs at its head escapes 28,300 cusecs through the Jogisahi escape and 1,800 cusecs through Ramchandrapur escape, passing 22,500 cusecs below.

Kusbhadra river.—The usual reduction in flood range occurs as a river approaches the sea but in the Kusbhadra there is a very big difference. The flood range at Gop between floods in 1939 is limited to about $2\frac{1}{2}$ ft. and that at Charheigaon below to 3 ft. as against the 10 ft. range of the river at Balipatna 17 miles above where the river is double embanked. This is due partly to the fact that the river is double embanked at Balipatna and later single embanked and then from 4 miles above Gop, free of embankments. The other cause is the Dhanua flood which returns to the Kusbhadra from Gop downwards and causes backing up in the river.

The tidal variation seems to die out at about R. L. 7.0 and there is no noticeable difference in flood heights above this level due to the incidence of spring or neap tides.

The river mouth was in fair order in 1939 and there is no noticeable difference in flood slope caused by the seasonal enlargement of the mouth.

The river flood slope shows steepening as the escapes are approached then a gradual slope steepening again where the left embankment end and spill occurs. Thereafter the flood flattens gradually until the sand-hills are reached when the slope steepens to the mouth. A big heading up amounting to 3 ft. or so is shown at the sand-hills gap for the 1939 flood observations as the river channel is good and pending verification by careful observation in 1940 floods, is trusted with suspicion. If such large heading up is finally observed correct then there will be reason for great improvement here.

Bhargovi river.—In the 1939 floods the Bhargovi was passing about 52,600 cusecs at the head, 14,500 cusecs through Achutpur escape and 20,100 cusecs below. At Jankadeipur the Kauchi river took off about 7,200 cusecs as may be seen from the graphs of gauges. From the graphs of gauges it is seen that flood range at Gobakund in 1939 was 10 feet as compared with the Jankadeipur gauge range of 8 ft. This is due to the Kauchi taking off flood here.

Sur Lake System.—The interflow between the Bhargovi-Kanchi, the Kusbhadra, Dhanua, Dal, Samang Pat, Atharnalla, Sur Lake and sea cut have been described under the chapter on "Flooding". The controlling factor is the level of the Sur Lake and Samang Pat which rise as the flood season advances. The importance of the Sur Lake Sea Cut in lowering the level of the Sur Lake is clearly demonstrated.

The Bhargovi and Dhanua breaches spill from the Dal to the Sur Lake were always flowing into the Sur Lake and the sea cut was always flowing out once the cut bed level of about R. L. 11.0 was reached. The graphs show clearly the variations of flow of the Kanchi and Attarnalla to and from the Sur Lake. Thus, studying the Kanchi lower gauge at Nuapatna and the Bhargovi gauge at Jaukadeipur it is seen that the flow of the Kanchi was to the Sur Lake in varying degree up to 6th September : was reversed on 7th September varied in degree up to 20th September and then flowed back slowly to the Phargovi thereafter. A study of the Attarnalla and Sur Lake Cut head gauge shown the Samang Pat flowing via the Attarnalla to the Sur Lake prior to 19th August 1939 (due to the previous small floods) then the flow reversing to the Samang Pat or remaining about steady until 7th September 1939 when the flow was again slowly to the Sur Lake and thereafter was fairly steady. The Siaro gauge curve shows the state of flooding in the lower Dhanua basin.

An investigation of the flow conditions in the Dhanua basin and round the Sur Lake was made in the 1939 floods in 4th September 1939, when flooding were highest in the Dhanua basin. The various discharges are shown in the general flood map. This data with some adjustment for maximum flood conditions can be used for determining probable conditions when the various schemes for flood control in this area are worked out and a repetition of these observations will be useful.

It is seen that during a high flood the quantity of flood entering the Dhanua basin through the Jogisahi and Achutpur escapes more than equals the volume of the Bhargovi and Kusbhadra rivers themselves lower down. The balance of flood in the Dhanua basin was as noted below : -

Volume entering through escapes.		Outflow.	
Jogisahi	25,500	... Bengai to Sur Lake	400
Achutpur	14,900	Dhanua through Dal to Sur lake	18,720
	<hr/>	Dhanua through Dal to Kusbhadra	6,740
	40,400	Known difference between Kusbhadra	6,690
		at top and Charhoigaou.	
		Total	... <hr/> 32,550

The balance of 7,850 cusecs is easily accounted for by the unknown quantity of flood spill to the east into and over the Kusbhadra to the Kadua area and by the rate of rise of flood levels in the Dhanua basin.

This shows that the Dhanua flood through the Dal Nadi is the main source of flood in the Sur Lake at present, and the importance of developing the Sur Lake sea cut to deal with this inflow is clearly demonstrated otherwise the Dhanua basin floods will continue to cause congestion and wide-spread damage. Alteration in the sea cut discharge and consequent lowering of the lake level will cause a bigger in-drought from the Bhargovi through the Kanchi and also through the Atharnalla and these channels may have to be controlled eventually.

APPENDIX III (2).

Report on Kadua-Prachi area.

As recommended by the Orissa Flood Advisory Committee in paragraph 51 (iii) (1) of their Interim Report of January 1939, a special survey and investigation of the Kakatpur-Prachi-Kadua area has been done to determine the flood conditions, supply adequate data and propose schemes for relief. Such a report has been prepared and is now given in a condensed form.

The report is considered under the following headings :—

General Topography.	Flood Damage.
Rivers.	Flood Hydraulics.
History.	Possible relief schemes.
Flooding.	Recommendations.

GENERAL TOPOGRAPHY.

The area under report lies mostly in the Puri district and as may be seen from the map attached is bounded on the west by the Kusbhadra river, on the east by the Katjuri-Debi group of rivers, on the south by the Bay of Bengal and on the north may be considered as far as the sources of flood from the Surua and Kusbhadra rivers.

The river system is shown in the accompanying map in which the main rivers are the Kusbhadra and the Debi river group and the interior drainages the Prachi and Kadua. The area conforms to the usual deltaic formation in that the land is higher near the main river banks and slopes gradually inland to the central drainage. The average ground levels given on the map indicate the conformation. This simple deltaic formation is somewhat upset by the Prachi river which for a large part of its length is bordered by higher lands and in some places by sand-hills indicating that it belongs to an older system of rivers and has since deteriorated to its present state of part drainage part flood carrier. This comparatively high strip of land bordering the Prachi is of importance as the Cuttack-Madhab-Kakatpur road runs along it and it forms a flood spill ridge between the Debi river and the Kadua basin. This Kadua basin is the lowest land in this area being only 6 or 7 ft. above mean sea level in many places, and as it receives flood water from north, west and east suffers most from stagnation.

Between the Kusbhadra and Prachi mouths, extends a strip of coastal sand dunes about $2\frac{1}{2}$ miles wide, at a generally higher level than the hinterland. From the Prachi to the Debi mouth the sand dunes are less than $\frac{1}{4}$ mile wide but also act as a barrier to free run-off of flood water.

The land as a whole is intensely cultivated, the chief crop being rice. The only uncultivated areas are patches of jungle along the Prachi higher sandy lands, a long strip of low lying flood-affected land just east of the Prachi ridge, very low lands bordering the Kadua, and the sand-hill area along the coast. There is little rabi cultivation beyond the usual crop of poor pulses grown after the rice crop; extensive *pan* gardens along the Prachi ridge yield a valuable income, and some spring rice is grown in lower lands.

RIVERS.

Kusbhadra river.—The Kusbhadra river on the west is one of the Kuakhai river branches. During maximum floods it takes about 62,100 cusecs at the head, escapes 28,600 cusecs through Jogisahi escape on the right bank to the Dhanua basin, 7,000 cusecs through Ramchandra-pur escape on the left bank to the Prachi, and the remaining 26,500 cusecs passes below. Flood spill takes place in many places over the left or east bank into the Prachi and Kadua areas and further down, near Nagpur, the Dhanua flood water, about 800 cusecs, comes in from the west to join the Kusbhadra and after further spill to the Kadua, the Kusbhadra passes through the sand-hills to enter the sea with the usual deflected sand-bar mouth. The tidal effect extends as far as Bedpur, 15 miles from the mouth.

The Kusbhadra is double embanked for 12½ miles from its head as far as Banamalipur and thereafter the right embankment extends another 11½ miles to beyond Nimapara.

Debi River System.—The Debi river is the name given to the lower Katjuri. In full flood it takes about 450,000 cusecs or a little less than ½ of the main Mahanadi entering the delta. As may be seen in the map, the Debi river, a short distance below the Surua-Katjuri confluence divides into many subsidiary rivers. Apart from the main Debi river the Kandal and Taunla loop rivers on the west are the important channels and these rivers spill freely during flood to the west. These rivers show a tendency to scour to the west throughout. The lower Debi has a large and efficient channel and estuary and the mouth is always of sufficient size to maintain a good flow. The river is tidal as far as Alipingal, 25 miles from its mouth.

Prachi River.—The Prachi river commences from the bridge on the Jagannath road 9½ miles from Cuttack. It was formerly connected to the Kuakhai and as stated previously in this report is evidently the remains of an old river which after building up the land around has deteriorated from its head downwards and is now, except in its tidal reaches near the sea, only a series of broken up deteriorated channels with a few pool reaches. Its bed is planted in many places with long "Inkar" grass used in *pan* garden construction. It is tidal as far as Bajpur, 12 miles from its mouth. The Prachi may be looked upon as a sort of high level canal which catches the flood water from the north and east but being incapable of carrying the full spill, passes the excess

over its west bank to the lower Kadua lands. The sea mouth varies considerably and leading cuts are made in the sandbar to develop a mouth when necessity arises.

Kadua river.—The Kadua is a typical deltaic drainage channel. It is low-lying and tidal as far as Kantigram, 16 miles from the sea. An older branch called the "Patharbaha" used to connect with the Kusbhadra near Bedpur and pass by Konarakh, as seen in the map, but this channel is not now connected and only takes flood spill. The Kadua joins the Prachi about 1 mile from the sea to form a joint mouth. An additional mouth for the Kadua about 1 mile west of the Prachi mouth was in existence at the beginning of last century but has long since closed up.

HISTORY.

The Kadua-Prachi area always seems to have been subject to bad flooding and previous records are largely confined to amounts of flood damage until 1921 when a survey of the coastal districts of Orissa was done and the flood situation described in detail in Mr. G. Stevenson's report. No material suggestions for relief were put up however and later the 1928 Flood Committee recommended a further special investigation of this area. Due to subsequent economy this was not done until in 1939 the recently constituted Orissa Flood Advisory Committee recommended investigation which has since been carried out and report prepared. During 1938 and 1939 full particulars of flooding were observed throughout the flood season with an extended gauge system and a special officer of the new Floods and Drainage Division of the Public Works Department.

FLOODING.

The extent of land at present flooded during high flood is shown in the map, indicating general submergence of most of the area. The chief sources of flood and the direction of spill are also shown on the map.

Kusbhadra flood.—The Kusbhadra during high flood contributes about 7,000 cusecs through Ramchandrapur escape to the Prachi and from Banamalipur downwards where the left bank is mostly open, high flood spill takes place in long lengths inland to the Kadua basin.

Debi flood.—Serious flooding has been caused in the past by breaches in the Government embankment on the Surua river during very high floods. Below Gobindpur at the head of the Debi river a privately maintained embankment extends to the mouth of the Tel drainage but this is frequently breached and a permanent breach called the Manikunda Ghai, at a bend of the Kandal river passes about $\frac{1}{2}$ of the river water inland. Part of this big breach water returns to the river lower down, part passes off down the low lands east of the Prachi ridge, and some passes through the big permanent breach in the Cuttack-Niali-Madhab road to the Prachi at Bainroi. At various

places on the Prachi ridge as shewn, the Kandal, Taunla and Debi flood pass inland to the Prachi, notably at the Purua and Nua Betanda Ghais, round the flank of embankment 2 B, and if the breach-closing private embankment does not hold, through the large breach at Kandasahi near embankment 1 B. With the long standing big breaches in embankment 2 B the land inside is exposed to flood and through the mile-wide permanent breach in embankment 1 B at Osian the whole land to the south is flood-affected.

Prachi flood.—Unless breaches in the embankments and road near the Kuakhai, or breaches in the Surua occur, no flood water comes into the Prachi until the Ramchandrapur escape water from the Kusbhadra enters. Excluding breaches in the Debi-Kandal private embankment, the next flood supply is from the Manikunda Ghai through the road breach at Painroi and lower down below Athaspur. Kusbhadra left bank spill then enters and some water is passed off east through the road to the Kandal low lands as shown. North of Madhab the Taunla flood crossed the Prachi ridge and further south the two big channels at Nua Betanda and Purua Betanda add considerable volume to the flood. The Prachi is now spilling flood westwards to the Kadua and further spill takes place when the Sohagpur outflanking breach at the end of embankment 2 B contributes more flood water. Flood overtops the high ridge between embankments 2 B and 1 B. Some further floodspill to the Kadua takes place near Bangurigaon at the beginning of floods.

Kadua flood.—The Kadua receives flood water from the Prachi and from the Kusbhadra left bank spills, and over and round the Gop-Konarakh road all as shown in the map. A small amount of water passes in devious ways through the sand-hills near Konarakh to Chandrabhaga and to the Kusbhadra mouth.

FLOOD DAMAGE.

Flood damage here as elsewhere is variable. In years of medium or low floods little damage is done and in many cases, excluding possibly the lowest land near the drainages, such floods over the land are actually welcome. They irrigate the crops, wash off injurious salts and do good. It is the prolonged flow or stagnation of floods over the land which ruins the crops and damages houses. When the land is exposed to low spills either natural or by breaches in an embankment then damage is likely. The sudden breaching of an embankment or a strong low spill channel carries sands and destroys a certain area nearby. The time of floods with the stage of the crop is also an important factor in damage as the seedling and flowering time are specially vulnerable and taller crops remain only partly submerged.

Each big flood causes damage in this area and records are to hand of the rough extent of seriousness of the damage so it is possible to reckon the average cost of flood damage yearly.

Original flood damage is often partially recouped by extra labour with rabi crops and cash from foreign labour, but many lands are unsuitable for growing paying-rabi-crops so the figures given represent cash value of crop and labour-loss after transplantation only.

The average annual flood damage in the area under report is about Rs. 3,26,830 of which about Rs. 2,08,880 occurs in the Prachi tract affected by the Debi and Prachi floods and Rs. 1,18,000 in the Kadua area affected by the Prachi and Kusbhadra floods. In the Kadua basin area about Rs. 56,300 damage may be attributed to Kusbhadra spill and Rs. 61,700 to spill from the Prachi.

These figures will be compared later with the cost of possible relief schemes.

FLOOD HYDRAULICS.

Flooding conditions in the area under report are controlled by flooding in the Kusbhadra and Debi rivers and to some extent by the condition of the sea mouth and prevalence of storms.*

Chart I gives the graphs of the river gauges affecting this area during a series of 1939 floods. It can be seen, as expected, that flood rises first in the Debi and Kusbhadra rivers, then in the Prachi which is fed from the Kusbhadra, Debi and Kandal; and later in the Kadua which is supplied from the Kusbhadra and Prachi spill. The Kadua flood, however, as may be seen from a comparison of the two Bangurigaon gauges, eventually exceeds the Prachi flood levels here.

The average ground level as shown in the map compared with the gauge levels on the chart show the depth and intensity of flooding over the land.

Kusbhadra river.—Chart I includes the Kusbhadra river gauges and Chart II shows the longitudinal section of the river with the 1939 flood levels, bank and bed levels, and cross-sectional area of the river between banks at various places.

There is a noticeable decrease of river area after the left embankment ceases and general spill takes place.

The flood slope shows the steeper gradient as the Jogisahi and Ramchandrapur escapes are approached, and the alteration after the left embankment ceases at Banamalipur where bank spill takes place. The striking feature is the flood levels at Gop where the range of high flood is very restricted being about 3 feet as compared with the 10 feet range in the same river levels at Balipatna 17 miles above, where the river is double embanked. This small range is caused partly by the spill over the left bank to the Prachi and Kadua and largely by the backing up effect of the Dhanua floods which enter the Kusbhadra from Gop to the Dhanua junction. The range of flood decreases as the sea is approached, but taking as a rough comparison the Debi river gauges of

Alipingal and Sikhar we get 10 ft. and 7 ft. range; so the backing up effect of the Dhanua floods and the effect of the spill to the Kadua is obvious.

A gauge level of 10 ft. at Gop indicates the commencement of the general spill to the Kadua above and below Gop.

The river mouth was in fair order in 1939 and there is no noticeable difference in flood slope or duration of flood with the seasonal enlargement of the mouth.

Tidal variation is seen to die out at a flood height of R. L. 7.0. The mean sea level is the same during spring or neap tides and the occurrence of high or spring, and low or neap tides seems to make no noticeable difference in the height or duration of the floods a short distance inland. For further discussion of seasonal variation of mean sea level which would affect floods see Appendix IV.

Debi river.—Chart I includes the Debi river gauges and Chart III gives the longitudinal section of the river with details and flood slopes in 1939.

About R. L. 36.0 at Karmanga gauge at the head of the Kandal river, spill may be said to begin to the Prachi and similarly at R. L. 16.0 at Sikhar and R. L. 8.5 at Machgaon. With its good tidal estuary, tidal variation is here seen to die out about R. L. 8.0 during floods and there is no perceptible difference in gauge relationships or flood behaviour at time of spring or neap floods.

The sea mouth was in good order and its further development had no noticeable effect on flood behaviour.

Prachi river.—Chart I includes the Prachi river gauges. It is seen that the Prachi river gauge at Kakatpur follow the Debi gauges at Sikhar and Machgaon closely. The lag in the Prachi flood is less than a day in the first flood but the floods of 3rd and 10th September 1939 take a full day longer to reach the minimum turning point and rise again. The Bangurigaon gauge further down the Prachi lags about 1 day behind the Kakatpur gauge in the first flood but later on is only $\frac{1}{2}$ a day behind as the river is running fuller. This gauge is about 1 to $1\frac{1}{2}$ days behind the Debi gauge at Bilpara opposite.

Kadua river.—The lag in rise of the Kadua with the Kusbhadra and Prachi flood gauges is seen in Chart I. The Bangurigaon gauges on the Prachi and Kadua are about equal distances from the junction of the two rivers to show well relative behaviour. The Prachi is seen to rise earlier and higher than the Kadua by 2.5 feet, then the Kadua rises higher than the Prachi by 1.5 feet and remains higher for a considerable time. Flood water passes over land into the Prachi. This indicates clearly that a connection between the rivers here would on the whole be beneficial.

APPENDIX III (3).

Daya Area.

This brief report on the area affected by the Daya river is considered under several headings:—

General Topography.		Flooding.
History.		Flood Damage.
Flood Hydraulics.		

A map is attached to this report illustrating all important references.

GENERAL TOPOGRAPHY.

The area under report lies mostly in the north-west Puri district and includes that land west of the lower Kuakhai and the Daya river as far as the hills, together with the land south and east of the Daya affected by the Daya river flood escapes and the Nuna drainage from Pipli and the Jagannath Road to Delang and the Chilka Lake. The map attached shows the river system and configuration of the ground.

As with most alluvial rivers in the deltaic plains the land is higher near the river bank where most of the flood borne silt is deposited. In this case there is the lower strip of land between the Kuakhai-Daya rivers and the hills, with its drainage channel and flood flow parallel to the rivers themselves. Between Khurda Road Railway station and the Daya river at Kanti the high land projects to the river and occurs in scattered portions for a further 7 miles downstream of Kanti. Beyond this, from Tirimul to the Chilka Lake, the low land continues and on the east side of the Daya river south of Delang to the Chilka Lake the land is still lower and forms the Nuna drainage basin.

The Chilka Lake with its vast area and small sea mouth is the destination of all floods in the area under report.

The Kuakhai river takes off from the Katjuri and divides up into the Kusbhadra, Bhargovi and Daya rivers.

The Daya river, some 7 miles from the Chilka Lake, divides into two channels, the Daya and the Makra, the latter being the larger and developing river and both rivers flow into the Chilka Lake.

The Gangua Nadi drains into the Daya above Kanti taking drainage water and flood spill from above.

The Monaguni is a river draining a considerable area of hilly country to the west and joins the Daya some 2 miles below Kanas.

The Rajua Nadi drains the land west of the Daya and south of the Kanti high lands. It also helps to pass the considerable amount of spill from the Daya river at Tirimul.

The Nuna river is the drainage channel of the semi-protected area south and east of the Daya. It also takes considerable flood water from the Daya river escapes at Belmora, Madhipur and Kanti and joins the Daya and Bhargovi rivers near the Chilka Lake.

The Bhargovi river, after passing the larger part of its volume elsewhere, finally joins the Daya river just at its entrance to the Chilka Lake.

HISTORY.

Before the Naraj weir was constructed in 1860 and the Barang Nullah closed at its head, a larger volume of water passed down the Kuakhai and Daya than now-a-days. Continual efforts were made to maintain the Kuakhai right or west embankments and the Daya right embankments, but these continually breached in high floods. Chief Engineer Mr. Odling in 1892 reported on this area that it was not practicable to maintain the Kuakhai and Daya right embankment continuously from head to sea against high floods as this would require the embankments to be retired and raised to excessive heights. He therefore recommended that the embankments then existing be kept at their present inefficient state to keep out ordinary floods and repaired after big floods. The embankments should not be extended, the Tirimul breaches which constantly opened should be left open and no right embankment maintained below these breaches.

At present the Kuakhai right embankments above Mancheswar have been abandoned and are in a breached condition, a large gap for flood water is left at Mancheswar and the right embankment is maintained from here continuously with the Daya right embankment as far as opposite Madhipur escape, the Daya portion being Khasmahal. Thereafter there is no right embankment on the Daya.

The Daya left embankment is now kept in better order as far as the Monaguni junction chiefly by the provision of three large paved flood escapes at Belmora, Madhipur and Kanti which pass off considerable flood volume but lower the flood levels in the river and prevent breaching of the right embankment.

On the recommendation of the 1928 Flood Committee the last 4 miles of the Daya left embankment were abandoned by Government and numerous breaches take place here in high floods.

The only noticeable developments are the increase of the Makra river at the expense of the Daya, the increased spill and sand deposits from the Kuakhai below the Barang Nadi, and the development of the Tirimul breaches into a regular deep channel.

FLOODING.

Practically the whole of the area under report is flooded more or less during a high flood in the Kuakhai river system as shown in the accompanying map which also shows sources of flood spill. Ground levels and flood levels show the depth of water over the land in 1939.

The area between the Kuakhai and the railway line is flooded first through openings in the higher ridge of land south of the Barang Nala then by the two bad sand carrying Ghais on the Kuakhai just below the Barang outfall, then through various breaches in the old Kuakhai right embankment.

The accumulated flood spill then meets the Public Works Department Kuakhai right embankment at Mancheswar and part of the flood passes further down south through the 1,300 feet wide gap between the embankment and the railway, while the rest passes back into the Kuakhai river. Nearly $\frac{1}{2}$ of the whole Kuakhai flood passes through Mancheswar Gap during a maximum flood.

No further flood spill is received until a few miles below Belmora escape on the Daya river where the right embankment opposite is overtopped in many places and there is little difference between the river and country flood levels.

The flood from Mancheswar gap passes south through the low levels and forms a large sheet of water against the Daya left embankment, then turns west to Kanti and the narrow space between encroaching hills.

During a high flood the Belmora, Madhipur and Kanti flood escapes in the left embankment carry off a little less than half the accumulated flood and the remainder passes west down the Daya at Kanti Gap and between the hills just north. There is no further spill over the embankment until the breaches in the abandoned end length of embankment are met with.

Below the Delang-Khurda road crossing on the Daya, the Tirih breach occurs on the right bank. This is a well defined channel near river-bed level and carries water continuously inland. During big floods about half the river passes inland at this point.

Further spill passes inland at places on the unprotected right bank of the river and the accumulated flood passes south to meet the Monaguni right embankment and with the Daya river flood, and with water there is in the Monaguni, passes through the wide gap and down the Makra and Daya rivers and over the country to the Chilka Lake.

The Adal embankment gives protection to a small area west of Makra river.

The flood water from the Daya left embankment escapes past over causeway and through bridges in the Pipli-Khurda road, then south through the railway line which has ample waterway and over the Delang road on the lower land below. A higher spur of land about half way on the Delang-Kanas road joins up with the private embankment on the right of the Nuna river and directs most of the Nuna flood water to the east giving partial protection to the area between this embankment and the Daya left embankment. At present this embankment is generally overtopped in places and in its low reaches by flood from the east.

The area south of the Bhargovi is a protected area except for the Kani Nadi which passes through it to the Chilka Lake, and spill and breaches which take place in the length of privately maintained embankment between Khajuria and the Chilka Lake embankment.

During high flood the Chilka Lake water level rises and back water extends inland for some distance as shown.

FLOOD DAMAGE.

Flood damage varies according to the time, size, duration and sequence of floods, the occurrence of breaches, the state of the crops and the prevalence of storms. The general state of affairs caused by high floods is however fairly regular; so some description and estimate of average damage is possible.

The area north of Mancheswar gap to the Barang Nullah does not suffer regular severe damage from flooding. There are a few low lying lands which suffer but damage is largely caused by the force of water in high floods and the extension of sand deposits over the land from the two Ghais.

The area from Mancheswar gap to Bhubaneswar is damaged more by the rush of water than by submergence. Between Bhubaneswar and the Daya at Kanti the land remains submerged for a considerable time and although the crop system has been altered to make the most of such conditions, a fair amount of damage is caused in this area.

From Kanti to Tirimul on the Daya right a certain amount of damage is caused on the neighbouring lower lands.

Between Tirimul and the Monaguni damage is frequent due both to rush of water and submergence. The crop system has been adapted as much as possible to these conditions.

From the Monaguni and the Chilka Lake damage is frequent due to submergence by flood. When the Adal embankment breaches, as often happens during high flood, then most crops inside are destroyed.

Between the Makra and the Daya, flooding and damage is frequent. On the Daya left the area as far as the railway line does not suffer much damage from the escapes floods as the water passes off in time. Only when the Daya left embankment breaches, does real damage occur as this means continuous heavy flood.

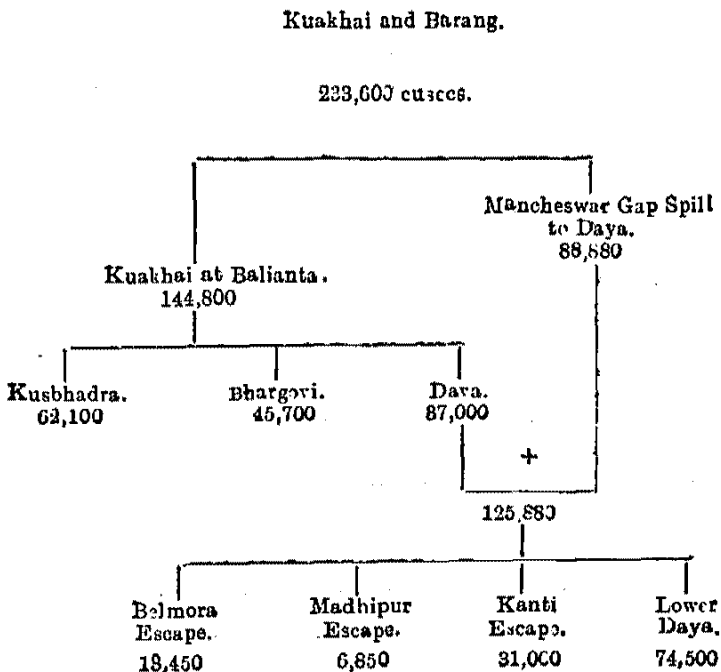
From the railway line to the Chilka Lake damage is caused by submergence and by the frequent breaches in the abandoned lower Daya left embankment. The worst affected areas are near the Lake and east of the Nuna river embankment except when the lower Daya left embankment breaches when worst damage occurs between the breaches and the Nuna. When the small and larger embankments are breached by floods and the lake is brackish and driven inland by strong

winds then salt water flooding occurs and the damage is great and prolonged. Flood damage has been very frequent in this lower Daya area and the chances of recuperation small.

In the Brahmagiri semi-protected area between the lake and the Bhargovi river the land is low lying and drainage restricted by the level of the Chilka Lake, so if flood water enters by breaches in the Bhargovi embankments or Lake embankment and the lake level remains high then severe damage occurs. If breaches allow salt water to be driven inland later then further damage occurs.

FLOOD HYDRAULICS.

During the 1937 flood the distribution of flood was as shown below :—



The above distribution shows spills or escapes taking about as much water in a high flood as the river which seems extraordinary but is the outcome of experience up-to-date in that it was not found possible to hold a high flood within the existing marginal embankments. To attempt to do so meant raising the embankments to a height of about 20 feet which is impracticable, or retiring them far inland. The latter proposition meant exposing more area, including many villages on the higher lands near the river, to higher and more frequent flooding, and so was abandoned.

The graphs of river gauges show the relative rise of the gauges. The flood range at Kanas is only about half that in the upper river area due to the large spill which takes place at Tirimul from the right bank generally. The Khetandi gauge showing the Chilka Lake level on the Nuna embankment shows the lag in rise of the lake seven days after the flood of 22nd August 1939 instance and three days after the flood of 3rd September 1939. The rise due to floods in 1939 was about 3 feet.

The Chilka Lake rises with the inflow of floods from the Daya area and the lower Bhargovi. If a storm from the north-west coincides with the flood then the Chilka Lake levels on the east can be raised by the wind an extra 2 feet or so which makes a big difference to flooding and run off for the Daya area. In the record flood of 1938 in the Chilka lake the Lake level was 5.5 feet higher than the sea outside and in 1937 was 4.3 feet higher and in 1939 was 3.5 feet higher.

APPENDIX III (4)

The Kimiria-Brahmini Area.

The report is considered under the following headings :—

General Topography.	|	Flooding.
Rivers.	|	Flood Damage.
History.	|	Flood Hydraulics.

A map and sections are attached illustrating this report.

GENERAL TOPOGRAPHY.

The area under report is in north Cuttack district south-west of Jajpur and comprises the island between the Kimiria-Berupa and the Brahmini rivers and the flood-affected lands just west of the Kimiria along the Genguti river.

The island is about 18 miles long with a greatest width of $3\frac{1}{2}$ miles and like all deltaic islands forms a basin, the higher lands being near the river bank where silt is deposited in quantities and the interior being low with a central drainage system. Contouring has not yet been done in this area but generally speaking the centre of the island in the upper half is about 5 ft. lower than the riverside lands while at the downstream and the interior averages 3 ft. or less below the river banks. The interior is flat and interspersed by many drainages fed by " Ghais " or river spill channels, and by general bank spill. There is a large expanse of low land with permanent water at the downstream end of the island.

The whole area is cultivated except for some sand deposits near the river edge and the very low lands on the south. The chief crop is rice. The population is comparatively light.

The area along the Genguti river on the west is flat land forming a basin between the surrounding hills, with the Genguti river, and to a small extent the Berupa river, acting as the drainage. This land is intensely cultivated, the main crop being rice. The population is scattered.

Both the above areas, except for village high lands, are wholly submerged in a big flood. With the exception of a kutchha unmetalled road from Jajpur which passes through the area to the south-west there are no roads, only cart tracks and footpaths.

RIVERS.

The Brahmini river bifurcates below Dharmasala to form the rivers Brahmini and Kimiria on the east and west and these two rivers reunite at Indipur about $18\frac{1}{2}$ miles below to continue as the Brahmini river to the sea. The Kimiria river is joined on the west by the Genguti and Berupa rivers bringing flood water from the Mahanadi system.

Kimiria river.—The Kimiria river takes about $\frac{2}{3}$ of the discharge of the main Brahmini. A capital embankment stretches on the right bank from its head for $6\frac{1}{2}$ miles, then after about 6 miles the Pattamundai canal embankments extend to Indipur and beyond. On the left bank there are scattered embankments as shown on the map with several big breaches and spills. The influx of the Genguti and Berupa rivers with their Mahanadi water keeps the lower Kimiria in a more continuous state of flow; so it is in better condition than the Brahmini loop.

Genguti and Berupa rivers.—These rivers bring the flood water of the Mahanadi into this area. The Genguti is the larger river, taking about $\frac{2}{3}$ of the discharge. Except for the Pattamundai canal flood bank on the south these rivers are unembanked.

Brahmini loop river.—This river is about the same length as the Kimiria. There are only strong embankments along either bank, chiefly at the bend of the river as seen in the map attached. Flood spill takes place on both banks at several places. A large loop of the river was cut off at its outfall from about 1926 and is now the main channel.

HISTORY.

There is little on record about this area which has always been subject to floods. Scattered embankments have grown up gradually, spill channels have grown and deteriorated and Ghais have formed as the river scoured away its high banks in places. No alteration of importance seems to have taken place with the exception of the various Ghais formed.

FLOODING.

As previously stated, the whole island area and the Genguti-Berupa area is covered by high floods excepting the village homestead lands and some high riverside land. The map attached shows the intensity of flooding as indicated by the flood damage. The lower lands suffer from the strong flood current in low floods and from prolonged immersion in the higher floods.

In the Genguti area flooding is caused by the Genguti river itself, by the backing up effect of the Kimiria flood and by the Rambhapur Ghai at the end of the upper right embankment. This Ghai carries a lot of water and much sand and causes a lot of damage. A smaller Ghai called the Patna Ghai on the Kimiria just before the end of the right embankment also contributes to the flood of the Rambhapur Ghai.

The Berupa area near the Kimiria is small and narrow and flooding is caused by the Berupa and by the backing up of the Kimiria floods.

In the Kimiria-Brahmini island, besides general bank spill which takes place in many places in high floods, the following Ghais and spill channels flood the interior. In order of volume of flood contribution these are as follow.

The Niali Ghai about $1\frac{1}{2}$ miles above the Genguti outfall which is giving an increasing quantity of flood and sand and causes a lot of damage.

The Kelua Nadi, an old spill channel about 1 mile upstream of the Berupa outfall, which maintains a regular channel and is useful in low floods.

The Manda Ghais at the head of Kimiria on the left side. This Ghai is of comparatively recent origin and has been caused by the river scouring away the embankment and high spill bank and so obtaining easy access to the country behind. A great quantity of sand and water is brought in and damage caused.

The Bhagabati Ghai midway down the Brahmini loop on the right banks has developed lately due to scour of the river bank and embankment and is now causing trouble.

The Balia Ghai on the Kimiria left bank near the Jajpur road crossing is a narrow channel and takes sand and water to the interior.

There is another old small spill channel about $1\frac{1}{2}$ miles below the Bhagabati Ghai, which flows through higher land, has its exit in the river about 7 miles further down. Flood water also backs up the outfall of this narrow channel.

The accumulated flood water passes down the interior to the downstream end of the island and back into the rivers over the land and through a few drainage channels.

The Brahmini also spills over its left bank in several places as seen in the map but most of this water flows back into the Brahmini as the floods go down.

When the Mahanadi river system is in flood shortly after the Brahmini system, as frequently occurs, then the Genguti and Berupa floods maintain a high level in the lower Kimiria and Brahmini and delay the run off from the lowest southern lands in the island.

Professor P. C. Mahalanobis of the Presidency College, Calcutta, has shown in his report of floods in Orissa prior to 1928 that there has been a tendency in the Brahmini to have periods of high floods followed by periods of comparatively low floods. Thus from 1891 to 1902 the

frequency of floods increased, from 1900 to 1908 steady, from 1909 to 1918 decrease, from 1919 to 1927 increase. From 1928 to 1935 there is a decrease and from 1936 the frequency appears to be on the increase. These results are not regular but show an average tendency as above. During a year when the river maintains a high level much damage is done while in years of low floods or even one large quick flood followed by low floods the damage is not much.

FLOOD DAMAGE.

The severity of flood damage in this area is indicated in the accompanying map and the statement attached gives an account of the damage caused in a bad flood season and the average annual flood damage. Here as elsewhere crop damage varies according to the time, frequency and prolongation of the floods. The worst damage is caused by the comparatively new Ghais as these bring in considerable quantities of sand and render the land sterile for some distance inland.

Flood damage however is small as the villages are built above flood levels and crop damage is caused by sand deposits and rush of water near the Ghais and interior channels but mostly by prolonged submersion of the crops. This means that flood damage varies according to the height of the land and the map shows this too well to require further description here.

FLOOD HYDRAULICS.

Longitudinal sections are attached showing the details of the Kimiria and Brahmini and the floods slopes in the high floods of 1939. As stated previously, variations occur in the lower parts according to the coincidence of floods in the Genguti and Berupa. Little further can be said about the flood behaviour in this area other than what has been described above. Further investigation is going on.

APPENDIX III (5).

Area between the Brahmini and Kharsua Rivers.

The report is considered under the following headings :—

General Topography.	|	Flooding.
Rivers.		Flood Damage.
History.		Flood Hydraulics.

A map and section are attached illustrating this report.

GENERAL TOPOGRAPHY.

This area under report lies in south-east Cuttack district, west of Jajpur and comprises the land between the Brahmini river on the west and the Pattia-Kharsua river on the east. It is about 50 miles long and averages 4 miles in width and is part of the Brahmini delta.

The area is typical of flooded tracts between rivers in an alluvial plain, i.e., the higher lands raised by silt deposit from the river are near the river banks and the interior remains low with central drainages. In this case the centre of the interior averages about 5 feet lower than the river-side lands. The accompanying map illustrates the situation. The upper part of this area above the Brahmini-Kimiria bifurcation is higher sandy land. A central strip of higher land extends from here southwards along the old spill channel called the Dudhai Nallah. The rest of the land from here southwards is low, much exposed to floods, and covered with a network of spill channels. In the lower part of the area is the Aul ring bund area extending from the Brahmini to the Kharsua. Through this run the Kendrapara-Chandbali road on a higher strip of land and just west of this up to the abandoned ring bund is extensive low land.

Almost the whole area is cultivated the chief crop being rice. Population is confined to the higher land described above. There is only a small portion of metalled road, i.e., the Orissa Trunk Road in the north which is in poor condition owing to the floods. Other more important roads are shown on the accompanying map.

RIVERS.

The main rivers are the Brahmini on the west and the Kharsua on the east. The interior drainages are scattered and there is only one loop river of importance called the Kani which leaves and re-entered the Kharsua above Aul.

Brahmini.—The Brahmini river in maximum flood carries a volume of about 347,100 cubic feet per second (cusecs). Of this about 150,260 cusecs is diverted down the Pattia or Kharsua branch river which takes off at the head of the delta. Further down the Kimiria branch on the west takes off about 67,800 cusecs and about 18 miles below rejoin the Brahmini bringing also the water of the Genguti and

Berupa from the Mahanadi system. Beyond Aul the Kharsua rejoins the Brahmini and the Brahmini continues to the sea giving off the Hansua creek just above the Kharsua junction, then the Patsala-Mayapara and being joined by the Baitarani river to continue as the Dhanra river into the Bay of Bengal. The Brahmini is tidal almost as far up stream as Indipur at the Kimiria junction, about 33 miles up stream of the Kharsua junction.

The Brahmini river is embanked on the left bank for 15 miles from the head but thereafter there are only low scattered embankments until the Aul circuit embankment extends for 10 miles along the lower reaches.

Pattia-Kharsua.—The Pattia river which takes off at the head of the delta carrying about 150,260 cusecs in a maximum flood, is called the Kharsua, or swift running river, beyond the Orissa Trunk Road crossing about $8\frac{1}{2}$ miles further down. After another 11 miles it is joined at Kamalpur by the Burah river which is a branch of the Baitarani river and carried about 124,090 cusecs in a maximum flood. The Kharsua river gives off a lot of flood water by various Ghais or spill channels into the interior and about a further 11 miles downstream of the Burah junction, the Kani Nadi, a loop river, takes off inland and rejoins the Kharsua about 10 miles below. The Kharsua is tidal to above Singhpur, a distance of 22 miles from its junction with the Brahmini. In the tidal reaches there are many creeks on both banks.

The Pattia-Kharsua has only low scattered embankments as far as the Burah junction. Thereafter a capital embankment protecting the irrigated area on the east extends along the left bank.

Hansua Nadi.—The Hansua Nadi is a large tidal creek about 10 miles long, running from the Brahmini right bank at the Kharsua junction south to the Bay of Bengal. It carries about 11,350 cusecs to the sea during a maximum flood in the big rivers and is scouring its banks and developing gradually. It is double embanked for most of its length, having a funnel shaped embanked approach at the head as far as Rajnagar.

Patsala or Mayapara.—This is a large tidal estuarine branch of the Brahmini but has been deteriorating slowly by shoaling at the head for many years.

HISTORY.

Prior to the commencement of irrigation works at the end of last century there is little on record about this area. Old records give an account of a few scattered embankments, generally in a bad state of repair and the usual story of continual flood damage. In 1871 Mr. Taylor made an inspection and reported on the embankments in this area, which confirmed the above state of affairs. As a result of this various embankments were thereafter maintained by Government.

At the head of the delta the main Brahmini was formerly divided into three rivers, the Kharsua river taking off midway between the present Brahmini and Pattia rivers. The Kharsua and Pattia joined at the Orissa Trunk road crossing to continue on the Kharsua. There were very bad spills and sand deposits over the Brahmini left bank near here and the upper part of the area under report was in a wretched flood swept condition. In about 1886 an embankment was constructed between the Pattia and Brahmini heads and the Kharsua head closed. The Brahmini and Pattia anicuts, the high level canals and irrigation systems and the capital embankment on the Burah-Kharsua left bank were then constructed. The Dudhai Nallah, an old spill channel was canalised and fed from the Brahmini anicut to supply irrigation for spring rice in the low central lands.

The Pattamundai canal on the south-west was also constructed with its flood embankment extending along the Berupa-Kimiria-Brahmini as far as Albha. The Chhota Brahmini river which led further Brahmini water at Pattamundai to the Gobri drainage on the south was closed at its head by the canal.

The Aul circuit embankment was in a bad state and Government took over that portion bordering the Brahmini river and also the Uttikan estate embankment on the Brahmini right bank in extension of the Pattamundai canal embankment from Albha as far as beyond Damerpur. The Damerpur circuit embankment was also taken over by Government.

Several bad spill channels on the Kharsua right bank called Similia, Tanti and Palasabi Ghais had stone weirs constructed at their heads to reduce the low level spill volume, and similarly on the Brahmini left banks near the head, the Jauardhan, Bisoi, Manika and Sutanai Ghais or breaches were revetted with stone and left open passing a considerable volume of water and some sand to the interior. It was considered after investigation that it was not possible to confine the Brahmini and Kharsua floods with double embankments and that these spill-ways were considerably necessary to prevent the breaching of the existing embankment system.

An investigation into flood conditions and damage was made of the lower area after the damaging big floods of 1920 and certain survey and levelling work done and a report submitted included in Stevenson's report of flooding in the coastal districts of Orissa. There were no worthwhile recommendations made for flood relief.

A rough scheme of escapes and embankments was also worked out for the upper part of this area but abandoned as data was poor and results very questionable.

In 1928 a special flood committee of three engineers was set up and included this area in their investigation and report making many recommendations for flood protection and relief. As a result of these recommendations the Brahmini weir was dismantled, a new flood

embankment made on the Brahmini left bank below the four Ghais which were closed and one large higher level of stone escape given. That part of the Aul circuit embankment maintained by the estate on the north and the east was allowed to remain in a freely breached condition. Various other recommendations were found on investigation to be too expensive or inadvisable.

In 1938 the present Orissa Flood Advisory Committee consisting of three engineers was formed and in their Interim Report of January 1939, they made various recommendations on this region depending on the collection and study of data which was very inadequate. Careful flood observations have been made throughout the floods of 1939 and much valuable data obtained. Much further survey and data are still required and are in process of collection and preparation.

FLOODING.

The extent and intensity of flooding in this area is shown in the accompanying map. This shows that except for village sites and some higher lands along the river banks and in the upper area, about the whole area is covered during a big flood.

Considering the area north of the Dharmsala-Jajpur road, flooding here has been greatly reduced since the reconstruction of the Brahmini left embankment and the closing of the various low level Ghais and the only source of flood here from the Brahmini is now the Jabra escape just below the old anicut. Water from this escape passes over the land and down the old Dudhai Nallah without causing appreciable damage. Spill from the Pattia takes place down an old loop channel which is not developing and rejoins the river at the Trunk road crossing. The banks of the Pattia are high here and bank spill takes place only in high floods, but continual high flooding causes damage as shown. At the right angle bend of the Kharsua east of the Trunk road several Ghais (called Banka Ghai) have recently formed by scour of the river banks and embankment and contribute to flooding and give sand deposit during high floods.

Further downstream there are no big spill channels from the Brahmini inland. At Rudrapur and 1 mile below there are two open channels through which flood water backs up and later flows out again since the Janardan and neighbouring Ghais on the upper Brahmini have been closed and flood levels in the interior reduced, these two channels flow inland for a longer period. Along the lands between the river and the Indupur road a certain amount of flooding takes place and upstream of Aul circuit embankment flood water passes into the interior overland and also by a small channel parallel to the embankment. Below Aul the flood water from the Kharsua is passing overland into the Brahmini and at the river bend at the Kharsua junction a certain amount of flood water passes off down the Hansua creek to the sea.

Downstream of the Dharmsala-Jajpur road the Kharsua spills inland through several Ghais. Just below the above road is the Similia Ghai, a revetted escape at a fairly low level. Then comes Tanti Ghai

about $1\frac{1}{2}$ miles lower down which is also a revetted escape and where channel joins up with Similia Ghai channel and continues down the middle of the island. A lot of flood water from the Jamuna Ghai and another channel from the Burah river here passes into the Kharsua and $2\frac{1}{2}$ miles downstream the Burah river joins the Kharsua bringing flood from the Baitarani. A further $2\frac{1}{2}$ miles downstream on the right bank is the Palisahi Ghai another revetted escape which passes a small amount of water inland. Then occurs the Rautra Ghai, a large low level open breach, some 800 ft. wide, which takes an enormous quantity of water and sand into the interior. This Ghai has been an open breach for about 12 years now. A glance at the map shows how the interior is now cut up by a series of spill channels 6 to 8 ft. deep.

Beyond Rautra Ghai, at about 3 miles below Binjharpur the Kani Nadi, an old established channel, brings flood water into the interior and returns to the Kharsua just above Aul embankment. The whole interior here is deeply flooded in high floods and flow is general so the submerged Kani Nadi is much reduced in size in the interior but develops to a deep and large tidal creek where the accumulated flood returns to the Kharsua. About $1\frac{1}{2}$ miles upstream of Singhpur another spill channel passes flood inland and bank spill also occurs in many places.

As previously stated, the Aul circuit embankment is no longer intact and except for the Government portion of embankment along the Brahmini river is in an abandoned and breached condition. There are three large permanent breaches on the west as shown in the map and flood water passes freely into the interior. Most of this flood passes south-east into the Kharsua above Aul: the remainder crosses the Aul-Pattamundai road which is largely at field level and passes into the Brahmini, concentrated spill taking place at the southern end. The map shows the flood-affected area which covers practically all the Aul area except the village sites and some land behind the embankment on the Brahmini side.

A lot of flood water from the Kharsua above Aul passes off north-east over the lower lands to the Baitarani. Below the Kanika embankments the Kharsua spills over its banks to the east over the country to the Brahmini. Just above the Brahmini-Kharsua junction the Hansua river takes off flood water southwards to the sea.

FLOOD DAMAGE.

The extent and intensity of flood damage is shown in the map attached. Flood damage is caused largely by prolonged submergence. Where breaches or Ghais occur then damage is caused by sand deposits and by the washing away of crops and soil. The worst offender is the Rautra Ghai which has rendered a large extent of land unproductive.

The central area from the Jajpur road downwards to the Brahmini-Kharsua junction is the worst flood-affected area in Orissa but the flood damage is not so great as might be imagined simply because conditions are so bad that ordinary paddy cultivation is now limited to

the higher lands where there is some reasonable chance of growing and harvesting a crop. The lower lands are utilised after the flood season for Dalua or spring rice in the lowest places and for some sort of a *rabi* crop elsewhere. In reckoning the possible advantages of control of floods and partial protection it is therefore necessary to consider not only the average crop damage but the areas which could be brought under crop with improved conditions. The map shows roughly the area in which a main paddy crop is not grown due to continual bad flooding conditions.

Flood damage in the northern area has greatly decreased since the upper Brahmini Ghais were closed and Jabra escape constructed. In the upper middle area conditions and damage are about the same for a very long period. In the lower middle area the Rautra Ghai has made conditions worse. The practical abandoning of the zamindari portion of the Aul embankment has resulted in turning the low area west of the Aul road from an area in which a precarious paddy crop might be reaped to an area in which no attempt is made to produce a crop until the dry weather. Conditions just east of the Aul road are slightly worse owing to the now regular flooding from the west.

A statement is attached showing the average annual flood damage for this area under report. This varies with the time, frequency and duration of floods in the Brahmini and Baitarani and to a lesser extent the Mahanadi-Berupa.

FLOOD HYDRAULICS.

As has been previously stated, flooding in this area depends on the state of flood in the parent rivers affecting the area, i.e., the Brahmini, the Baitarani through the Burah and the Mahanadi through the Berupa. The rain storms which cause the floods generally pass across the country from the upper part of the Bay of Bengal to the west or north-west. It thus frequently happens that the same rain storm travelling west produces floods in the Baitarani and Brahmini and also in the Brahmini and Mahanadi. The Baitarani having a smaller and circular catchment nearer the delta rises in flood before the Brahmini which has an elongated catchment stretching north to south and whose flood peak comes later. The overlapping of the Brahmini floods and the Baitarani floods through the Burah is sufficient to cause extraordinary floods and prolong their duration. The Brahmini rises in flood several days before the Mahanadi floods for the same rain storm reach the Brahmini area through the Berupa but their overlapping causes bad flooding on the Berupa and Genguti area where the Brahmini flood takes up the Mahanadi flood.

Brahmini River.—Prior to 1939 flood the flood data was little and unreliable. From the gauge diagram of the 1939 floods it is seen that the tidal effect on the Brahmini dies out about R. L. 9.0. The difference between Indupur gauge on the upper Brahmini and Damerpur in the tidal area is about the same on the 23rd August and 3rd September at time of spring and neap tides respectively. This shows that the peaks of the floods and any flood level over R. L. 10.0 do not seem to be affected to any noticeable extent by the range of tide large or small if

the mean sea level remains the same. Of course if a depression and storms raised the mean sea level here temporarily there would be a difference.

Indipur gauge shows a flood range about 2 ft. greater than the lower gauges. Chandanpur gauge range is about 1.2 ft. less than Pattamundai gauge and 0.4 ft. less than Albha gauge. This is due to the open flood spill conditions over the left bank at Chandanpur and the double marginal embankments at Pattamundai and Albha. The Pattamundai gauge also shows larger rise than the Albha gauge. The above would seem to indicate heading up of the river between the Aul and Pattamundai canal embankment but actually the Pattamundai gauge is an old gauge not in a properly exposed position and so shows backing up and is not truly representative. It would seem, however, that the 0.4 ft. extra range of the Albha gauge shows some backing up effort. Actually on the flood diagram it is seen that the heading up between the embankment near Albha is about 0.2 ft. It may be assumed therefore that the embankment system in its present state near Pattamundai and Albha is responsible for about 3" to 4" heading up of the whole floods in the immediate neighbourhood and dying out quickly upstream to nil and this is negligible in considering damage done by submergence and duration of flood. This data contradicts the opinion previously held by many that the embankments here cause damage by holding up the floods above. The flood slope diagram of the Brahmini shows a steep slope from above, then a break with a flatter slope where the Kimiria river goes off and thereafter a slowly flattening curve to the sea with little discrepancy or sign of interference.

Kharsua River.—The tidal effect seems to die out at R. L. 8.5 and as in the Brahmini, there is no trace of spring and neap tides affecting flood levels or slopes above this peak of the flood to travel from Binjharpur to Aul, a distance of $22\frac{1}{2}$ miles, i.e., the highest flood peak travels about $\frac{1}{3}$ mile per hour on the average over this stretch.

Owing to the great amount of flood spill that takes place from the river into the interior by the numerous Ghais and channel the flood range of the upper gauges is limited such that Binjharpur and Aul gauges have about the same range. Singhpur gauge has about 1 foot less flood range than the other gauges and this is probably positive where the left embankment ends and free spill takes place over both banks and through large spill channels above and below. There is no trace of heading up to any noticeable extent.

In the longitudinal sections showing the flood slope it is observed that the slope is steep from the Pattia weir to the Similia and Tanti Ghais, then flattens out considerably and proceeds in a slowly flattening curve to the sea. This break in the regular slope is due to the backing up effect caused by the Burah river flood joining the Kharsua near that point.

Brahmini-Kharsua.—A noticeable feature between the two rivers is that the flood peak in the Kharsua between Binjharpur and Aul takes about 29 hours to cover the 29 miles, i.e., travels at one mile per hour whereas the Brahmini flood peak from Indipur to Damerpur, a distance of 26 miles, takes only $9\frac{1}{2}$ hours or travels at a rate of $1\frac{1}{2}$ miles per hour.

This is due to the direct flow of the Brahmini while the Kharsua flows so largely over the country that the waters take some time to merge in full force again lower down.

The interior gauge at the Kani Nadi at Natra shows that the flood water in the interior rises quickly with the river and taking the average field level here to be about R. L. 12.0. This gauge indicates the period of and depth of submergence of the fields.

Hansua.—The Hansua river or creek has a flood slope of about .67 ft. per mile against the lower Brahmini slope of 0.38 ft. per mile due to the shorter distance to the open sea, so it is evident that this creek will tend to develop and it is observed to be developing strongly by cutting its bed deeply and causing side slope of the bank throughout. It is a matter under consideration as to how far this development should be allowed.

Flood distribution.—Observations were taken during the peak of the 939 floods and the distribution of floods in the lower Brahmini-Kharsua area is as shown in the general flood map attached which explains this best. The distribution is extraordinary and illuminating and conforms to conditions observed. Distribution is as below :—

Kharsua river at Singhpur	...	...	32,000	cusecs.
Flood passing by the Kani Nadi and over the country between the Kharsua and Brahmini west of the Aul embankment.			104,000	"
Do. part passing through Aul embankment breaches and east to the Brahmini.			10,500	"
Do. do. and north-east to the Kharsua (of which 500 cusecs pass south of Aul to the river).			49,500	"
Flood passing down the Kani and over the land north of the Aul embankment to the Kharsua.			38,000	"
Flood spill across country north-east to the Baitarani	...		13,000	"
Kharsua river and flood spill at Aul	...	...	106,000	"
Brahmini river upstream of Aul embankment		...	108,000	"
Kharsua river and spill above junction with Brahmini		...	106,500	"
Brahmini river and spill above junction with Kharsua		...	124,500	"

The distribution of flood through and round the Aul embankment and also to the Baitarani is only approximate and is based on general observation of depths and flood and deductions from other discharge sites since no suitable discharge could be observed. This shows that a river of flood enters little less than the full Brahmini river and passes over the country west of the Aul embankment. The amount going through the breached Aul embankment in the north is very great.

The Kharsua river channel as may be expected shows considerable reduction in size after every large spill channel passes off regaining in size in the lower tidal reaches where the flood spill returns to the river. The adjustment and control of the enormous spills indicated is a major problem.

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APPENDIX IV.

Notes on tides and sea levels of the Orissa Coast.

Since the final slope and flood levels of the Orissa rivers depend on the ultimate sea level, it is most important to determine whether there are any variations in the sea level. The lands worst affected by water logging are in most cases those nearer the sea and slight differences in the prolonged level during a flood may ruin or partly save the crops.

Range and time of tides.—The ocean tide advances north up the Bay of Bengal increasing in range and arriving later in the day as it does so. Thus the maximum tidal range at Madras is 4.3 ft., at Vizagapatam 5.5 ft., at False Point 8.4 ft., at Shortts' Island off the Dhamra river 11.0 ft., at Dublat off the Hoogli 13.2 ft. Compared with Vizagapatam the time of tide at False Point averages about 20 minutes later, then at Dhamra a further 10 minutes later, and at Dublat 50 minutes later. The spring and neap tides are in proportion.

The highest tides of the year according to the tide tables occur in mid July, August, September and October. Actually the worst tides are in the hot weather and are caused by storms and wind and it is against these very salt tides backed up by stormy winds, that salt embankments are necessary in the low coastal lands which are very little higher than ordinary high tide level. These salt embankments are generally 1 to 2 ft. high. Half way up the Dhamra river the average ground level near the river is R. L. 5.2, the Salt Embankment crests about R. L. 6.0 to 6.5, hot weather high salt tide R. L. 5.6 and river H. F. L. 8.25. Low tide hot weather is minus 0.4 and high and low tide in cold weather 3.78 and (—) 3.2. This gives a mean sea level of 2.3 and (—) 0.2 a seasonal difference of 2.5 ft. In the Balasore area north of the Dhamra, storm tide levels are about R. L. 9.5 on the coast. The hot weather wind tides are about R. L. 7.0, the ground level about R. L. 6.0.

Storm tides.—Storm tides are of fairly frequent occurrence and are caused by low barometric pressure and high winds accompanying the cyclones which pass inland from the Bay of Bengal. The cyclones generally occur at the end of September and in October when there is generally no big flood in the rivers but in 1938 a violent cyclone crossed the Chilka Lake on 16th July 1938, raised the sea level very high all along the coast nearby and drove the waters of the Chilka Lake inland for a great distance also washing out the railway line near Rambah and causing devastation. In 1911 a cyclone gave a high tide level at Puri of about R. L. 12 to 13. The great storm and tidal wave of 22nd September 1885 reached R. L. 14.5 at False Point Light House and flooded the land for about 3 miles from the coast altering the coast line to some extent. On 4th October 1937 a cyclone crossed the coast with accompanying high tides and broke open the long closed mouth of the old cantra river, South of the Mahanadi besides altering the Mahanadi, Debi and Prachi mouths. Puri sea gauge was not recorded as being above ordinary (this is questionable).

Mean sea level.—The line of high sand-hills which extends along the coast from the Chilka to the Debi protects the main land to considerable extent from high storm tides and the sand bars which form across the mouth of the rivers in the hot weather also hinder high tides from going inland to a great extent. Where such sand-hills do not exist it is necessary to maintain high salt embankments along the coast as is done in the north of the Dhamra.

From an examination of our coastal sea gauge at Puri and the other tidal gauges nearest the sea we get the following average results or mean sea level at these places during the monsoon months:—

Puri (open sea gauge) M. S. L.	...	...	R. L. 2.5.
Khalkata (Kushhadra mouth)	...	...	R. L. 2.3.
Tandahar (Prachi mouth)	...	...	R. L. 1.8.
Bilpara (Debi estuary)	...	...	R. L. 1.5.
Dhamra (Dhamra estuary)	...	...	R. L. 1.3.

The open sea gauge is difficult to read and none of the gauges are automatic, so some error is possible and likely. Zeros of gauges have been checked and appear correct. Owing to several variations it would take a long series of accurate observations to determine the correct M. S. L. of the coast and in estuaries and behind sand-barred river mouths and results are bound to vary. From the tide tables it is found for Shortts' Island for example which is well clear of the Dhamra river mouth that the M. S. L. for September is 1 ft. higher than that for January. There can also be a daily difference in M. S. L. of 1.8 and for False Point 2.0. The Superintendent, G. T. S., Dehra Dun, has lately been written to on the subject of variation of sea level off the Orissa coast as compared with G. T. S. M. S. L. and states that the Orissa G. T. S. levels are taken for the apparent M. S. L. at False Point. At Sonajar Island and Diamond harbour the mean sea level may be about 1 ft. above G. T. S. M. S. L.

Effect of 1939 storms at Puri.—The state of Puri sea gauge was studied for the flood season of 1939 when there was a storm with a 34—40 miles per hour, gale for 17th, 18th and 19th August with a high sea. The rise in apparent M. S. L. was about 0.5 ft. Again on 29th and 30th August there was a storm and the rise was also about 0.5 ft. Both these storms coincided with spring tide time.

Flood and Salt water problem.—The problem in flood and tide affected areas is difficult as if embankments are raised only sufficiently to keep out high salt tides as in the hot weather these embankments are overtopped and breached during the flood season if of any height. Also where such embankments are above flood level of the adjoining river they are in many cases exposed to flood from behind and so breach from behind.

Various solutions can be considered and all have actually been tried as below:—

The affected tidal areas can be enclosed sufficiently by high embankments on all sides and so completely protected from salt tides and floods. In such cases cross sluices are necessary for drainage and

actually unless some flood water is allowed for flushing the land periodically to a good depth, say 2 to 3 feet, the land remains poor. The drainage is generally difficult and apt to get worst. A string of such protected areas reduce the general spill area to the sea and so may possibly head up the floods above causing delay in run-off and damage and higher and longer floods to the area above. This is the system followed near the Hausua river. This system obviously has its limits and must be strictly controlled and sufficient waterway allowed for passing off floods above. It frequently happens that the river channel scours out deeper between such marginal embankments and so causes little heading up eventually.

The river marginal embankments can be raised to keep out the highest salt tides and many large sluices or paved escapes can be given to pass off the flood from behind. This solution is the perfect solution but the expense of constructing adequate flood waterway through the embankment without danger to the embankment is prohibitive in most cases.

The practical solution appears to be to construct embankments just high enough to keep out highest salt tides, give sufficient sluices for ordinary drainage and when threatened by overtopping from floods behind, cut the embankment at selected places and repair it again after the flood season. This is what is now done by Kauika Estate in the case of the Dhamra salt and flood embankments.

Flood relief schemes and salt tides.—Generally speaking the people have raised small salt embankments as field ridges wherever necessary and these are overtopped about 2.4 ft. by maximum floods. These small embankments are sufficient for present conditions. If, however, as would be generally indicated, attempt is made to lower flood levels and increase the rate of run-off of floods by short cuts to the sea, by new cuts in embankments in the coastal strip, or by developing existing creeks which are in a favourable position, then the sea tide will have a quicker means of entrance and the range of tide inside the country behind will increase. This would require the salt embankments to be raised slightly and so offer slightly more resistance to the passage of floods. In this way the effects of the relief cut would be partly diminished though not of course to such an extent as to damage the benefit of such cuts. It is much more important for the land immediately concerned to keep out salt water tides than to suffer occasionally from bad floods.

The effect of any such cuts or development which work in the hot weather would also be to increase the distance inland to which salt water extends and it does not improve the large low tracts of settled and cultivated land to have salt tides at higher range and greater salinity than previously. In some cases the salinity of drinking water may also be temporarily affected. As an illustration any big permanent improvement of the Chilka Lake mouth would affect the salinity of the Lake which would improve fishing but be disadvantageous to cultivation. The use of seasonal sea coast relief cuts however which would be closed by

high sand bar in the hot weather when the dangerous high salt tides are in season, would do only good and may be well worth the small expense of clearing the mouth annually and ensuring its proper closure during the hot weather.

In considering such flood relief cuts and developments in salt tide affected areas it is therefore necessary to examine closely the probabilities of increasing tidal range and salinity inside and weigh these factors against and the flood relief factors before a final decision is taken.

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APPENDIX V.

Diary of Tours.

- January 14th, 1940 ... Cuttack to lower Surua-Katjuri junction. Inspected dangerous river scour.
- January 16th, 1940 ... Cuttack to Puri. Sur Lake Sea Cut and back to Puri. Inspected Katjuri near Cuttack, Daya Bhargovi bifurcation and Sur Lake Cut developments.
- January 17th, 1940 ... Puri to Jaipur, Gobakund and back. Inspected parting of the Bhargovi river site of possible off-take of spill-way to the Sur Lake and affected country.
- January 19th, 1940 ... Puri to Pipli, Nimapara, Gop, Konarakh and back to Pipli. Inspected part of Dhanua basin, Kusbhadra river spills to Kadua and Pattharbaha channel.
- January 20th, 1940 ... Pipli to Delang, Kanas, lower Daya and back to Pipli and Cuttack. Inspected waterways-Daya river and embankment, Monaguni and Makra river junction, part of flood-affected area and Tirimul breach.
- January 23rd, 1940 ... Special inspection of Mahanadi river and anicut near Cuttack, by Messrs. Inglis and Vipan.
- January 24th, 1940 ... Cuttack to Jagatpur and Albha, thence by river to Keraragarh. Inspected Brahmini river *en route* for Hansua.
- January 25th, 1940 ... Keraragarh down Hansua to Tiarkat Nadi, thence back to Keraragarh down Hansua to Tiarkat Nadi, thence back to Chandbali. Inspected Hansua creek Brahmini and Baitarani rivers, Patsala head and neighbouring affected areas.
- January 26th, 1940 ... Chandbali to Bhadrak and Cuttack. Inspected conditions near Chandbali and on the Chandbali-Bhadrak road, affected by the Baitarani-Salindi floods.
- January 29th, 1940 ... Special inspection of Surua river throughout, by Mr. Inglis.
- January 30th, 1940 ... Special inspection by Mr. Inglis of Mahanadi river above Naraj to Ran Nullah.

JAMES SHAW,

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