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PAPERS

CONNECTED WITH

THE BETWA CANAL PROJECT IN THE NORTH-WESTERN PROVINCES.

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PAPERS

CONNECTED WITH

THE BETWA CANAL PROJECT IN THE NORTH-WESTERN PROVINCES.

From LIEUT.-COLONEL W. W. H. GREATHED, C.B., R.E., Chief Engineer of Irrigation Works, N.-W. Provinces, to Inspector General of Irrigation Works—No. 663, dated 16th September 1868.

WITH the approval of the Lieutenant-Governor, North-Western Provinces, I forward, for your information, papers noted in the margin, on the subject of irrigation canals from the Betwa and Dussan Rivers in Bundelkhund, as there is at present no case to lay before the Government of India.

Superintending Engineer, 2nd Circle, Irrigation Works, No. 1615, dated 25th August 1868.
Lieutenant Home's Rough Report, dated 24th August 1868.
Chief Engineer's remarks, dated 3rd September 1868.
Minute by His Honour the Lieutenant-Governor, dated 4th September 1868.

Map of Bundelkhund.	Burocah Section.
Betwa Section.	Surowlee "
Bedoura "	Humeerpoor Line.

2. Colonel Meade, C.S.I., Agent, Governor General for Central India, has this day been asked if any survey of drainage area of the Betwa within the territories under his control, and through the territories of Scindhia, has yet been executed, and if not, whether he is prepared to promote such survey, wholly or in part, as far as Jhansie border, with a view to preparation of a comprehensive scheme for utilizing the waters of Betwa.

3. Colonel Meade has also been asked to furnish this Government with a copy of any survey of the upper waters of the Betwa already made, and Surveyor General has been asked for what he can give us. Chief Commissioner, Central Provinces, has been requested, in case he has it in contemplation to undertake survey of any part of basins of rivers which discharge into Jumna, to place Superintending Engineer of Irrigation, Central Provinces, in communication with Chief Engineer of Irrigation, North-Western Provinces, in order that uniform results may be ensured. But there is very little hope of getting any information of importance from any of these sources, and I shall be glad to know if you are prepared to help us in the surveys of Upper Betwa and Keyn, or if we must only look to what we can do ourselves?

4. I propose, if no one else will do it, to survey the Upper Betwa this season; to examine the Keyn and the country it might irrigate, and to examine sites for tanks in Banda District, as far as our resources will allow, leaving Allahabad and Mirzapoor Districts, and the Futtehpoor Canal for another season, unless we get more men than I at present expect.

5. It seems right that the examination of Allahabad Canal as a serious project should be deferred until we know how much water we shall allow to go into the Jumna from the rivers of Bundelkhund; but if an Engineer is available to run a trial section, and see if the thing can any how be done or not, we will have it done.

6. Return of accompanying Map and Sections is requested.

From MAJOR C. T. STEWART, R.E., Superintending Engineer, 2nd Circle, Irrigation Works, N.-W. Provinces, to Chief Engineer of Irrigation Works, N.-W. Provinces—No. 1615, dated 25th August 1868.

I HAVE the honour to forward the documents as noted in the margin, regarding the project for irrigation from the Betwa and Dussan Rivers in Bundelkhund.

1. Rough Report of Project for Irrigation from Betwa and Dussan Rivers, Bundelkhund.
2. Sketch Map of Bundelkhund, showing levels taken in 1867-68.
3. Longitudinal section main line of Betwa.
4. Do. do. of centre line do.
5. Do. do. of Humeerpoor Branch do.
6. Do. do. for a Canal, Dussan River.
7. Do. do. of above canal to irrigate Doab between Birma and Chundrawul Nuddees.

2. The project is scarcely in a state to submit, even in the first instance, but I am induced from the tenor of your demi-official of the 18th instant to forward it, rather than to delay any longer.

3. Lieutenant Home having discussed the subject with me, I shall send up his Report in original—as it is.

Rough Report by LIEUTENANT F. HOME, Executive Engineer, Bundelkhund Irrigation Survey, on Project for Betwa Canal—Dated 24th August 1868.

THE following tracings are submitted to give a rough idea of the project, *viz*:—

1st.—Sketch Map of Bundelkhund showing levels (at half-mile distances) taken during the season of 1867-68.

2nd.—Longitudinal Section of main line of Betwa Canal.

3rd.—Longitudinal Section of centre line (Jaloun Branch) of Betwa Canal.

4th.—Longitudinal Section of Humeerpoor Branch of Betwa Canal.

5th.—Longitudinal Section for a canal from the Dussan River, to irrigate Doab between Dussan River and Birma Nuddee.

6th.—Longitudinal Section for a Branch of the above canal to irrigate Doab between Birma and Chundrawul Nuddees.

2. *Betwa Project.*—Tracing No. 1 shows the general directions of the lines taken for the canal from the Betwa River. The canal starts from a point on the river near the village of Pureecha, where a convenient site for a weir has been selected. The bed of the river at this point consists entirely of rock, its banks are of fairly firm soil, and its course is straight. As will be seen from tracing No. 2, the rocky bed forms of itself a natural weir, and it is proposed to raise the surface of the water by means of an artificial weir of masonry in line, to within 3 feet of the highest point of the section of the river bed at site of dam (*i.e.*, to R. L. 622·66); in addition to this, 3 feet of planking would be added when the river is low, bringing the water surface to a level with the highest point of the section (R. L. 625·66). The river banks on either side would be protected with retaining walls, for which rock foundations can be obtained in the bed of the river. The regulating head would be on the left bank, connected with the retaining walls. The discharge of the Betwa in highest flood, as calculated from the flood sections taken, is 714,904 cubic feet per second; the length of the sill of weir would be 2,426 feet; the flood-level would be raised 7 feet by the construction of the weir (or to R. L. 652·67), which would bring it 0·81 feet above the right, and 2·01 feet above the left bank; a small embankment would therefore be necessary to prevent the floods turning the weir on the right bank, or getting into the canal on the left bank. In calculating the afflux, the velocity of approach has, for safety's sake, not been taken into consideration, otherwise the afflux would be reduced by 1 foot. The velocity of flood passing over the weir is 11·12 feet per second, which, considering the nature of the bed, is not excessive.

3. It is proposed to give a maximum depth of water in the canal at the head of 8·25 feet; the reduced level of the regulating head has been fixed at 617·16 or 5·50 feet below top of planking of weir; this would give a slight head of water into the canal of 0·25 feet. The depth of digging for the first 7 miles being considerable, it has been considered advisable to give a good depth of water, and a moderate slope to the bed (0·82 feet per mile), so as to reduce the sectional area of the digging. These calculations have been made on the supposition that the maximum supply during the Khurreef would be 1,000 cubic feet per second, and are of course liable to correction as soon as the actual culturable and irrigable areas have been ascertained. The slope of bed has been fixed after several trials, and gives about the cheapest result, for if it were reduced, either the width of bed or the depth of water would have to be increased; the former would add to the sectional area of digging, and the latter would necessitate lowering the regulator head, as the weir could not well be raised higher.

8·50 below planking.
5·50 below sill of weir.

4. From the end of the 7th mile the digging is moderate, and at 13½ miles the bed comes out on to the level of the country; beyond this the surface of the country falls very rapidly down to the Branch head (31¾ miles), it is proposed therefore to increase the slope of bed to 1·50 feet per mile, to decrease the depth of water to a maximum of 5·50 feet, and to increase the width of bed as required. Notwithstanding this increase of declivity, a great number of falls will be required, and these have been arranged so as to obtain about enough earth to form the banks. It will be noticed that the falls are all small, the largest being only 6 feet, and this has been done for two reasons; *firstly*, to decrease the amount of digging; and *secondly*, to reduce the cost of the falls. It is believed that weirs of rough stone capped with masonry n lime, and with suitable lengths of crests, would pass the canal water quite safely, provided that the height of fall be not too great. Stone for such weirs is obtainable in large quantities, and cheaply, as far down as the Branch head, and it is therefore proposed to adopt some such structure for the overfalls down to that point. Beyond that it would probably be necessary to use brick-work.

5. From the Branch head (31¾ miles) the canal would be divided into three Branches, *viz*:—

Left (Madhogurh Branch)—tailing into Jumna, with a length of about 40 miles.

Centre (Jaloun Branch)—tailing into Mullangah Nullah, with a length of about 34 miles.

Right (Humeerpoor Branch)—tailing into Jumna, with a length of about 64 miles.

The size of each branch will be proportioned to the area it commands, and will be reduced at points where the channels to irrigate smaller Doabs are taken off; the dimensions of these minor channels will also depend on the area of country they have to water.

Escapes will be made into the rivers or nuddees at points above the heads of the minor channels, so that in case of a sudden fall of rain, the supply may be readily reduced. The slope of the country on the lines of the branches is good, and with the exception of 10 miles at the tail of the left branch, where one foot per mile has been given, 1·50 feet per mile has been allowed for the slope of the canal bed. The maximum velocity allowed either for the main line or branches is 3·50 feet per second.

6. The fall of the country is so great that to adapt the canal to navigation would add enormously to the cost of construction, and unless any special orders are received to the contrary, the estimates will be made out for irrigation only. It may be noticed that if navigation be insisted on, the velocity of the current would probably have to be reduced, and the number of overfalls would consequently have to be increased.

7. It will be remarked that the Betwa Canal passes through the Sumpther Independent State: as the supply is certain to be limited during the rubbee, it is proposed to throw out of the calculations of area irrigable the land belonging to that State. After excluding the above, and deducting for ground marked on the maps as covered with ravines, it is found that the total area, which will probably come under the influence of the canal, is about 792,300 acres; of this area a certain proportion will be unculturable waste, and it is proposed to take the proportion of "cultivated and culturable areas" to total area obtaining in the Jaloun District, (nearly the whole of which will come under the influence of the canal), and to apply it to the total area of 792,300 acres. The total area cultivated and culturable which will come under the canal will thus be obtained, and from it the discharge required for the khurreef (which will also be the maximum discharge) can be deduced; and the dimensions of the canal settled accordingly.

8. *The Dussan project.*—The prospects of getting a canal out of the Dussan River do not improve on inspection of the levels and longitudinal sections. The depth of digging and the rock and water which will certainly be met with at the head of the canal, take away all hope of carrying out this project. I have drawn four horizontal lines in the section showing what the effect would be of raising the head flooring 10, 15, 20, and 25 feet above level of low-water supply; even the highest of them gives a great depth of rock-cutting, and is, at two places where water-level was observed in wells, 22 and 38 feet below water. In the face of this, I do not consider it worth while to make any further investigation of the project.

Dated 3rd September 1868.

Remarks by LIEUTENANT-COLONEL W. W. H. GEEATHED, C.B., R.E., Chief Engineer, Irrigation Works, Public Works Dept., on Lieutenant Home's Sketch Report of Betwa and Dussan Canals.

1. Lieutenant Home's Report shows that the only means by which rubbee irrigation can at present be obtained from Betwa is by forming a weir across the river, proposed to be 27 feet above bed in lowest part of section, and 19 feet above cold weather (April or minimum) level of water in the river. The cross section of river is very uneven, the deepest portion is only 60 feet wide, and owing to the natural rock rising in a great part of the section of the river to the level of sill of proposed weir, the amount of masonry in such a weir would be much less than would be expected from the statement that it is proposed to put a dam 27 feet high, across a river 2,300 feet wide, which in the monsoon is a raging torrent, carrying 715,000 cubic feet of water per second to absolute waste.

2. The rock bed renders such a work possible at moderate cost, but if there is anything at all carried down by the current (and a current of 8 or 9 feet a second must move everything but rock before it), the effect of such a dam would be to raise the level of the river behind it permanently.

3. This opens a large subject, but as the greater part of the water would be wasted if the bed is not raised, it is desirable during this next season to investigate whether the bed of the Betwa can be so regulated as to give us control of all the water we want at reasonable

height in reference to the surface of the country. Until this is done, I should not be inclined to recommend the establishment of an isolated weir of such dimension, and it cannot be done unless at the same time means are found of dispersing and distributing the water which the Betwa carries, so as to obviate the necessity of considerable embankments to retain it in the artificial channel we should create, and to make the works pay.

4. This enquiry must be comprehensive, and embrace the area of drainage and the course of the river from Bhilsa downwards, much of which between Bhilsa and Jhansie lies in Scindiah's and other Native States.

5. Should such a system of remodelling the bed of the river prove unadvisable, it would perhaps be necessary to abandon all idea of rubbee irrigation from the river and open khurreef canals without dams wherever practicable: but before deciding upon this course, it is necessary to know for how long a period of the khurreef a sufficient volume of water can be depended upon for such irrigation. We have no record as yet, but Lieutenant Home will, I understand, be able to give Betwa gauge readings for this monsoon, which as a season of deficient rain will be an excellent criterion.

6. Though these conclusions tend to the necessity of a great deal more survey before canals can be decided upon from the Betwa, it will, I think, be advisable to let Lieutenant Home finish his project, that the Government may know what results can be obtained if water can be made available, and in this view to consider his report as if the work were to be carried out at once.

7. His sections show that after 7 miles of deep, but not prohibitive digging, water can be brought to the surface of the country, whose only disadvantage thenceforward, in an irrigating sense, is that its slope is so rapid as to require frequent falls, and so considerable a slope of canal bed as to render navigation impracticable, which is a great misfortune. The natural slope of the country upon the proposed central canal is 197 feet in 70 miles, or 2·7 feet per mile.

8. Irrespective of the question of weir, Lieutenant Home's proposals, explained in paragraphs 3 to 6, may, as far as judgment can be formed at the present stage, be approved.

9. He should, I think, be instructed to provide for the complete irrigation of the Sumpther State referred to in paragraph 7. The more work a canal with such deep and expensive digging at starting can be made to do, that is to say, the more water it can be made to carry and dispense economically, the cheaper the water will be; and satisfactory arrangements can no doubt be made with the Sumpther or any other State when the time comes for doing so.

10. The Dussan Project is impracticable at present. But there is a vast amount of water in it during the monsoon, which we must endeavour to turn to useful account.

11. There is good reason to hope that by judicious combination of canals and reservoirs Bundelkhund, or more broadly, the territory on the right bank of Jumna, bounded by Gwalior on the west, and the Kymore Hills on the east, may eventually become a highly irrigated and fertile province; but there is a great deal to be done before this can be brought about.

Dated 4th September 1868.

Minute by Sir W. Muir, K.C.S.I., Lieutenant-Governor of the North-Western Provinces, on the Betwa and Dussan Canals.

I know few parts of the country (the Bhuttiana territory perhaps excepted) for which canal irrigation would prove a greater blessing than the area which would be open to these canals. In the Jaloun District, the water is at immense depths, and wells consequently are sunk and worked at an expense, prohibitive, as a rule, for irrigational purposes.

2. Any failure in the monsoon is therefore felt with peculiar severity in this tract. The rainfall is generally more scanty, irregular, and uncertain, than in the Doab and the Trans-Gangetic Provinces. At the approach of drought, the people are in the habit of emigrating for the time to more favoured quarters. The tenure of land is consequently far less valuable and fixed than where the production is tolerably certain. There is less accumulation of capital and less ability to tide over seasons of difficulty. And so, when drought and famine do come, the miseries of want and depopulation are experienced with an intensity and duration quite unknown in the more favoured tracts to the north of the Jumna and Ganges. It takes years often for a famine-stricken tract to recover itself.

3. On these grounds I should not be inclined to favour any project that did not include an ample rubbee supply. It is true that there are great stretches of the fine black soil (locally called *mar*), which have an extraordinary retentive character; so much so, that one finds the

rubbee crops often green and flourishing in February, though not a drop of rain may have fallen for five months previously, if the rains were good during the monsoon. On the same grounds it might be urged that a plentiful watering in September or October would impart sufficient moisture to produce good rubbee crops. But in the first place, the above remarks refer only to the finer mar soils, and not to the others (kabur, purowa, and rakur), of which the *purowa* (a light soil with admixture of sand) is specially well fitted for irrigation; next, the effect of irrigating the black soils during the rains or immediately after is uncertain; when wet they form into a miry, sludgy mass, and which might be difficult to work; and lastly, it is doubtful, apart from the last mentioned result, whether the people would be ready to take water in the khurreef, excepting under pressure of extreme drought. Then no doubt, as in the present season, water would be eagerly sought; but I should be unwilling to support the project of a canal likely to be useful only in seasons of drought, unless it were shown to be absolutely impossible to construct one that should answer also for the spring crops of ordinary seasons.

4. I am therefore in favour of carrying on the present scheme, with any modifications that may be found advisable for avoiding the objections adduced by the Chief Engineer. As regards silting up above the dam, I am under the impressiou that the Betwa, flowing as it does so much through rocky country, does not carry with it the same amount of alluvium and sand as the Himalayan Rivers. Still of course there would be sufficient matter brought down, and suspended in the water, to occasion some considerable silting. The amount of such matter, as compared with that in the Himalayan Rivers, might be made the subject of experiment.

5. At the same time, while the present project should, as recommended by the Chief Engineer, be matured, I quite agree that it would be expedient to prosecute enquiries as to the upper portion of the river. Perhaps Colonel Meade, C.S.I., Agent to the Governor-General, and Major Osborne, C. B., Political Superintendent of Bhopal, could give us some information on this head, and if there have been any surveys, supply us with the result. The Chief Commissioner, Central Provinces, might also be asked; but the Betwa, I believe, keeps clear to the west of that Province; only one affluent,—the Bind—flows through the Saugor District.

6. I am sorry to find that the Dussan scheme proves so unfavorable. I trust that some better project may yet be found of drawing water from it.

7. Neither of these schemes extends to the Banda District. I think that the Cane River might be surveyed with the view of providing irrigation for that District.

8. In judging of the amount of water that will irrigate a given area in Bundelkhund, it should be borne in mind that the black soil will probably absorb a greater quantity than the soils of the Doab, at least for rubbee crops. The black soil opens up into greater cracks and fissures, which I apprehend would swallow up, and run to waste a considerable amount of water before the surface land was well-irrigated.

Dated 26th September, 1868.

Note by Colonel R. Strachey, R.E., Inspector-General of Irrigation Works, on irrigation in Bundelkhund.

The results of Lieutenant Home's surveys on the Betwa and Dussan Rivers have been sent to me in the rough by Lieutenant-Colonel Greathed, with comments by himself, and a Minute of the Lieutenant-Governor of the North-Western Provinces on the subject.

2. The Betwa Project is comparatively simple. The only difficulty is how to get out of the river. The sketch sent up shows rather heavy digging for 4 or 5 miles, but nothing impracticable, and so far as I can judge, a great deal of this might be avoided, as I shall explain presently. The dam does not seem to be formidable, and I should not think that there was any risk in its construction. Colonel Fife has built a dam of 22 feet fair fall on a river in the Deccan, and it stands quite well. There is a subsidiary low dam wall of 7 feet a short distance below to break the water, and some such plan could of course be followed here.

3. The Betwa floods seem to rise some 40 feet or so, and a special arrangement would be necessary for shutting them out of the canal, but in this there would be no difficulty.

4. I do not exactly follow the scope of Lieutenant-Colonel Greathed's remarks regarding the effect of such a dam as would be necessary on the Betwa (paragraph 3). Lieutenant Home says plainly that allowing for a theoretical afflux of 7 feet (which is impossible), there would be only 2 feet embankment needed, and the slope of the country is so strong that the length of any embankment would be very small. Further, it would only be in the extreme floods that the water would rise in this way at all.

5. Nor do I follow what is said about the rubbee cultivation from such works as are proposed. We have quite sufficient evidence to show that there will be a fair body of water passing down the Betwa during October and November, sufficient at all events to give absolute certainty to the sowing of the rubbee, and that the supply will continue so as to give some help to the crops even as late as March. It is quite certain, moreover, that if arrangements can be made for storing water above the dam in sufficient quantity to give a full rubbee supply for the whole area commanded, the water must be distributed through the same canals that deliver the khurreef water, and in fact that the stored water must be thrown into the Betwa, and taken up at the dam.

6. Therefore it seems to me, that there can be no sort of question that some such scheme as is sketched out by Lieutenant Home will be the only means by which irrigation can be given to the Districts under consideration, and that there need be no hesitation whatever in working out the project at once in detail, and proceeding to execute it, unless the cost should be far more heavy than I anticipate. The investigations into the possibility of a full rubbee supply may of course be properly put in hand as early as practicable, but it would be most objectionable to delay the maturing of the project for the khurreef canal for any such purpose.

7. Neither am I very certain whether I should not prefer to have the khurreef canal in actual operation before attempting to deal finally with a stored supply of water to supplement the rubbee cultivation. I have no doubt that what I call a khurreef canal will practically save the country from famine, and I have not perfect confidence in our being able to store water in the manner in which it must be done in this case to give what we want in an economical way. I think with our limited Engineer power that we may best do at once, and as speedily as possible, what we know that we can do certainly, and unless the available strength of Engineers is much more than I anticipate, I should distinctly oppose any immediate investigation into the Upper Betwa during the next season at least.

8. I have already stated my conviction that the extreme North-West view of refusing irrigation, unless a *permanent full* rubbee supply be given, is a grave mistake, and I regret to see that the Minute of the Lieutenant-Governor of the North-Western Provinces seems to take this view in the present case. The 3rd paragraph does not reject absolutely the sort of scheme which could *at once* be carried out from the Betwa; but it seems to imply that the Lieutenant-Governor would prefer to have nothing done till the Engineers have tried to get a permanent water-supply for the whole tract to be irrigated, and have either succeeded, or finally shown that it is impossible. I cannot too plainly declare my own convictions to be quite opposed to this course, and I trust that on further consideration it will not be pursued; but that immediate measures should be taken for maturing the design for a canal, which will at all events give complete khurreef irrigation to a large area, and which will be perfectly suited for the distribution of a rubbee supply if hereafter the means should be found for obtaining it.

9. The experience of the present year seems to be sufficient to show that the real apprehension of serious danger arose from anticipated failure of the September and October rains. As soon as the late rain fell, every one declared himself easy. Such a canal as we can with *perfect certainty* set about *at once* from the Betwa, will do much more than give the equivalent of a good September rainfall. My belief is, that in 19 years out of 20, it would give such protection to the rubbee as to secure a moderate crop, though of course the greatly superior advantage of the thorough irrigation that would be got by a full cold weather supply is not disputed.

10. To think that when a satisfactory supply of water is available, the khurreef crop is likely to be altogether secondary, also seems to me a delusion. In Bundelkhund particularly, I believe that rice cultivation will greatly expand on an abundant khurreef supply. There is no solid ground for Sir W. Muir's apprehensions that black soil may be unfit for irrigation. There has been abundant experience on the subject in Madras and Bombay to remove all cause of fear as to this soil being unsuitable for artificial irrigation in any sense, either as regards the agriculture, or the fitness of the soil for embankments or channels. So far from its being bad, it is very retentive, and so long as it is kept moist, which channels in use always would be, there is no disposition to crack.

11. On the subject of the value of khurreef irrigation, it is worthy of remark that at the present time the irrigated area on the Western Jumna Canals is as nearly as may be equally divided between the rubbee and khurreef. I am not at all disposed to take Colonel Rundall's extreme view, that the khurreef crops are likely to displace the rubbee in Northern India at least, but I see no sort of reason why the natural capacity of the soil should not be as fully utilized in the khurreef with tropical products, as in the rubbee with temperate ones.

12. Returning to the project as it is roughly sketched by Lieutenant Home, I would remark that the levels indicate that there will not be much gained by bringing the water to the surface at a higher level that 585, which is at a point near the town of Mote. Above this the fall is great, and the space between the Betwa and Pahooj, which rivers practically limit the area irrigable, is narrow. Now this point of 585 feet level is about 16 miles from the proposed head, and in this distance falls aggregating 21½ feet have been introduced in the canal channel to overcome excessive slope. The natural inference would be, that the canal bed level should be worked *back* from the 16th mile, when the canal bottom is, say, 581 feet with a proper slope until the river is reached. So far as I can see from the levels shown on the map, there is nothing to prevent this being done. The project shows the level of the canal bed at the dam as 617. The *necessary* level to lead to the level of 581 at the 16th mile would be 595·5, so that the water is taken off about 21½ feet higher than is essential. The difference might be made up either by reducing the height of the dam, or by taking a point lower down the river to start from. This part of the project should be revised at once I think.

13. I would add that I see no objection, if it be more convenient or economical to carrying the canal channel within the bed of the river, so as to be wholly submerged in extreme floods. All that would be necessary would be to have a proper regulating work at that point on the canal where it finally left the river bed.

14. It appears from the levels that a line could be taken for the canal from the head as now proposed much nearer the river with important saving of digging. There may be reasons for not having done this, but no allusion is made to the subject, and the detailed surveys and levels not having come up, it is only possible to speak generally on all these points.

15. The only other point to which I need refer is that of navigation. The velocity proposed by Lieutenant Home, 3½ feet per second, is about 2½ miles per hour. This does not seem to me at all to *prohibit* navigation. With steam power acting on a sunk chain, a velocity through the water of 5 miles per hour might easily be given, and therefore an effective velocity of 2½ miles: whether the traffic would be enough to pay for such an arrangement, is another affair. I think Lieutenant Home should be told to make a design with *one* line of canal fit for navigation, probably that passing Koonch and Jaloun. But if thought worth while, the Humeerpoor line also could be so treated. It will not be necessary to carry out locks at first if the expense is great, but I think the falls should all be so placed and arranged as to be suitable for locks hereafter.

16. I may add also that Sir W. Muir seems to be under some misconception as to the silting up *above a dam*. No harm or inconvenience can arise from it, if proper under-sluices are constructed (para. 4 of Minute). The pond formed will be of no practicable value as a supply for irrigation of course, as its surface is only at the level of the canal surface.

17. I now turn to the Dussan scheme, which Lieutenant Home and Colonel Greathed seem to regard as hopeless. I confess to not seeing why this condemnation should be declared.

18. It may at once be admitted that the line sketched by Lieutenant Home is impracticable from the tremendous digging at the head, but it seems quite simple to avoid it.

19. I have sketched out in a rough way my idea of how the project should be modified. From a general view of the contour level lines which I have sketched in, as conveying a vastly better idea of the surface formation than a host of figures, it will be seen that the slope is too high along the whole upper edge of my map to admit of general canal irrigation. I have therefore discarded that part of the area, and have limited myself to the more moderately inclined portion.

20. The head of the canal (coloured in green) would be taken below and inside of Lieutenant Home's line. There is a line of levels given on the actual line I have followed, and so far as I can see, there is no sort of difficulty about it. The water in this canal, too, would come to the surface somewhere about the 585 feet level. There would be no difficulty whatever until we come to the Betwa Nullah, which must be crossed by an aqueduct, the canal bottom being about 50 feet above the dry season level of water in the nullah. There is no proper section of the nullah, and I cannot say whether or not such a work would be very expensive, but I do not see why it should be. After this nullah is passed, there is nothing further whatever to cause difficulty.

21. The general comments made as to the rubbee supply of a Betwa canal apply here also, and I think a design for a khurreef supply should at once be worked out and, if possible, begun.

22. It seems that the area for the Betwa Canals is about 800,000 acres, and for the Dussan I calculate it at 600,000 acres. Rejecting one-fourth as unculturable, which is probably too low a proportion however, we get 600,000 acres and 450,000 acres, respectively, to be irrigated. Taking one-third of these areas as the annual irrigated crop, we should require something less than 1,000 cubic feet per second for the Betwa, and 750 cubic feet for the Dussan. If the supply in November is more than this, I think the volume given might be increased, say to 1,500 cubic feet, and 1,000 cubic feet. Above this I do not think it would be necessary to go. The data of the present season will certainly give as bad a supply as we need think about. I incline to think that the design should be worked out so as to admit of an increase of volume from 1,000 cubic feet to 1,500 cubic feet, hereafter for the Betwa Canal, if the 1,000 cubic feet capacity is first adopted: and the same in the case of the Dussan Canal the original 750 feet being made expansible to 1,000 feet.

From LIEUTENANT ARTHUR H. BAGGE, R.E., Executive Engineer, Bundelkhund Irrigation Surveys, to CLINTON ANDERSON, Esq., Superintending Engineer, 2nd Circle, Irrigation Branch, N.-W. Provinces, No. 289, dated Jhansie, November 27th, 1869.

I HAVE the honour to submit the Betwa Canal Project, consisting of a general report on the scheme, together with designs, estimates, &c., as appendices thereto.

2. The cost of the Betwa Canal (see Appendix B) is close upon 90 lakhs of rupees, of which one-half represents the estimated cost of the reservoir-dams.

3. The total cultivated area is equal to 527,981 acres. Taking one-third of this as likely to be irrigated in one year, and Rs. 3 per acre as profit to Government in Land and Water Revenue (*vide* Chief Engineer's No. 209$\frac{11}{20}$, reporting on Lieutenant Home's project), the revenue will amount to Rs. 5,27,981, which is a return of 5·86 per cent. on an outlay of 90 lakhs.

4. The Betwa Canal will not have to bear the burden of the 54 lakhs—the estimated cost of the head-weir and the two reservoir-dams—if khurreef canals are taken out in directions similar to those laid down in the accompanying map.

5. Lieutenant Home's project (omitting the head-weir) amounted to 18$\frac{1}{4}$ lakhs of rupees; this amounts to 36—nearly double. The difference is attributable to the necessity of providing for navigation, to heavy expenditure in crossing drainage, and to a more complete development of the project.

6. The Chief Engineer, in his letter above referred to, says, in para. 25:—"By reducing depth of digging, doing away with falls, and deferring building of bridges, the cost of the canal will probably be much reduced below Lieutenant Home's estimate." I wish I could think that the Betwa Canal, its branches and irrigating-lines, when completed, will have cost less than what I have estimated. In the cases of the Ghusgowan weir, and the reservoir-dams, large reductions may be made should it be found unnecessary to use granite facing and paving, and if some more economical way be devised of holding up the extra 10 feet water at the Khoord Dam. In the other works it does not appear that any great reduction can be made; the rajbuhas might have been taken somewhat more in digging, but such a course would only lead to remodelling hereafter, as the rubbee supply is about one-third of that of the khurreef.

7. The guiding principle in designing the main canal and the navigable branch, may be said to be similar to that laid down by Colonel Brownlow in his reply to Colonel Strachey's memo., dated July 13th, 1867; the difference being that Colonel Brownlow would take down the average minimum at a velocity of 2$\frac{1}{2}$ feet per second, restricting his khurreef volume to that which gives a maximum velocity of 3 feet per second, and that I have taken down the maximum required supply at the highest limit of velocity, with a section giving the least difference in depth as the supply falls consistent with the necessity of providing for navigation—a necessity which is a fatal obstruction in executing a canal for high and low supply to the best advantage.

8. On former infomation it was decided that the Betwa Canal should be so designed as to carry about 1,000 cubic feet per second, capable of being increased to 1,500.

9. The maximum demand I find to be 1,408 cubic feet, including 150 cubic feet per second for navigation at the tail of the Calpee Branch. By taking this down at the highest velocity other requirements are satisfied.

10. The Betwa River Survey Maps and Sections are also submitted with the appendices to the report, a list of which is as follows:—

Appendix A.—Mr. Richardson's memo. upon his design for constructing lock and fall in the same channel where the Calpee Branch supply has been much reduced by the Kudowra Rajbuha which runs towards Humeerpoor.

Appendix B.—Calculation and general estimates.
" C.—Estimates of masonry-works.
" D.—Designs for ditto.
" E.— Ditto Rajbuha bridges.
" F.—Answers to questions put to Revenue Officers.
" G.—Opinions of Local Officers (reply to No. 1159IC., dated 7th September, 1869, from Joint Secretary).
" H.—Volume containing the sections of the main canal, its branches and the rajbuhas.

11. On the main canal the double locks designed in the Ganges Canal remodelling project have been adopted.

12. With the exception of the first fall, where the canal-bed widens out from 40 to 84 feet, all falls are laid oblique to the axis of the canal.

13. The fall from the tail of the Calpee Branch to the bed of the Jumna is 114 feet in a distance of about half a mile, necessitating some fourteen locks, with a fall of 8 feet in each.

14. In submitting this project, I desire to express my sense of the great assistance I have received from my assistant, Mr. Richardson, who, though frequently suffering from fever and debility, has, nevertheless, adhered manfully to his work. His steady application, and the great interest he takes in his profession, have done much towards enabling me to submit the project at the present time.

PART I.

REMARKS ON THE PHYSICAL GEOGRAPHY OF THE DOAB.

THE triangular space extending from latitude 25° 42′ 30″ N. to the River Jumna, bounded on the east by the Pahooj, on the west by the Betwa—its affluents—and embracing an area of some 1,500 square miles, forms the irrigation field of the proposed Betwa Canal. Higher up the Doab, the country presents generally an undulating surface, alternating in hills and valleys, broken here and there by quartz dykes, and huge disintegrating masses of granite and its associate rocks.

The proximity of these rocks to the surface, and the irregularity of the elevations, which possess no natural connected form of anticlinal axis, together with the rapid outfall of the country, present formidable obstacles to the construction of a large canal from a much higher point on the Betwa River than that now selected; and this is further prevented by the necessity of having to fall back upon the bed of the Betwa itself as the only available storage-basin for the proposed canal in seasons of extreme drought.

Should the Oorcha Reservoir-dam be constructed, it may be found desirable to take out a high-level khurreef canal at that point, to irrigate the sandy tracts which lie between Jhansie and our present starting parallel of latitude.

In the absence of a map exhibiting the arterial drainage system of a Doab, it is usual to assume that there is a backbone or watershed lying somewhere between the two rivers, from which the drainage disseminates and flows into them on either side.

The surface formation of the Betwa Canal Doab is widely different. The high lands border upon the khadirs or valleys of the Pahooj and Betwa Rivers, while the low lands occupy the central part, draining themselves by two separate channels which unite only as they approach the Jumna, falling into it about six miles above the town of Calpee.

It is in this central part that we have a basin for the formation of those great mar-beds, which, on account of their great fertility without artificial irrigation, and the peculiar nature of the soil composing them, have excited much enquiry and consideration, and must still be a subject for careful investigation, forming, perhaps, the most important of all questions affecting the financial prosperity of the canal. It attracted my early attention; my desire to arrive at some conclusion regarding the nature of these mar-beds, and those contiguous to it, being much increased by the apparently prevalent opinion that the contiguity was of such a perplexing character as to render it impossible to define their limits.

From the settlement papers of the district I obtained the distribution of the surface-soil, and from my own subordinates the thickness of each stratum by measurements in the wells of the country. These well-measurements were taken along the cross-section lines of the survey which furnished the reduced levels. and enabled me to compile the accompanying sections.

The amount of the central depression is shown in the section on the line GH; the other sections, on AB, CD, EF, exhibit the spring level, and the nature and depth of the various

soils characteristic of this Doab; while the map gives their general distribution. The difficulties in the way of constructing a more perfect map and sections were too great to admit of its being attempted. The present compilations are generally reliable—quite reliable enough for our purpose. In the sections, the vertical scale being 264 times larger than the horizontal, small errors in measurement become necessarily greatly exaggerated. Where there were no kutcha wells, the zemindars supplied the information required by stating the nature and depth of each stratum pierced when the pucca wells were sunk; two feet or so of error might easily occur in such cases. Again, the dividing-lines between such soils as mar and kabur, purwa and rakur, must often be ill-defined. Nevertheless, these drawbacks have not prevented us from establishing with certainty the order in which the beds are to be found throughout the Betwa Doab.

The different soils can be brought under four principal heads :—

(1) Mar . Black soil.
(2) Kabur . Rich loam.
(3) Purwa . Sandy soil.
(4) Rakur, . { Coarse sandy soil; sometimes containing nodules of kunkur, at others masses of quartz, gravel-beds, &c.

7. In the map or "soil-chart," the area coloured grey contains :—

Mar.	76	per cent.
Kabur	17	,,
Purwa	5	,,
Rakur	2	,,
	100	

The area coloured sepia contains :—

Mar	29	per cent.
Kabur	53	,,
Purwa	14	,,
Rakur	4	,,
	100	

The burnt-sienna tract is nearly all "purwa;" it contains patches of rakur, but this last is generally found underlying the purwa-beds, and is only seen on the surface on the edge of the khadirs, and in deep drainage-lines.

8. Mr. Anderson, the Superintending Engineer of the 2nd Circle, sent two specimens of dark soil to Dr. Murray Thomson, who gave the following analysis :—

No. 1 Specimen—Lighter coloured.

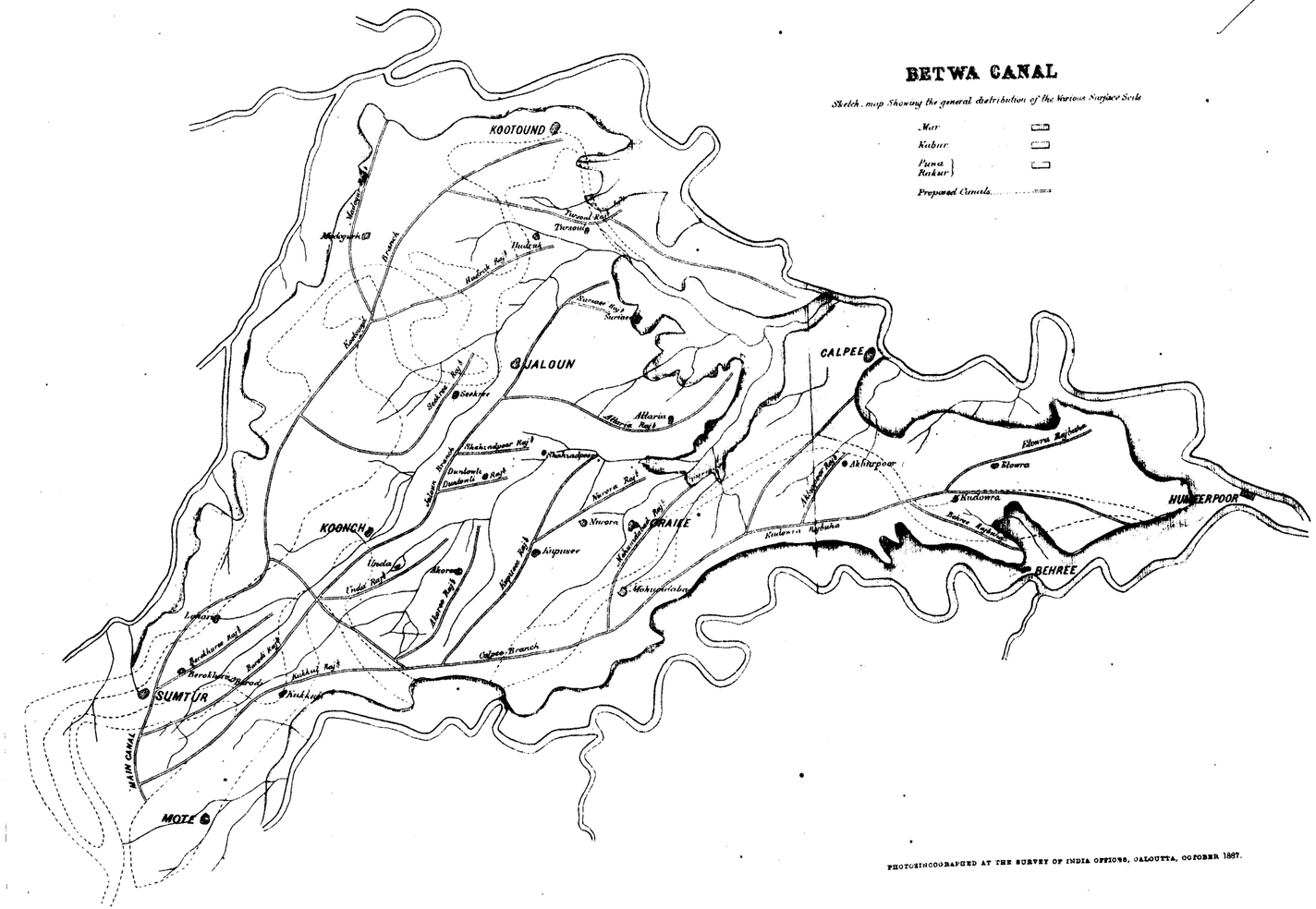
Siliceous matter	78·52
Oxide of iron and alumina	9·16
Lime	3·08
Magnesia	1·15
Organic matter	2·88
Water	5·21
	100·00

No. 2 Specimen—Darker coloured.

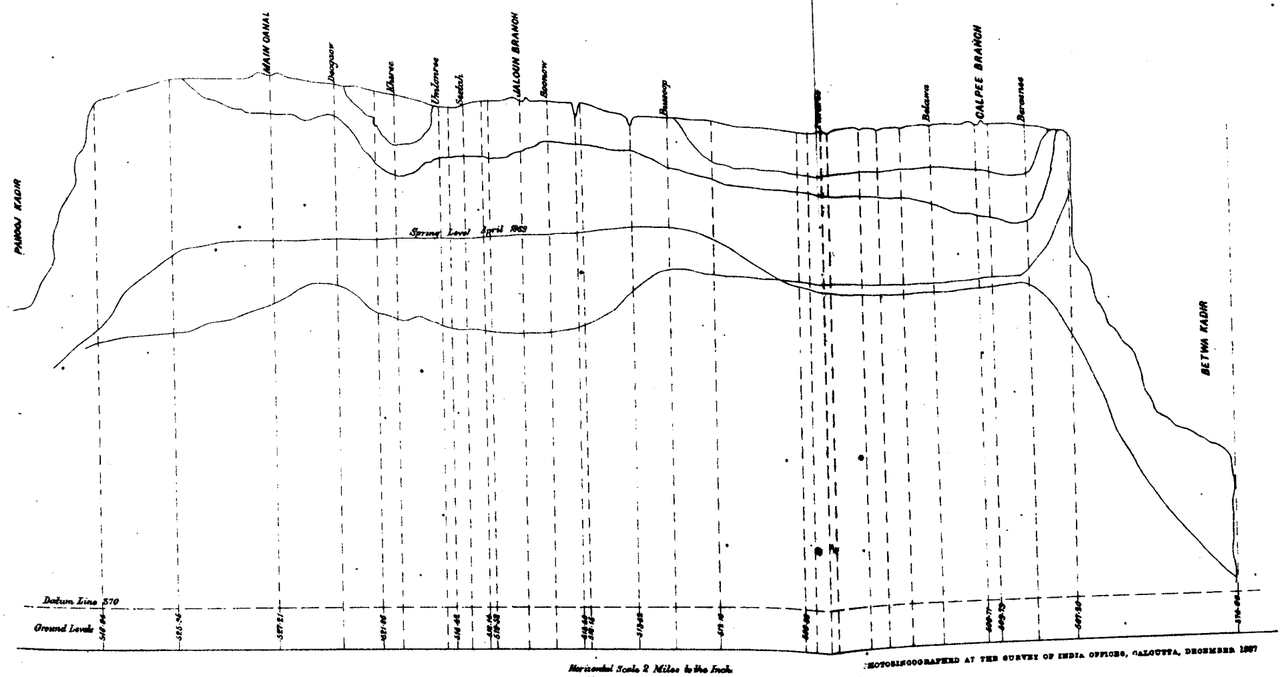
Siliceous matter	76·24
Oxide of iron and alumina	10·50
Lime	1·87
Organic matter	3·12
Alkaline salts	2·27
Small traces of magnesia, water	6·00
	100·00

9. Out of the 528,000 cultivated acres, 300,000 acres may be said to be "mar" soil; it is black, friable, very retentive, expands greatly under moisture, contracts as it parts with it, leaving a surface cut up by a network of fissures, fertile without irrigation.

10. Mr. Wilson, the Geological Surveyor, paid me a visit on the 28th October. During his survey of the district, he had been struck by the apparent unconformability of the alluvial deposits, and he requested me to allow him to have copies of the plans and sections I had made.



SECTION ON A B



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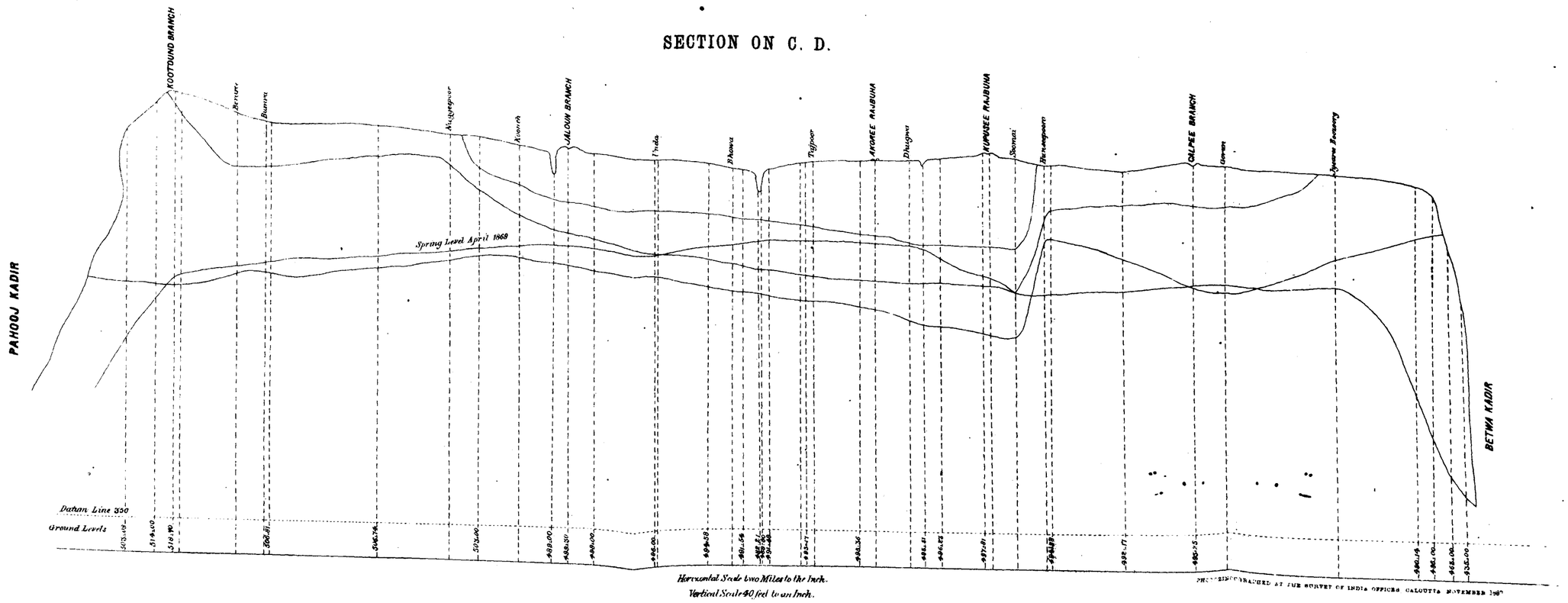
SECTION ON C. D.



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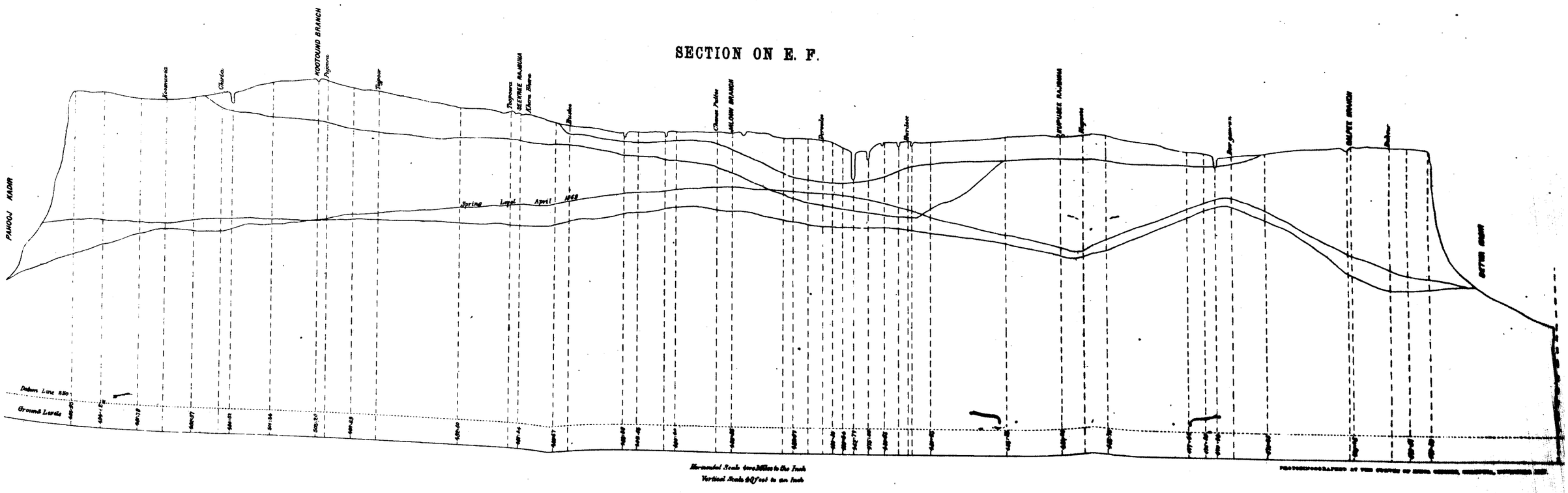
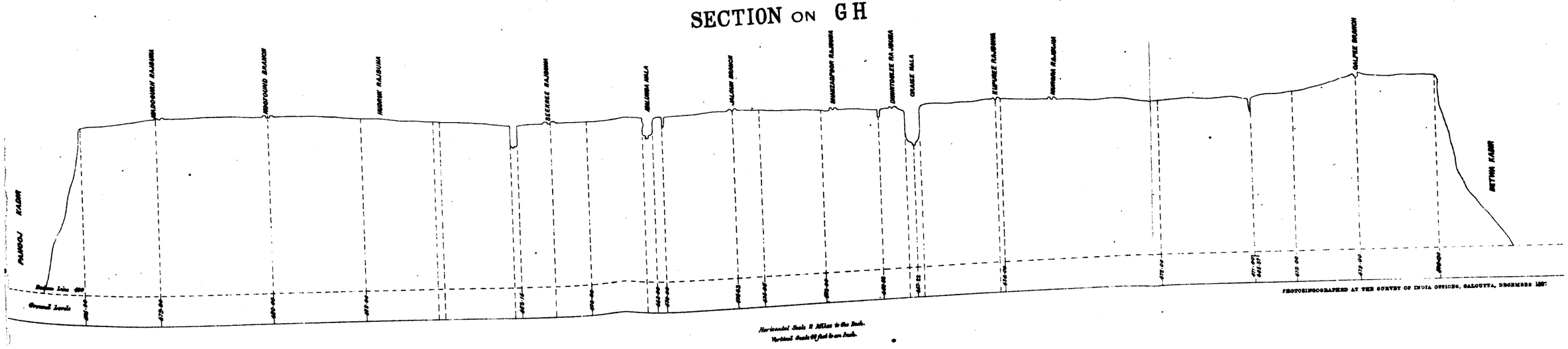
SECTION ON E. F.



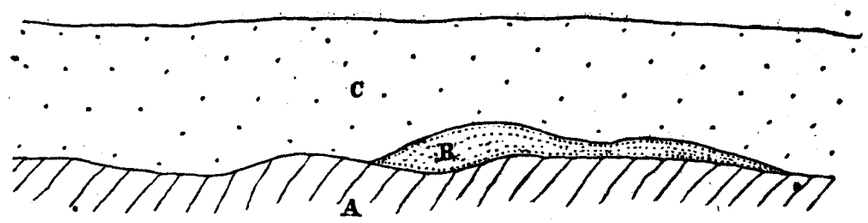
SECTION ON G H



PHOTOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICES, CALCUTTA, DECEMBER 1887

He considered "mar" was identical with "regur," the black cotton-soil of the Nerbudda Valley, and that it was chiefly derived from the decomposition of the "trap" rocks which abound in the high lands to the south:

In Vol. II., Records of the Geological Survey of India, page 282, a section is given of the lucustrine deposits in the Nerbudda Valley:—



A. Coarse conglomerate, with large boulders; also reddish clay, with kunkur.

B. Loose sands and gravels.

C. Pale brownish alluvion and regur, presenting a sequence similar to that obtaining in Bundelkhund. C = mar and kabur, B = purwa, A = rakur.

PART II.

THE IRRIGABLE AREA. THE CANAL SUPPLY, AND THE DISTRIBUTION OF THE WATER.

From latitude N. 25° 42′ 30,″ which we have taken as the parallel from which irrigation will commence, the triangular space bounded by the Pahooj, the Jumna, and Betwa Rivers, is much diminished in area by the extent of the ravines in the valleys in which these rivers flow. For instance, in the Jaloun District, the area is set down as 989,713 acres; of this no less than 146,777 acres are taken up by ravines, leaving 842,936 acres as ordinary land:—

Pergunnah.	Ravines.		Area of Pergunnah.	Balance.
	Square miles.	Acres.		
Jaloun	5·25	3,360	211,806	208,446
Attah	79·16	50,662	282,884	229,222
Oraiee	52·11	33,350	188,344	154,994
Koonch	25·54	16,345	139,304	122,959
Madhogurh	67·28	43,060	160,375	117,315
Totals	229·34	146,777	989,713	842,936

The cultivated and culturable . . . . . = 550,065

Leaving a balance barren . . . . . = 292,871

As the area of the Jaloun District amounts to nearly four-fifths of the whole area, and we have no knowledge of the distribution of the land in the Native States, we may apply these figures to the whole area. From the foregoing we have the following data for the Jaloun District:—

	Acres.	Percentage.	Acres per square miles.
Cultivated	466,070	55·29	354·
Culturable	83,995	9·97	64·
Barren	292,871	34·74	222·
Totals	842,936	100·00	640·

If one-third of the cultivated land be supposed to be irrigated any one year, in every square mile 118 acres will require irrigation; and taking half, and half 59 acres for the rubbee and 59 acres for the khurreef, every square mile of the "bangur," will have to be protected by 0·843* cubic feet per second in the khurreef, and 0·295,† cubic feet per second in the rubbee.

The "bangur," or high land, is what we have to deal with, rejecting the cultivated lands in the khadirs or valleys of the Pahooj, Jumna, and Betwa Rivers, as not wanting water. From the limiting-parallel to the Jumna, this high land contains an area of 954,880 acres, or 1,492 square miles, distributed as follows :—

British or Native Territory.	District.	Areas.	
		Square miles.	Acres.
British	Jhansie	49·0	31,360
Native	Sumpther	155·5	99,520
British	Jaloun	1,115·0	713,600
Native	Bownee	72·5	46,400
Do.	Behree	10·0	6,400
Do.	Dutteah	36·5	23,360
British	Humeerpoor	53·5	34,240
	Totals	1,492·0	954,880

At 0·843 cubic feet per second, in the khurreef this area will require a supply of 1,258 cubic feet per second.

At 0·295 cubic feet per second, in the rubbee this area will require a supply of 440 cubic feet per second.

The distribution of the supply is contained in the following table :—

Districts.		55·29. Cultivated.		9·97. Culturable.		34·74. Barren.		Total Areas.		Water-supply cubic feet per second.	
		Miles.	Acres.	Miles.	Acres.	Miles.	Acres.	Miles.	Acres.	Khurreef.	Rubbee.
British	Jhansie	27·10	17,344	4·90	3,136	17·00	10,880	49·0	31,360	41·30	14·6
Native	Sumpther	85·97	55,021	15·51	9,926	54·02	34,573	155·5	99,520	131·10	45·8
British	Jaloun	616·50	394,560	111·10	71,104	387·40	247,936	1,115·0	713,600	940·00	328·9
Native	Bownee	40·10	25,664	7·20	4,608	25·20	16,128	72·5	46,400	61·20	21·4
Do.	Behree	5·50	3,520	1·00	640	3·50	2,240	10·0	6,400	8·40	2·9
Do.	Dutteah	20·20	12,928	3·60	2,304	12·70	8,128	36·5	23,360	30·80	10·8
British	Humeerpoor	29·60	18,944	5·30	3,392	18·60	11,904	53·5	34,240	45·20	15·8
	Totals	824·97	527,981	148·61	95,110	518·42	331,789	1,492·0	954,880	1,258·00	440·0

Distribution Table, shewing the water required for the irrigation of the land dependent upon the main channels.

Canal.	Area to be Irrigated.	Water-supply, per Second.	
		Khurreef.	Rubbee.
	Sqr. miles.	Cub. feet.	Cub. feet.
Main Canal	252	212	74
Kootound Branch	467	393	138
Jaloun do.	198	167	58
Calpee do.	575	486	170
Totals	1,492	1,258	440

* $\frac{59}{70} = 0·843$ † $\frac{59}{200} = 0·295$

Sub-distribution Table No. I.—Main Canal.

Rajbuha.	Area to be irrigated.	Water-supply.	
		Khurreef.	Rubbee.
	Sqr. miles.	Cub. feet.	Cub. feet.
Kakkul Rajbuha	92	77	[illegible]
Baroda do.	31	26	[illegible]
Burokhera do.	20	17	[illegible]
Sumpther do.	10	8	3
Beona do.	14	12	4
Direct irrigation	85	72	25
Totals	252	212	74

Sub-distribution Table No. II.—Kootound Branch.

Rajbuha.	Area to be irrigated.	Water-supply.	
		Khurreef.	Rubbee.
	Sqr. miles.	Cub. feet.	Cub. feet.
Madhogurh Rajbuha	49	41	15
Tursole do.	71	60	21
Hurdruk do.	67	57	20
Seerkee do.	80	67	23
Direct irrigation	200	168	59
Totals	467	393	138

Sub-distribution Table No. III.—Jaloun Branch.

Rajbuha.	Area to be irrigated.	Water-supply.	
		Khurreef.	Rubbee.
	Sqr. miles.	Cub. feet.	Cub. feet.
Attaria Rajbuha	66	56	19
Lower Jaloun Line	63	53	18
Shahsadpore Rajbuha	12	10	4
Dhentouli do.	12	10	4
Direct irrigation	45	38	13
Totals	198	167	58

Sub-distribution Table No. IV.—Calpee Branch.

Rajbuha.	Area to be irrigated.	Water-supply.	
		Khurreef.	Rubbee.
	Sqr. miles.	Cub. feet.	Cub. feet.
Unda Rajbuha	26	22	8
[illegible] do.	22	18	7
{ Kupasee do.	61	52	18
{ Mujora do.	30	25	9
[illegible] do.	33	28	10
Calpee Tail Line	82	69	24
{ Akbarpore Rajbuha	22	19	7
{ Kudowra do.	97	82	28
{ [illegible] do.	61	51	18
{ Behree do.	25	21	7
Direct irrigation	116	98	34
Totals	575	486	170

The foregoing tables are comprised in the accompanying map. One hundred and fifty cubic feet per second has been added to the irrigation supply to admit of navigation at the tail of the Calpee Branch.

PART III.

FLOOD-DISCHARGE OF THE BETWA.

Lieutenant Home's calculation of the flood discharge of the Betwa River is based upon three flood-levels—one at the Burwa Sagur Ghât, another about two miles above Pareecha, and the third at his weir site. The discharge thus obtained amounts at 715,000 cubic feet per second.

The highest known flood occurred in the month of June 1866; the reduced level of its surface being ascertained—opposite each section-line of the Betwa (see Survey-sheets)—the flood-discharge thus calculated amounts to no less than 1,008,600 cubic feet per second, less fall to the water-surface. But such a debacle as this far exceeds the true discharge. It was only necessary to ascertain by calculations, based upon the flood surface-levels throughout that part of the river—which had a uniform section and an unbroken fall to the bed—what the discharge would be, for the sake of comparison with that obtained by other methods:—

Name of Section across Betwa River.	R. L. of River-bed.	R. L. of Flood, June 1866.	Distances in feet.	Areas.	Perimeters.	$\frac{A}{P}$
Burwa Sagur Ghât,	605·39	669·10	...	96,090	2,200	43·7
Kolwan	603·00	664·50	12,180	78,300	2,000	39·1
Bhoopnuggur	602·81	662·61	4,650	96,100	2,080	45·8
Tilheta	602·39	660·92	5,100	91,800	1,880	48·8
Lower Bihtari	602·39	656·83	11,080	81,100	2,100	38·6
Oojain	deep still	649·01	11,900	71,800	1,620	44·3
Pareecha gauge	water	645·67	4,500	74,600	1,700	43·9
Khurd	600·65	641·09	5,400	82,320	2,070	39·7
Moratta	571·33	625·81	14,750	126,900	2,940	43·1
Dhumna	broken and	619·56	6,300	94,000	3,260	29·0
Dhowanie	rocky.	619·21	4,750	...	...	...
Ghusgowan	deep still water basin	619·00	4,800	112,700	2,720	41·4

Calculating with these flood-levels and surface-fall—

The discharge between—

	Cub Ft. per second.
Burwa Sagur Ghât and Kolwan	= 983,400
Kolwan and Bhoopnuggur	= 1,036,400
Bhoopnuggur and Tilheta	= 1,061,100
Tilheta and Lower Bihtari	= 972,600
Mean discharge,	= 1,013,875

Taking a mean area 88,680 square feet, and a mean hydraulic mean depth 43·2, of all the sections from Burwa Sagur Ghât to Lower Bihtari, the fall in flood-surface being = 12·27, and distance = 33,010 feet.

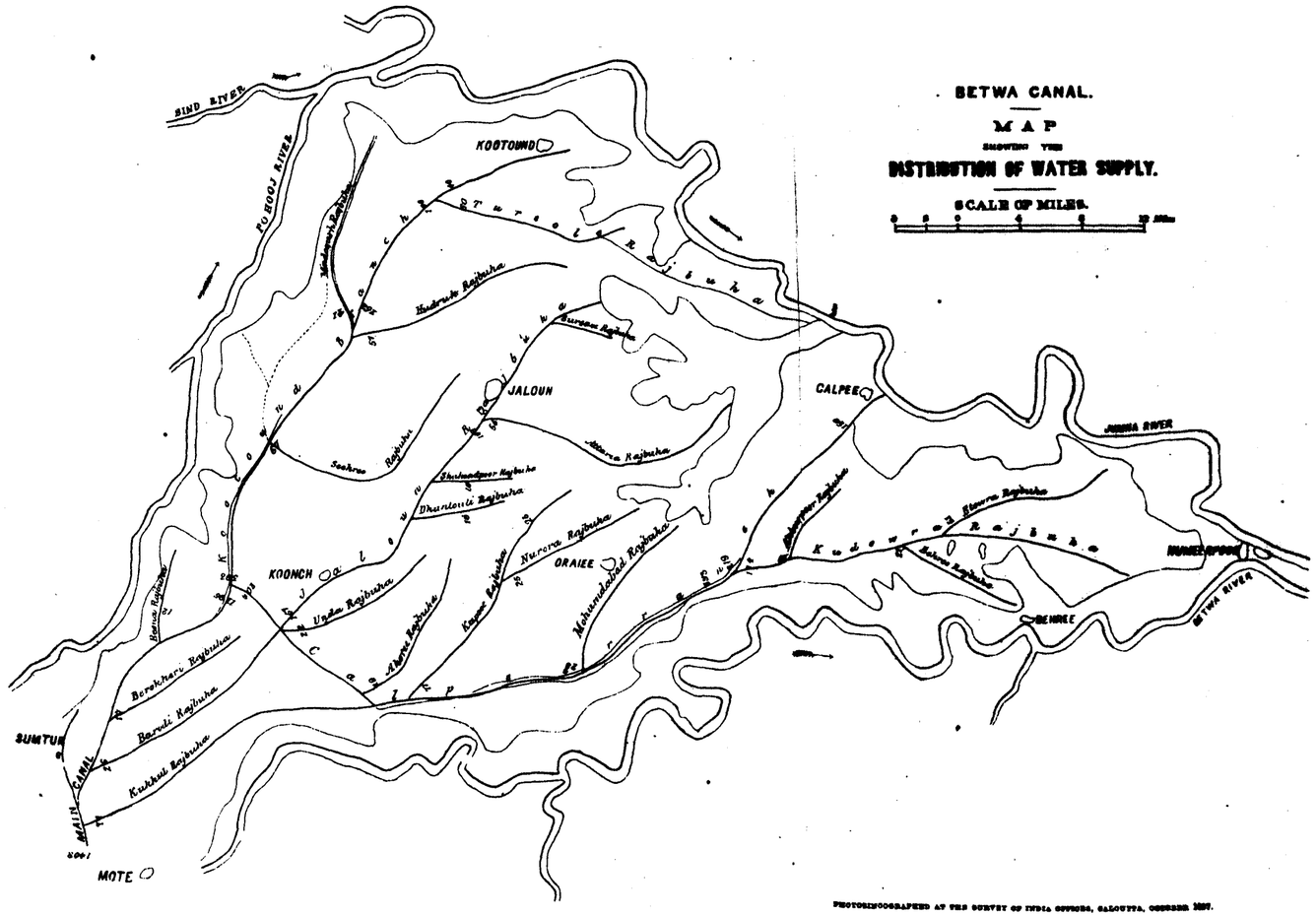
The discharge $= 88{,}680 \times 90 \times \sqrt{43{\cdot}2 \times \frac{12{\cdot}27}{33{,}010}} = 1{,}000{,}600$ cub. ft. per second.

Between the Burwa Sagur Ghât and Kolwan there is a small sudden drop in the river-bed. This part, then, has to be thrown out, and the rest, as far as Lower Bihtari, used for calculating the discharge by slope of bed—

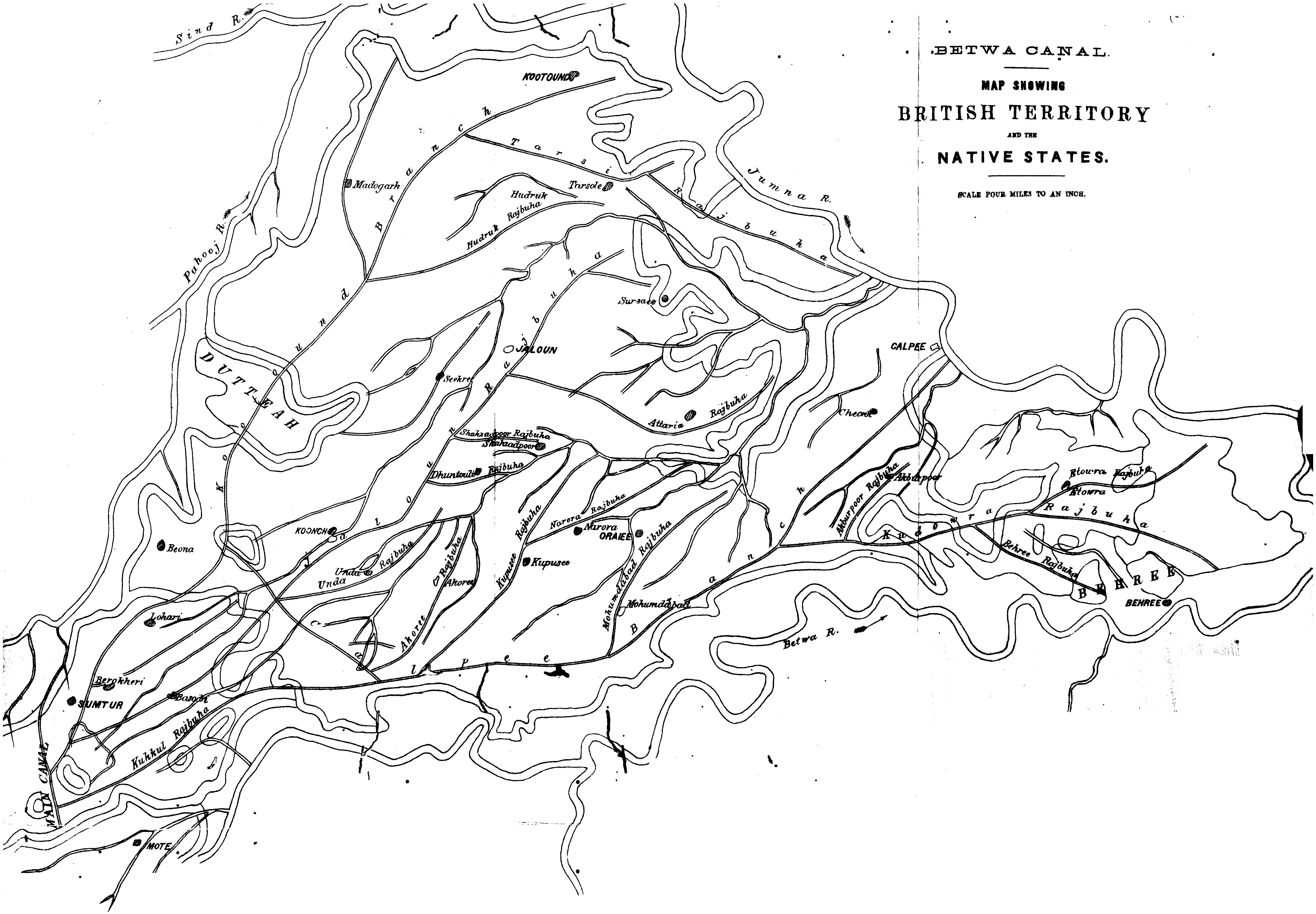
Mean of the areas = 86,825
Do. of hydraulic M. D. = 43·07
Distance = 20,830 feet.

Fall in bed = 0·67. Taking water-surface, the river being nearly dry, and allowing of three days' evaporation at 0·02, as three days elapsed from the time the levels were taken at lower Bihtari and Kalwan and the Pareecha gauge gave this daily depression in the water's surface—

Discharge = 293,034 cubic feet per second, with co-efficient 90;
And with co-efficient 92·5 = 301,200 cubic feet per second.



PHOTOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICE, CALCUTTA, OCTOBER 1867.


BETWA CANAL.
MAP SHOWING
BRITISH TERRITORY
AND THE
NATIVE STATES.
SCALE FOUR MILES TO AN INCH.
Sind R.
Pahooj R.
Jumna R.
Betwa R.
KOOTOUND
Madogarh
Tarsole
Hudruk
Hudruk Rajbuha
Tarsi Rajbuha
Koound Branch
Sursaee
JALOUN
Seekree
DUTTEAH
Jaloun Rajbuha
Attaria Rajbuha
CALPEE
Cheonk
Shahzadpoor Rajbuha
Shahzadpoor
Dhuntouli
Rajbuha
KOONCH
Beona
Unda Rajbuha
Unda
Ahoree Rajbuha
Ahoree
Kupusee Rajbuha
Kupusee
Narora Rajbuha
Narora
ORAIEE
Mohumdabad Rajbuha
Mohumdabad
Akburpoor Rajbuha
Akburpoor
Etowra Rajbuha
Etowra
Kudowra Rajbuha
Behree Rajbuha
BEHREE
Bhanch
Lohari
Berokheri
SUMTUR
Basodi
Kukkul Rajbuha
Calpee Branch
MAIN CANAL
MOTE

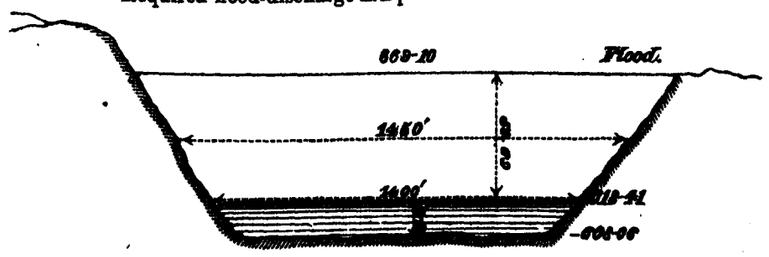
On the 10th September, 1869, Lieutenant Dyce, R.A., assisted me in taking the discharge of the Betwa River. The observations and other data are contained in the following table :—

Observations.			Deductions.		
No.	Areas, square feet.	Surface Velocity.	Mean Velocity.	Sectional Velocity.	Discharges, cubic feet per second.
I.	442	V0=1·10	1·00	1·65	730·12
II.	286	V1=2·56	2·30	2·65	757·90
III.	693	V2=3·33	3·00	2·96	2,051·28
IV.	1,206	V3=3·25	2·92	3·21	3,873·18
V.	1,971	V4=3·89	3·50	3·50	6,898·50
VI.	1,792	V5=3·89	3·50	3·71	6,648·32
VII.	1,028	V6=4·6	3·93	3·66	3,762·48
VIII.	2,116	V7=3·76	3·38	3·34	7,067·40
IX.	672	V8=3·67	3·30	3·20	2,150·40
X.	399	V9=3·44	3·10	3·12	1,244·88
XI.	2,035	V10=3·50	3·15	3·04	6,186·40
XII.	714	V11=3·25	2·92	2·63	1,877·82
XIII.	1,138	V12=2·60	2·34	1·67	1,900·46
XIV.	...	V13=1·10	1·00	...	...
	14,492	Total discharge . .		...	45,149·14

With our present means it would be difficult, if not impossible, to take the discharge when the river rose much higher than R1.618·41—on account of the velocity preventing the use of boats—the level of its surface when the above discharge observations were made.

To calculate flood-discharge therefrom—

Data {
- Discharge at R1.618·41=45,150=D
- Flood-level, June, 1866=669·10
- Level of river-bed=608·06
- Depth of water, time of observation=10·35=d
- Ditto ditto flood=61·04=d_1
- and d_1-d=50·69
- Area of water section=14,494 square feet=A
- Mean velocity=3·11 feet per second
- Breadth of river on water-line=1,400 feet=b
- Slope of banks——45°=...
- Perimeter of section=1,440′
- Required flood-discharge=D_1



$$\left.\frac{D_1-D}{D}\right\} = (d_1-d) \times \left\{\frac{3.b}{2A} - \frac{1}{p.\sin\theta}\right\} = 7{\cdot}60$$

and D_1 = 388,290 cubic feet per second.

If we calculate the flood-discharge by using mean values for the area and hydraulic mean depth, all the way from the Burwa Sagur Ghât down to Khoord, the result is not far off the last :—

Thus: The mean area =84,000 square feet
Do. hydro. M.D.=42·99
the fall in the bed = 4·74 feet
and the total length =54,810 feet.

Then: Discharge $=84{,}000 \times 90 \times \sqrt{42{\cdot}99 \times \frac{4{\cdot}74}{54{,}810}}$
=425,400 cubic feet per second.

Making this up to 500,000 cubic feet, so as to give a wide margin, and allowing that 50,000 cubic feet per second might be discharged into the Betwa between Pareecha and Ghusgowan, the area drained being 200 square miles, and the rainfall once this year 16 inches in 36 hours, we shall have a total discharge of 550,000 cubic feet per second to pass over the canal head-weir; and I think that we may safely assume that the flood-discharges cannot exceed this quantity.

PART IV.

THE BETWA AS A SOURCE OF SUPPLY.

In the following table, exhibiting the discharge of the Betwa for every month from December 1867, to October 1869, a period which includes a season of severe drought, we have at a glance almost all the information required on the subject of the "Betwa as a source of supply":—

Year.	Month.	Date.	Discharge.	Year.	Month.	Date.	Discharge.
1867	December	21	1,028	1868	July	6	120
1868	January	18	878	,,	,,	18	914
,,	February	5	740	,,	August	22	4,072
,,	,,	17	590	,,	September	30	1,500
,,	,,	29	427	,,	October	,,	160
,,	March	6	343	,,	November	,,	81
,,	,,	18	250	,,	December	,,	71
,,	,,	30	220	1869	January	,,	62
,,	April	5	196	,,	February	,,	53
,,	,,	17	145	,,	March	,,	44
,,	,,	29	109	,,	April	,,	15
,,	May	6	100	,,	May	,,	...
,,	,,	18	89	,,	June	,,	...
,,	,,	30	74	,,	July	,,	22,000
,,	June	6	70	,,	August	,,	...
,,	,,	19	68	,,	September	,,	45,000
,,	,,	30	68	,,	October	,,	...

By the beginning of May 1869, the water ceased to flow. The first freshes came down on the 9th July, since which date the lowest discharge was about 10,000 cubic feet per second. The table tells us that in *ordinary* years we shall always have enough for the canal from July to February, and that in the months of March, April, May and June, the supply must be supplemented by storage, if regard be had to the cultivation of sugarcane, rice, indigo, &c. In ordinary years there appears to be no doubt of the Betwa yielding sufficient to give full irrigation to the rubbee crops, but in times of drought we have no hope of a supply after the middle of October. In plain words, the river may be said to be dry during the whole of the rubbee and the early months of the khurreef; so that if perennial irrigation is to be our aim, the reservoirs must contain enough for nine months. It appears, however, unnecessary to make provision for "sugarcane," &c. During years of drought, it will be sufficient if we ensure the irrigation of the rubbee by a five-months' supply, from October to February. These rubbee reservoirs will in ordinary years be full in February, and be ready to irrigate the early khurreef; and this can be done without any danger of the reservoirs not being re-filled, as at the worst of times the river brings down 4,000 cubic feet per second during the rainy season, and is still discharging 1,500 cubic feet per second towards the end of September.

Without reservoirs we can always secure the khurreef, and this saves the country; the produce does not go to pay the State as the rubbee produce does, but the people get a store of food in their homes which staves off the terrible day which a bad khurreef and no rubbee must inevitably bring upon them.

The prevailing opinion is, that in Bundelkhund, owing to the regularity of the rainfall and the excessive fertility of the soil, a canal project cannot be a remunerative one, especially as the Betwa dries up with the rest of the country in years when a canal is most wanted. It so happens that nearly every year there is some pergunnah or other which has suffered from want of rain; and it is worthy of consideration that the Betwa might be carrying the full supply of ordinary years, although the whole tract we intend to irrigate be suffering from the severest drought; for its source of supply lies in a belt of country extending hundred of miles away from the irrigation plain, and very different conditions may obtain in the upper part of its course to those, perhaps, in the lower. Superabundant rain might be showered over the

hilly country through which it flows, creating vast reservoirs among the substrata, which would, by percolation into the river-bed, afford the usual supply when the lower part of that Doab has been denied its share of the life-giving drops, and presents a barren, miserable waste.

As to the readiness of the cultivators to make use of canal-water, it is very probable that at first the results will not be encouraging, but it is still more probable that the use of the canal-water will continually be on the increase, and that a higher and more profitable state of cultivation will develop itself through its fructifying channels. That the transition will be slower in Bundelkhund than in the Gangetic Doab must not be a matter of surprise, considering the backward condition of the country and the natural indolence of the people.

PART V.

THE BED OF THE BETWA. THE BARRIERS AND THE SITE FOR THE CANAL-HEAD.

From the Burwa Sagur Ghât, which may be said to be the point where the river debouches from the hilly country, down to the neighbourhood of Ghusgowan, a distance of seventeen miles, the Betwa is crossed by four rocky barriers:—

No. 1, at Pareecha.
,, 2, at Khoord.
No. 3, at Dhumna.
,, 4, at Ghusgowan.

These barriers form almost continuous natural weirs in the river's bed, the cold-weather supply flowing through narrow gorges; but in two cases only does the bed of the river assume a lower level beyond—at the barriers of Khoord and Ghusgowan. In the Pareecha and Dhumna barriers, the bed is, we may say, on the same level above and below them; disregarding of course the deep still-water basins which abound in the river, one of which lies immediately above the barriers at Pareecha.

At Khoord the bed falls rapidly, and at Ghusgowan the river takes it final leaps into the plains of our Doab. Such sites obviously present the most favourable conditions for the construction of weirs and reservoir-dams, diminishing the afflux, and allowing of the greatest possible storage.

The project being inseparable from the question of storage, I have chosen the Ghusgowan barrier for the site of the head weir. The drainage of the country must be crossed by the canal in the upper miles of its course; but this cannot be avoided except by taking the canal out at Pareecha—Lieutenant Home's weir site—and such a proceeding would entirely prevent our making use of the Betwa's bed as storage-basin from Oorcha downwards.

To make use of the supply stored up in the river-bed, the canal-head must of necessity be built below the first great fall at Khoord. The Dhumna barrier is the first available site, but there the flood-level already rises too close to that of the country to allow of a design giving much afflux. The canal would be about 2½ miles longer, and the drainage to be crossed very much the same if low levels are sought for to avoid deep digging.

The drainage flows towards Ghusgowan, parallel to the river in a defined channel, and a canal taken out at Dhumna could be carried so as to make use of it; but the same can be done at Ghusgowan, and it is a part of this project to make use of that drainage channel as far as possible, and thereby diminish the cost of excavating the main canal.

It does not appear possible to take the canal out at a still lower point without incurring a forbidding amount of expenditure on masonry works, in crossing the wide ravines which disfigure the country as the drainage nears the Betwa's banks. Were is not for this, the Ghusgowan weir would have been another reservoir-dam, holding up a large supply for times of scarcity and drought; but, whatever be the nature of the modifications and improvements suggested hereafter by the lowering of the canal-bed still more, and carrying the canal on a lower level despite drainage, I am of opinion that the Ghusgowan barrier is the best and last spot for the head-weir. Here the river takes its last great leap before the khadir begins. We are prevented from going higher up by the necessity of providing for storage; from going below, by the great depth of the bed below the surface of the surrounding country.

PART VI.

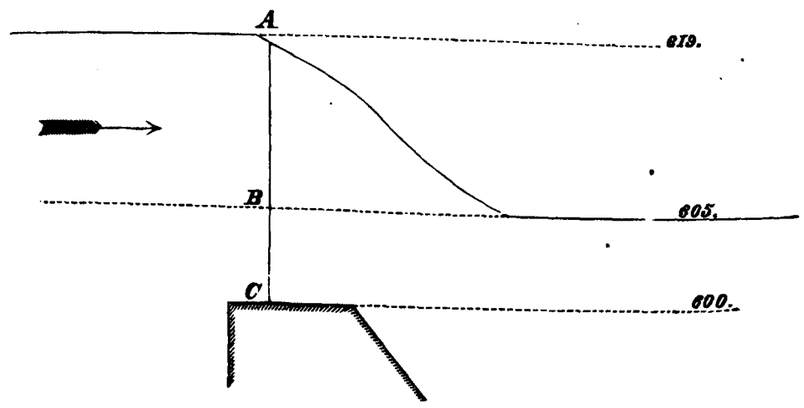
LINE OF CANAL. LEVEL OF BED AND WEIR.

I am satisfied that the line laid down by me from Ghusgowan to the obligatory point near Reo, is taken along the lowest eligible contours, having regard to the difficult nature of

the surface beyond, where a line at a lower level would involve a greatly increased expenditure in masonry-works; also that the sill of the weir cannot be raised sufficiently high to allow of a line on a higher contour being adopted—owing to the numerous ravines which such a line must cross but which adopted line turns—being adopted with due economy in excavation. Assuming, then, that the line chosen is the best that circumstances will allow, it remains to decide upon the most suitable level for the canal-bed, considered in connection with that of the weir-sill.

The level of the country at the weir side is 619—620, and R.1.605 may be taken for the level of the highest known flood (June, 1866, 604-83). The length of the weir would be 2,600 feet, and it has to discharge 550, 000 cubic feet per second.

If the sill of the weir be at R. 1. 600·00, to *calculate afflux*:—



Discharge through $AB = Q_1 = \frac{2}{3} c.b.\ AB\sqrt{2gAB}$

Do. do. $BC = Q_2 = c.b.\ BC\sqrt{2gAB}$

Total discharge $= Q_1 + Q_2 = Q$; $c = 0.5$, co-efficient; b = length of weir = 2,600 feet.

$$= c.b.\sqrt{2gAB.}\left(\frac{2.AB}{3} + BC\right)$$

$$= \frac{cb}{3}\sqrt{2gAB.}\left(2.AB + 3.BC\right)$$

$$= \frac{0{\cdot}5 \times 2{,}600 \times 8{\cdot}02}{3}\sqrt{AB.}\ (2\ AB + 15) = 550{,}000;$$

whence, by trial $x = AB = 14$ feet, and the reduced level of the flood passing over the weir = 619·0, or nearly that of the country.

At Ghusgowan the general level of the country is 620·0, about three-quarters of a mile above the weir site; so that any attempts to raise the sill of the permanent weir would entail the construction of long embankments on both sides of the river.

It seems, then, advisable to adopt this level 600·0 (or 599·96) for the sill of the permanent or masonry portion of the weir; and since the canal must carry 9 feet of water to avoid a broad bed, and to produce the highest limit of velocity with the most convenient slope, the canal-head flooring would be R1.590·96, which gives a uniform digging of 16 to 17 feet along the chosen line as far as the obligatory point near Reo, from which point the digging diminishes rapidly up to the site of the first fall.

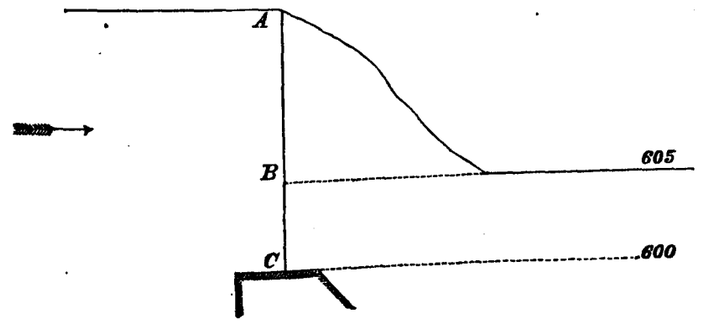
To diminish the depth of the digging, the height of the weir must be increased by self-acting apparatus which would admit of the flood passing off without sensibly increasing the afflux. The sudden rise of the river into flood renders the use of anything but self-acting apparatus too dangerous to be admissible.

If the depth of the digging be diminished 4 feet, by raising the weir-sill in the above supplementary method, the difference in the cost of the excavation will be found to amount to a lakh of rupees; but the cost of the additional fall at the obligatory point, and that of the apparatus, will more than counterbalance it, to say nothing of damages that will probably occur from the shock of many a gigantic forest tree brought down by the flood, nor of the impossibility of converting the reach of the river above the weir into a reservoir holding up water during the dry months to a height of 15 feet above canal-head flooring.

In the foregoing calculation of the afflux, the velocity of approach V was disregarded.

It is equal to $\frac{\text{Discharge}}{\text{Area}} = \frac{550{,}000}{65{,}000} = 8{\cdot}46$ feet per second:

Taking V = 8 feet—



$AB = x$; $BC = 5$; $k = \frac{V^2}{2g} = \frac{64}{64} = 1$ nearly.

$c = 0{\cdot}5$, and $b = 2{,}600'$.

Q_1 = Discharge through $AB = \frac{2}{3} c.\ b.\ \sqrt{2g\left\{(x+k)^{\frac{3}{2}} x + k)^{\frac{3}{2}} - k^{\frac{3}{2}}\right\}}$

$= \frac{2}{3} \times 0{\cdot}5 \times 2{,}600 \times 8{\cdot}02 \times \left\{\ (x+1)^{\frac{3}{2}} - 1\ \right\}$

Q_2 = Discharge through $BC = c.\ b.\ BC.\ \sqrt{2g\ (x+k)}$

$= 0{\cdot}5 \times 2{,}600 \times 5 \times 8{\cdot}02\ \times (x+1)^{\frac{1}{2}}$

and the whole discharge $= Q = Q_1 + Q_2$

$= 6{,}951 \times (x+1)^{\frac{3}{2}} - 1\} + 52{,}130.\ (x+1)^{\frac{1}{2}}$

by trial $x = 13$ feet.

This would admit of the sill being raised a foot, but it is safer not to take it into account.

The velocity of the flood-water $= V^1 = \frac{\text{Discharge}}{\text{Area.}} = \frac{550{,}000}{2{,}600 \times 19} = 11{\cdot}23$ feet per second.

Considering all things, I believe it to be best in the end to leave the weir-sill at 600·00, to have no supplementary apparatus, and to put up with having to dig 16 feet as far as the obligatory point.

PART VII.

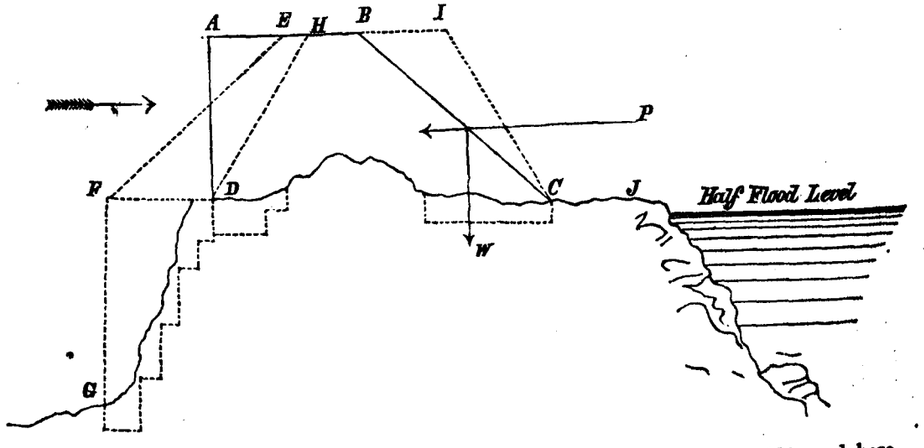
ON THE FORM OF WEIR.

Though the rocky bed of the river usually extends a long distance, the high ridges or barriers are rarely more than 50 feet broad, sometimes only 30 feet. It is therefore desirable that the weir should, while answering other requirements, be of a form which gives—

No. 1. The smallest convenient base.

„ 2. That it should possess a greater stability as the flood increases.

„ 3. That it should pass off the water as easily as possible.



The general level of two-thirds of the Ghusgowan ridge may be taken at 580', and here the weir would be 20 feet high; supposing the ridge to be 50 feet broad, we must endeavour to use this base in the most efficient manner consistent with every requirement.

It appears that the form ABCD is the best adapted to these conditions.

If the crest be diminished to BE, and a batter given in front, the rock would not give sufficient base, and the piece DFG would have to be built up to supply the excess wanted. If to avoid this, the form DHIC were adopted, the water at half-flood would strike with great violence against CJ; an action which would in time produce dangerous results if the rock had any inclination to disintegrate at that place.

The long batter BC both eases the flow of the water and supplies the backward forces P and W, to add to the weir's stability at full flood. For these reasons I consider the form ABCD that which should be adopted under the circumstances.

It is true that the above considerations are not necessary in the deep part of the longitudinal section, where the weir reaches its greatest height—50 feet; but it appears desirable that the weir should have a uniform appearance, and I have therefore thought it fit to adopt the same form throughout.

PART VIII.

CALCULATION FOR THE DESIGN OF THE GHUSGOWAN WEIR.

Point G is the centre of gravity of the weir.

Let W=weight of the weir;

P=pressure (at flood) of water;

R=resultant;

S=stability of weir;

AB=b; AD=h; CE=nh;

AU=f; $\left\{\begin{matrix} g = \text{weight of 1 cubic foot water,} \\ g_1 = \text{ditto ditto of weir.} \end{matrix}\right\}$

Then, resistance offered by the weir=$Wg_1 \times CT=\left(\frac{2b+nh}{2}\right)\times h \times g_1 \times CT$ to find CT

From similar triangles, MQ:QV :: GT:TV $\therefore TV=\frac{QV \times GT}{MQ}$

$$=\frac{\frac{nh}{2}\times\left(\frac{3b+nh}{2b+nh}\right)\frac{h}{3}}{h}$$

$$=\frac{nh}{6}\times\left(\frac{3b+nh}{2b+nh}\right)$$

and CT=CV+VT

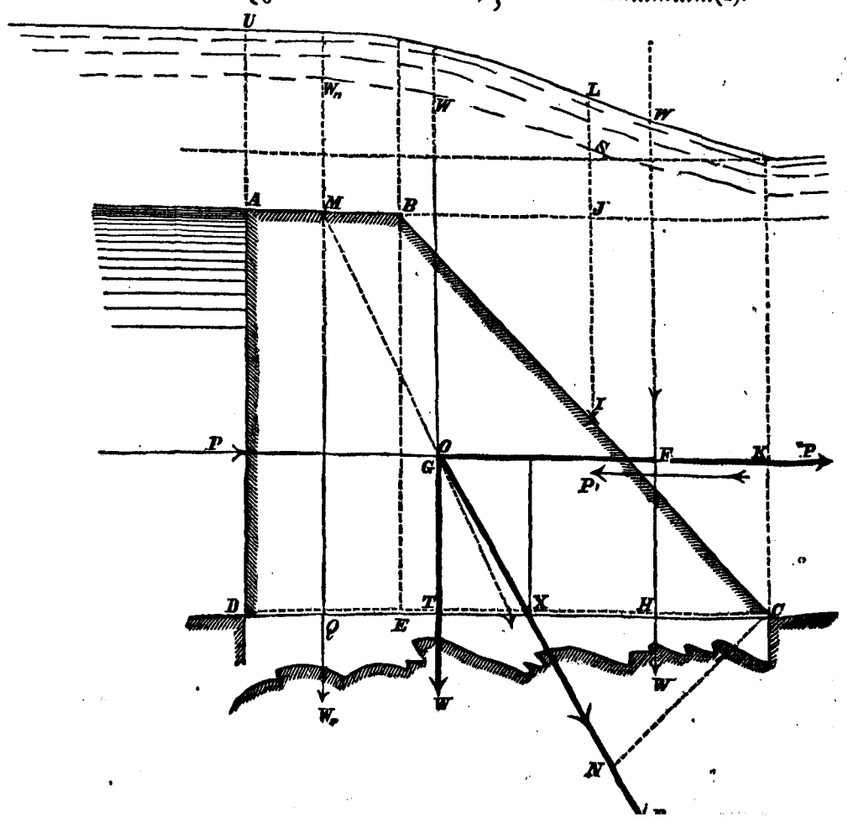
$$=\left(\frac{b+nh}{2}\right)+\frac{nh}{6}\times\left(\frac{3b+nh}{2b+nh}\right)$$

whence $CT=\frac{6.b.n.h+2n^2h^2+3b^2}{3(2b+nh)}$

and resistance offered by weir=$Wg \times CT$

$$=\frac{(2b+nh).}{2}\,h.g_1\times\left\{\frac{6.b.n.h+2n^2h^2+3b^2}{3(2b+nh)}\right\}$$

$$=g_1\left\{\frac{h}{6}.\,(2n^2h^2\times 3b^2+6b.n.h.)\right\}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(\alpha).$$



The overturning force=

$$=Pg\times CK=Pg\times\frac{h+f}{3}$$

$$=h.\left(f+\frac{h}{2}\right)g\times\frac{h+f}{3}$$

$$=g_t\left\{h.\left(f+\frac{h}{2}\right)\times\left(\frac{h+f}{3}\right)\right\}$$

$$=gh.\left\{\frac{2f+h}{2}\times\frac{h+f}{3}\right\}$$

$$=\frac{gh}{6}\,(3fh+2f^2+h^2)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(\beta).$$

and the stability of the weir is equal to $\alpha-\beta$; also=R×CN.=S, to find the point X where the resultant R cuts the base of the weir, we have, by similar triangles—

CX : CN :: OX : OT

$$\text{or } CX=\frac{CN\times OX}{OT}=\frac{CN\times R}{W}$$

$$=\frac{S}{W}$$

That is

$$CX=g_1\,\frac{\left\{2n^3h^3+3b^2+6bnh\right\}}{g_1.3.(2b+nh)}-g\,\frac{\left\{3fh+2f^2+h^2\right\}}{\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(\gamma).}$$

$$\frac{\text{The resisting force of the dam}}{\text{overturning force}}=\frac{Wg_1\times CT}{Pg\times CK}$$

$$=g\,\frac{\left\{\frac{h}{6}.\ (2n^3h^3+3b^2+6b.n.h.)\right\}}{g.\left\{\frac{h}{6}(3fh+2f^2+h^2)\right\}}$$

And if g_1, the weight of stone masonry, be taken as double that of water g, the ratio

$$=\frac{2(2n^3h^3+3b^2+6b.n.h)}{3fh+2f^2+h^2}$$

and putting this equal to 4 we have

$$2\,(2n^3h^3+3b^2+6.b.n.h)=4\,(3fh+2f^2+h^2)$$

$$2n^3h^3+3b^2+6b.n.h=2(3fh+2f^2+h^2)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(\delta)$$

In the deepest part the weir will be 50 feet high, h=50′; the level of the flood passing over it is R1. 619·00, or 19 feet above sill, f=19′. Substituting these values for h and f in the foregoing equation (δ) we have,

$$5{,}000n^3+3b^2+300b.n=2\,(2{,}850+722+2{,}500)=12{,}144;$$

and if n the batter=1

$$3b^2+300b=7{,}144$$

$$b^2+100b=2{,}381$$

$$b+50=\sqrt{2{,}381+2{,}500}=\sqrt{4{,}881}=69{\cdot}9$$

$$b=19{\cdot}9,\text{ or } 20\text{ feet.}$$

If in equation (δ)

n=1; h= 5; then b=21·4 feet.

h=10; „ b=21 „

h=15; „ b=20·7 „

h=20; „ b=20·5 „

h=25; „ b=20·3 „

h=40; „ b=20 „

This result is of course due to the calculation of the pressure from flood-surface, and to disregarding the downward pressure or weight of water over the dam.

If in equation (γ) we substitute the following values—

b=20′; n=1; h=50; f=19; g_1=2g

the distance from C to X where the line of resistance cuts the base of the weir

$$=2\,\frac{\left\{2\times 50^3+3\times 20^2+6.20.50\right\}-\left\{3.19.50\times 2.19^2+50^2\right\}}{2.3.(2\times 20+50)}$$

=33.9 feet.

The distance CT of the centre of gravity from C was found to be

$$= \frac{6.bnh + 2n^2h^2 + 3b^2}{3\,(2b + nh)}$$

Adopting the same values

$$= \frac{6.20.50 + 3 \times 20^2 + 2.50^2}{3.\,(2.20 + 50)}$$

$$= 45.185 \text{ feet.}$$

Height of centre of gravity = GT

$$= \left(\frac{3b + nh}{2b + nh}\right).\ \frac{h}{3} = \left(\frac{60 + 50}{40 + 50}\right) \times \frac{50}{3}$$

$$= 20{\cdot}37 \text{ feet.}$$

To find the line of resistance in the weir when $b = 20$; $n = 1$; $f = 10$; $g_1 = 2g$;

$$CX = g^1.\ \frac{(2n^2h^3 + 3b^2 + 6.b.n.h) - g\,(3fh + 2f^2 + h^2)}{g_1 3.(2b + nh)}.$$

$$= \frac{(4h^3 + 2{,}400 + 240.h) - (57h + 72h + h^2)}{240 + 6h}$$

$$= \frac{3h^2 + 189.h + 1{,}678}{240 \times 6.h} \qquad (a)$$

From which—

when $h = 50$; CX = 33·94 = ·484 of base.

$h = 45$;	"	= 31·35 = ·482	"
$h = 40$;	"	= 26·74 = ·479	"
$h = 35$;	"	= 26·13 = ·475	"
$h = 30$;	"	= 23·30 = ·466	"
$h = 25$;	"	= 20·84 = ·463	"
$h = 20$;	"	= 18·16 = ·454	"
$h = 15$;	"	= 15·45 = ·441	"
$h = 10$;	"	= 12·69 = ·423	"
$h = 5$;	"	= 9·88 = ·395	"

As before stated, the effect of the pressure of the flood downwards on the weir, and thereby increasing its stability, has not been taken into account; but, as it may be thought necessary, the calculation would then be as follows:—

The overturning force will be

$$= (P.g \times CK) - (P^1g \times FH)$$

The resistance will be

$$= (Wg_1 \times CT) + (W^1g \times CQ)$$

Now $P^1g = BE + IL \times g = g.\ BE.\ (IJ + JS + SL)$

Let $JS = k$.

$$P^1g = g.h.\left(\frac{h}{2} + k + \frac{f - k}{2}\right) = \frac{g.h}{2}\left\{h + 2k + f - k\right\}$$

$$= \frac{g.h}{2}.\ (h + k + f)$$

$$FH = \frac{1}{3}\left(h + k + \frac{f - k}{2}\right) = \frac{1}{6}(2h + k + f)$$

Hence

$$P^1g \times FH = \frac{g.h}{2}.\ (h + k + f) + \frac{1}{6}(2h + k + f)$$

$$= g.\ \frac{h}{12}.\ \left\{2h^2 + 3hk + 3hf + k^2 + 2kf + f^2\right\}$$

$$W^1g = g.nh,\ \frac{(h + k + f)}{2};\ CH = n \times FH$$

$$= \frac{n}{6}.\ (2h + k + f)$$

Hence

$$W^1g \times CH = g.\ \frac{h}{12}.\ n^2\left\{2h^2 + 3hk + 3hf + k^2 + 2kf + f^2\right\}$$

$$W^1g = g.b.f;\ CQ = nh + \frac{b}{2}$$

and $W^{11}g \times CQ = g.bf.\frac{2nh + b}{2}$

Hence the overturning force $= g.\ \frac{h}{6}.\left(3fh + 2f^2 + h^2\right) - g.\ \frac{h}{12}.\left(2h^2 + 3hk + 3hf + k^2 + 2kf + f^2\right)$

$$= g\ \frac{h}{12}\left\{2\left(3fh + 2f^2 + h^2\right) - \left(2h^2 + 3hk + 3hf \times k^2 + 2kf + f^2\right)\right\}$$

Resistance $= g_1.\left\{\frac{h}{6}.\left(2n^2h^2 + 3b^2 + 6b.n.h\right)\right\} + g.\left\{\frac{h}{12}.n^2.\ \left(2h^2 + 3hk + 3hf + k^2 + 2kf + f^2\right)\right\} + g.b.f.\left(\frac{2nh + b}{2}\right)$

S = Stability of dam $= g_1.\left\{\frac{h}{6}.\left(2n^2h^2 + 3b^2 + 6b.nh\right)\right\} + g.\left\{\frac{h}{12} \times \left(\ n^2 + 1\ \right) + \left(2h^2 + 3hk + 3hf + k^2 + 2kf + f^2\right)\right\} + g.b.f\left(\frac{2nh + b}{2}\right)$

$$- g.\frac{h}{6}.\left(3fh + 2f^2 + h^2\right) \text{ and } CX = \frac{S}{W + W' + W''} =$$

$$CX = \frac{g_1\left\{\frac{h}{6}.\left(2n^2h^2 + 3b^2 + 6b.n.h\right)\right\} + g.\left\{\frac{h}{12} \times \left(n^2 + 1\right) \times \left(2h^2 + 3hk + 3hf + k^2 + 2kf + f^2\right)\right\} + g.b.f.\left(\frac{2nh + b}{2}\right) - g.\ \frac{h}{6}\left(3fh + 2f^2 + h^2\right)}{g_1 h \times \left(\frac{2b + nh}{2}\right) + g.h.n.\left(\frac{h + k + f}{2}\right) + g.b.f}$$

$$CX = \frac{g_1.\left\{2n^2h^2 + 3b^2 + 6b.n.h\right)\right\} + g\left\{\left(\frac{n^2 + 1}{2}\right) \times \left(2h^2 + 3hk + 3hf + k^2 + 2kf + f^2\right)\right\} + g.\left\{3.b.f.\left(\frac{2nh + b}{h}\right)\right\} - g\left(3fh + 2f^2 + h^2\right)}{g_1 3.\left(2b + nh\right) + g.3n.\left(h + k + f\right) + g.\ \frac{6b.f}{h}}$$

If the resistance be put equal to four times the overturning force we shall have—

$$g_1\left\{\frac{h}{6}.\left(2n^2h^2 + 3b^2 + 6bnh\right)\right\} + g\left\{\frac{h}{12}.n^2.\left(2h^2 + 3hk + 3hf + k^2 + 2kf + f^2\right)\right\} + g.bf\left(2nh + b\right) = 4.g\frac{h}{12}\left\{\ 2\left(3fh + 2f^2 + h^2\right)\right\}$$

$$- 4g.\frac{h}{12}\left(2h^2 + 3hk + 3hf + k^2 + 2kf + f^2\right) \text{ That is}$$

$$g_1.\left(2n^2h^2 + 3b^2 + 6b.n.h + g.\right)\left\{\left(\frac{n^2 + 4}{2}\right).\left(2h^2 + 3hk + 3hf + k^2 + 2kf + f^2\right)\right\} + g.\ \left\{\frac{3bf}{h}\left(2nh + b\right)\right\} = 4g\left\{3fh + 2f^2 + h^2\right\}$$

If in this equation

$b = 15$; $h = 50$; $f = 19$; $k = 5$; $g_1 = 2g$, it will be found that $n = {\cdot}29$; and the base $= 15 + (50 \times {\cdot}29) = 29{\cdot}5$ feet only—a smaller base than Molesworth gives for an ordinary reservoir-dam. From these calculations it appears that the strain on the weir is least during the full flood, and that the greatest pressure occurs when the river is in about half-flood, when the counteracting forces are so reduced as to have little effect. Such a head-pressure might have been used in the first set of calculations, instead of taking the head up to level of flood, but I thought it safer to deal with it as I have, disregarding all counteraction, and taking the pressure

PART IX.

RESERVOIRS.

THE difficulties that present themselves in the matter of storing up sufficient water to supply the Betwa Canal in season of drought are more of a financial character than created by any inadaptability of the country to the formation of reservoirs. The present scheme is to make a main storage-basin, twelve miles along, in the bed of the Betwa, from Khoord to the Burwa Sagur Ghât, in which length the river has little or no fall, and a subsidiary storage-basin higher up above Oorcha. This appears to be the cheapest way; and if other good sites are found, the Betwa Canal might have a perennial supply. In the hilly region to the south beyond the plains of Lullutpore, great facilities may occur for holding up large volumes of water at a small cost. Mr. Willson, the Geological Surveyor, lately told me that in the neighbourhood of "Jacklone," where the Betwa leaves the high lands and tumbles into the Lullutpore plain, there is a reach about five miles long in which during the hot weather the water lies still and fifty feet deep, the whole body being held up by an immense natural weir, over which the Betwa discharges itself at other times of the year. Perhaps other favourable localities exist, and although the distance of such reservoirs from the canal-head would be a great drawback, yet it is very advisable that these tracts be examined before the present scheme be finally adopted.

Turning from the Betwa's bed to search for reservoir sites in the surrounding country, the most favourable sites are those in which the drainage crosses the quartz ridges, a phenomenon produced by the formation of new watersheds by lines of intrusive trap traversing the country in a direction different to that taken by the quartz ridges. Generally, advantage has been taken of such places, and a number of lakes formed behind the ridges; these lakes cannot, I believe, be much increased in capacity, and now they only afford irrigation for the land lying immediately below the dams. There are, however, two sites which may on examination prove to be well adapted to the formation of large reservoirs. The first is about ten miles up the Jamnee River, within twenty miles of Oorcha, and the second eight miles higher up. The Jamnee cuts clean through two parallel quartz dykes, so that it is very likely that short dams could be made to hold back a large supply. It appears advisable to have the localities surveyed, with a view of ascertaining the merits of such a scheme. One great drawback exists in the fact of the Jamnee River being the boundary of British territory, so that one-half of the reservoirs would lie in a Native State, which would not benefit by the canal.

The "dam" of the proposed main reservoir will be situated opposite the village of Khoord, close to the "Lower Khoord Section," below which the river takes a sudden drop of twelve feet (see Betwa River Survey Plans and Sections).

The idea is to raise the crest of the permanent dam as much as possible without producing an affiux, which would entail heavy embankments; and on this crest, by means of piers and balance-gates such as are used in Holland, to hold up an extra supply.

On the supposition that gates more than ten feet high could not be easily worked, it is requisite, in order to hold up the greatest possible quantity, that the permanent crest be only ten feet below the surface, and that without producing excessive affiux.

No other site than that now selected offers these joint desiderata. At Khoord we have a sudden fall in the river's bed, a long crest to the dam, and this is placed on the very verge of the long level reach which is to form the reservoir.

From equation γ—

$$CX = g_1 \frac{(2n^2h^2 + 3b^2 + 6bnh) - g\,(3fh + 2f^2 + h^2)}{g_2 . S . (2b + nh)}$$

and from equation δ

$$2n^2h^2 + 3b^2 + 6bnh = 2\,(3fh + 2f^2 + h^2)$$

In the deepest part the dam will be 50′ high. The level of the flood is 647 or $f = 12'$; $n = 1$. Substituting these values in the last equation—

$$3b^2 + 300b = 9{,}176 - 5{,}000$$

$$b^2 + 100b = \frac{4{,}176}{3} = 1{,}392$$

$$b + 50 = \sqrt{1{,}392 + 2{,}500} = \sqrt{3{,}892}$$

$$= 62{\cdot}4$$

$$b = 12{\cdot}4$$

In the first equation, if $b=13$ feet, $g_1=2g$

$$CX=\frac{3h^2+120.h+726}{156+6.h}$$

From which, when

h=50.....	CX=31·197=·495	of base
=45.....	=28·641=·494	,,
=40.....	=26·075=·491	,,
=35.....	=23·500=·489	,,
=30.....	=20·910=·486	,,
=25.....	=18·304=·482	,,
=20.....	=15·674=·475	,,
=15.....	=13·012=·464	,,
=10.....	=10·305=·447	,,
= 5.....	= 7·532=·418	,,

The weight of the piers and gates have been left out of the calculation.

Calculation of the Capacity of the Main Betwa Reservoir-supply held up at Khoord to R. l. 645·00.

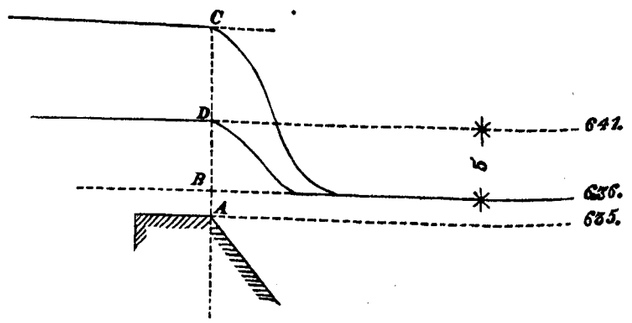
Name of Section.	Mean Depth.	Mean Breadth.	Sectional Area.	Mean Area.	Distances.	Contents in Cubic Feet.
Lower Khoord	37	2,180	80,660			
Ditto	30	3,220	96,600			
			177,260	131,600	2,100	276,360,000
Upper Khoord	43	2,000	86,000			
Pareecha	43	1,300	55,900	71,000	3,600	255,600,000
Oojain	42	1,400	58,800	57,400	6,300	361,620,000
Baraita	41	1,400	57,400	58,100	6,600	383,460,000
"Bihtari," Lower	43	1,400	60,200	58,800	5,300	311,640,000
,, Upper	43	1,100	47,300	53,700	5,300	284,610,000
Tilheta	41	1,600	65,600	56,400	6,100	344,040,000
Bhoopnuggur	41	1,600	65,600	65,600	5,100	334,560,000
Kolwan	40	1,150	46,000	55,800	4,600	256,680,000
Ghutwara	39	1,400	54,600	50,300	5,300	266,590,000
Nohut-Ghât	35	1,600	56,000	55,300	6,900	381,570,000
The End	...	...	...	28,000	19,900	557,200,000
						4,013,930,000

Add to this the mean supply derivable from October to February in years of drought=85 cubic feet per second=$85\times152\times60\times60\times24$ . . . 1,116,300,000

Total cubic feet . 5,130,230,000

To calculate the afflux caused by a dam opposite Khoord, the crest being raised to R. l. 635—

Flood-level above site=641·00
Ditto below ,, =636·00
Length of weir = b = 5,500 feet.
Flood discharge = 550,000 cubic feet per second.



Let affiux CD=x

Quantity discharged through BC

$$=Q_1=\tfrac{2}{3}.\ c.\ b.\ (5+x).\sqrt{2g\ (5+x)}$$
$$=\tfrac{2}{3}\times\cdot5\times5{,}500\times8\cdot02\times(5+x)^{\frac{3}{2}}$$
$$=14{,}703\times(5+x)^{\frac{3}{2}}$$

Quantity discharged through AB

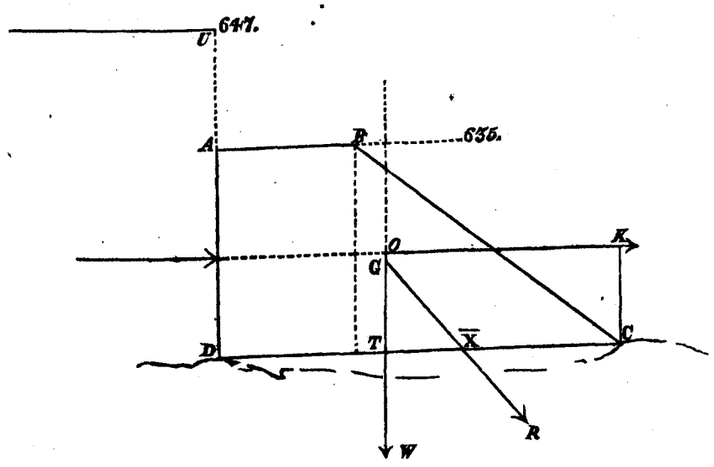
$$=Q_2=c\ b.\ AB.\sqrt{2g.\ (5+x)}$$
$$=\cdot5\times5{,}500\times1\times8\cdot02\times(5+x)^{\frac{1}{2}}$$
$$=22{,}055\times(5+x)^{\frac{1}{2}}$$

Hence total discharge=$Q=Q_1+Q_2=14{,}703\times(5+x)^{\frac{3}{2}}+22{,}055\times(5+x)^{\frac{1}{2}}$; and if $x=6$ feet, the weir will pass off 609,380 cubic feet per second. Putting the obstruction offered by the piers at 0·1, the discharge, with afflux=6, would be 548,442 cubic feet per second.

The flood-level lower down is only 631·53, but I have taken 636 for safety's sake.

With afflux=$x=6$ feet, the R. l. of flood above the dam will be 647, or two feet above the country, so that small embankments will have to be constructed for some distance up—a mile at the outside.

Adopting the same form as that used for the Ghusgowan Weir—



Calculation of the Evaporating Surface.

Name of section.	Mean Breadth of River.	Means.	Distances.	Evaporating Areas.
Lower Khoord	5,400	3,700	2,100	7,770,000
Upper ditto	2,000	1,650	3,600	5,940,000
Pareecha	1,300	1,350	6,300	8,505,000
Oojain	1,400	1,400	6,600	9,240,000
Baraita	1,400	1,400	5,300	7,420,000
Lower Bihtari	1,400	1,250	5,300	6,625,000
Upper ,,	1,100	1,350	6,100	8,235,000
Tilheta	1,600	1,600	5,100	8,160,000
Bhoopnugger	1,690	1,375	4,600	6,325,000
Kolwan	1,150	1,275	5,300	6,757,500
Ghutwara	1,400	1,500	6,900	10,350,000
Nohut Ghât	1,600	1,600	9,950	15,920,000
The End	1,600	...	...	...
Total Sq. Feet	...	...	...	101,247,500

In the month of June 1869, when the Betwa River had ceased to flow, the daily fall in the surface was=·02′=8·04 feet in five months. Applying this to the above evaporating surface, the loss by evaporation=307,792,400 cubic feet. Of course this assumption as to the amount of evaporation is subject to doubt; firstly, because, although the river had no apparent flow, yet its bed must have received a certain amount of supply by percolation; secondly, because the result is based on observations made during the hot weather, whereas the period

before us embraces the cold-weather months, I have adopted this value on the supposition that these influences counteract each other. I believe that Colonel Brownlow ascertained that ·75 of an inch disappeared by evaporation during the hot-weather months in "Bundelkhund tanks." It is needless to say that this does not help us under the peculiar circumstances of the case.

The question of loss by percolation is surrounded by still greater difficulties. I have no means of forming any reliable estimate of it, and I believe this is the first attempt of the kind in India to convert the bed of a large river into a storage-basin. Such cases, had they occurred, might also have differed widely from that which we are dealing with.

As regards the reservoir itself, the formatoin of the underlying rocks favours the idea that percolation will be confined by the quartz dykes running parallel with the Betwa, and that most of it will find its way over the crystalline base of the country back into the river below the reservoir-dam. But beyond this dam the water has to be held up 4½ feet above the canal-flooring, far above the bed of the river; and here the circumstances do not appear so favourable to the prevention of a spread in percolation as they are in the case of the reservoir.

Having, then, no means of ascertaining the loss by percolation, it appears best to leave it for the present out of the calculation. The loss may be sufficiently great to entail the necessity of constructing an extra reservoir-dam.

PART X.

CROSS-DRAINAGE.

The absolute necessity of making a storage-basin of the Betwa River in order to give the canal a perennial supply, forces us to take the canal out lower down the Betwa's course than the position assigned by it to Lieutenant Home. Had it not been necessary to provide this storage, preference might have been given to Lieutenant Home's line, or another line from Khoord, as avoiding interference with the natural drainage of the country. Under present requirements, the line of canal has been taken along the lowest possible contours, avoiding the deep and extensive ravines through which the drainage pours itself into the Betwa. Fifteen miles from the head it reaches the main, or general watershed of the country, in the obligatory point laid down by Colonel Greathed. The canal is then carried along the eastern watershed as far as its bifurcation into the "Kootound" and "Calpee" branches, and here the latter is carried across the central drainage on to the western or Calpee watershed.

It is quite open to question whether the present design is the best. It may be thought that the three great irrigation lines should emanate from a point somewhat near the site of the Kukkul Rajbuha head, and such a disposition would do away with interference with the natural drainage; but the rapid outfall of the country is an important part of the consideration, especially in connection with the necessity of providing for navigation on the Calpee line.

The reduced level of the ground at the Kukkul Rajbuha head (A on sketch-map) is 588·60, that of B (a point common to both lines) = 512·61, and of C = 527·85. The length of AB = 19 miles, and fall = 76 feet.

As the chief of the three lines, the Calpee branch, would have to overcome a fall of 76 feet in 19 miles, I believe that the expenditure involved in bringing down the supply by three separate lines to the level of BC would be greater than that involved in executing the present design; but the matter is worthy of further examination.

If the main canal were brought up to the Kukkul Rajbuha head, and there divided into the three branches, the supply of each would be as follows:—

Calpee branch	690	cubic feet per second.
Jaloun „	214	„ „
Kootound „	504	„ „
Total	1,408	„ „

The sections of the "Kukkul" and "Baroda" Rajbuhas being among the other drawings submitted with the project, an estimate can be drawn up without any further survey being required.

In the accompanying sketch map, the drainage areas interfered with by the canal are coloured pink, blue, and yellow: the pink colour represents the area that drains itself across the main canal from its head to the obligatory point on the watershed; the blue and yellow

colours represent the areas draining themselves across the Calpee Branch— the distinction in colour being given to show the quantity that it is proposed to pass over the Branch, and that which it is proposed to turn off into the Betwa Khádir.

The areas thus represented are:—

Pink	59	square miles.
Blue	92	„ „
Yellow	18	„ „

The rainfall on the 23rd of last July is stated to be the greatest yet known in the neighbourhood of "Mote;" in the tehsil register of that place it is entered as 0·85″ during the twenty-four hours, or above 10 inches.

I assume that the greatest probable fall distributed over such areas as those above will not exceed 9″, or 0·75; using this, every square mile would drain off 242 cubic feet per second, supposing that this exceedingly heavy fall occurred after the soil had been thoroughly saturated by previous long-continued showers, which was the case in July last.

With these figures, provision must be made to pass off—

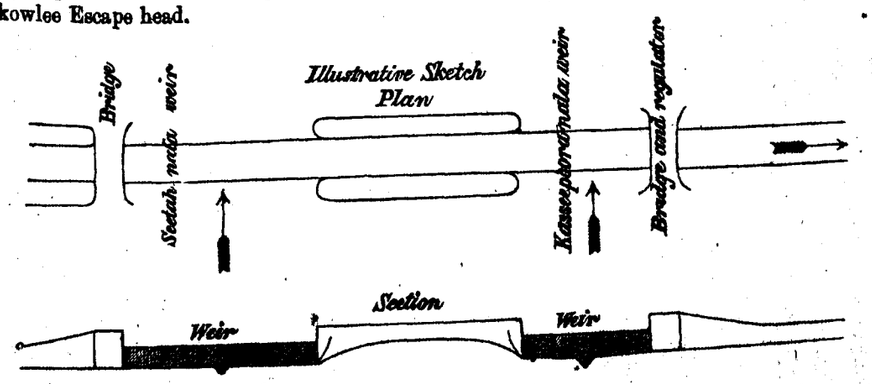
In the pink tract	242 × 59 = 14,278	cubic feet per second.	
„ blue „	242 × 92 = 22,264	„	„
„ yellow „	242 × 18 = 4,356	„	„
Total	40,898	„	„

And this through the following channels:—

(1) Saipoora Nulla	242 × 17 =	4,114
(2) Ramnuggur Nulla	242 × 12 =	2,904
(3) Burwa Nuddee	242 × 20 =	4,840
(4) Reo and other nullas	242 × 10 =	2,420
(5) Kaseepoora Nulla	242 × 36 =	8,712
(6) Seetah Nulla	242 × 56 =	13,552
(7) Lead into Betwa	.....	4,356
Total	Cb. ft.	40,898

Nos. 1, 2, 3, are well-marked, broad and deep, fed by numerous lateral drainage channels. The others, Nos. 4, 5, 6, are of a very different character, presenting a small waterway; indeed, Nos. 5 and 6 are so small that they are hardly noticed in traversing the country along the line taken by the Calpee Branch. It is evident, then, that in these cases the drainage submerges a wide expanse, instead of collecting and discharging itself through confined channels.

Nos. 1, 2, 3, can be crossed by ordinary aqueducts; of No. 4, part must be passed by syphons, part taken in and part thrown into the Burwa Nuddee; Nos. 5 and 6 have discharges too formidable to admit of their being collected and passed underneath the Calpee Branch, considering the nature of the country beyond—which presents a fertile richly-cultivated plain—until a more thorough survey is made of the country round about Koonch, and of the nature of the drainage lines in its neighbourhood, for these appear to develop rapidly a short distance beyond the Calpee Branch crossing. The most advisable way of dealing with these large bodies of water appears to be to interfere as little as possible with them, allowing them to pass in and ont of the canal over long weirs—providing a regulator at the down-stream wing to prevent the canal being flooded beyond, between the terminus of the weir and the Jakowlee Escape head.



A weir passes off 3·2 cubic feet per second over each foot of length with a depth on its crest of one foot. Adopting this, to prevent restriction and flooding the Kassepoora Weir would be 2,722 feet long, and that of the Seetah Nulla 4,235 feet.

Objection might be taken to this method of treating the drainage on the ground that the canal-bed might silt up. I do not think there is any probability of such a thing occurring. The water would be flowing along the canal at the highest limit of velocity; further I observed last July, when the whole country had the appearance of a large shallow lake, when the water was pouring out of it across the "metalled road to Cawnpore," that the water was remarkably clear, though its surface was in many places covered with bits of grass, sticks, and other floating matter.

Mr. Richardson has drawn up a design for the passage of this drainage on the above principle; the cost will be about two lakhs of rupees. The expenditure on the locks and fall, of the alterative line to Calpee, and that on the Kootound and Jaloun Branches will, I believe, be found to outweigh this by a considerable amount.

APPENDIX I.

BETWA CANAL.

Main line and Calpee Branch Navigable—Modifications and reductions on Captain Bagge's Project—Estimates of cost of Khurreef Canals, with irrigated Area—General result.

1. This project consists of—

36¾ miles main channel,		
61 „ branch to Calpee,	}	Navigable.
31 „ branch to Jaloun,	}	
39 „ branch to Kootound,	}	Irrigation only.

With 499 miles of distribution channels.

2. The head is situated about one mile below the village of Ghusgowan, where a suitable locality presents itself for the construction of the weir.

3. It is estimated that the khurreef requirements will be 1,400 cubic feet per second, including 150 cubic feet per second for navigation towards the tail of the Calpee Branch. The rubbee requirements are calculated to be 440 cubic feet per second.

4. To secure a perennial supply, of which 440 cubic feet shall be the minimum, two dams will be built across the Betwa—one opposite the village of Khoord, seven and a half miles above the canal head weir, another in some favourable site above the old city of Oorcha, some thirty miles higher up.

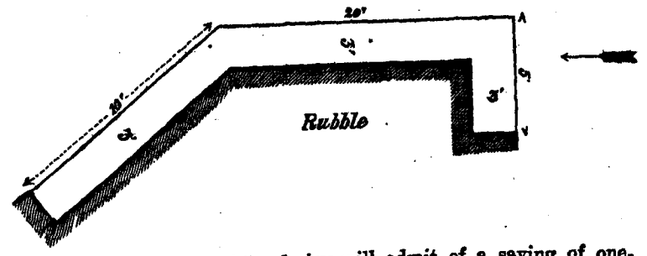
5. Including the head weir, the estimated cost of the canal, its branches, and distribution channels, is 45 lakhs of rupees, and that of the reservoir-dams an equal amount, making a total of 90 lakhs; and the estimated return 5·86 per cent.

6. This return may be increased by modification of the present design, allowing of reductions (A) in the expenditure; also by the construction (B) of khurreef canals taken out of the Betwa above the dams.

7. (A) *Reductions*:—

	R
(*a*) By doing away with the locks at the tail of the Calpee Branch and substituting ordinary falls, a saving may be effected of . .	1,02,000
(*b*) The Kasecpore and Seetah drainage works have been designed to pass off the total rainfall in six hours, which has been taken at a maximum of nine inches, and these works are estimated to cost R1,20,000. Assuming that one-third of the rainfall will be absorbed by the soil, and holding up the remainder for twenty-four hours longer, the works would only be required to pass off one-third of the total fall, and the cost may be reduced to R50,000 which is a saving of	70,000
(*c*) The cost of the distribution channels taken along the canal boundaries may be much reduced by keeping them close to the banks of the main lines, whereby the outer bank only would be required; and in cases where, for instance on the main canal, there is a sufficient surplus of earth from the digging, the construction of these rajbuhas might go on simultaneously with that of the main canal, and the expenditure on them would be hardly appreciable. In this way the estimated outlay on the earthwork may be reduced by	56,000
Carried forward .	2,28,000

	R
Brought forward .	2,28,000
(*d*) In the design for the head weir, R7,80,000 are devoted to facing and paving with granite; the estimate being 390,000 cubic feet at R2 per foot. This protects the whole of the sill and back-slope, and five feet of the breast, with dressed granite blocks to a thickness of three feet, the body of the weir being rubble masonry. It appears that if only ten feet of the back-slope be paved, sufficient protection will be afforded—	



This modification of the design will admit of a saving of one-half the estimated cost, or nearly	4,00,000
(*e*) In the Khoord reservoir-dam the granite paving is estimated to cost R15,20,000. Here, by adopting the same method of protection as in the case of the weir, a reduction may be made of nearly	7,00,000
And if it be assumed that the Oorcha reservoir-dam will cost the same as the Khoord dam, the saving on it will be	2,00,000
Making a total of .	15,28,000

8. In Appendix B,* Abstract of Estimates, the cost of construction, not including contingencies, is put down at 80¼ lakhs of rupees, from which if we take the foregoing reductions, the balance, 65 lakhs, will represent the cost of constructing the Betwa Canal, distributed as follows:—

	R
Reservoir-dams, ...	35,00,000
Canal head weir, ...	6,00,000
Betwa Canal, ...	24,00,000
TOTAL .	65,00,000

To this if we add contingencies of contraction at 5 per cent., the original outlay would be—

	R
Reservoir-dams, ...	36,75,000
Head weir, ...	6,30,000
Betwa Canal, ...	25,20,000
TOTAL .	68,20,000

9. (B) *Khurreef Canals*:—

From the accompanying tabular statements, it will be seen that the four khurreef canals will cost R2,96,000, and that the irrigated area will amount to 32,000 acres.

10. To the original outlay must be added the cost of maintenance and collection of revenue:—

20 per cent. on	perennial canal.	
15 „	khurreef „	
5 „	river works, the weir, and reservoir-dams.	

Nature of Work.	Cost of construction. R
River Works, ...	43,05,000
Betwa Canal, ...	25,20,000
Khurreef „	2,96,000
TOTAL .	71,21,000
Superintendence @ 7 per cent., ...	4,98,470
TOTAL OUTLAY .	76,19,470

* Not printed.

BUNDELKHUND IRRIGATION.—*Abstract of Estimates of Cost, &c., of Khurreef Canals taken out of the Betwa River above the Weir and Reservoir-dams.*

Name of Canal.	Length, in miles.	Area within influence, in square miles.	Water-supply required, cubic feet per second.	Total discharge.	Cost of each canal.	Total.	Grand Total.	Area that will be irrigated, in acres.
					₹	₹		
Arjar Canal,	54	164	138	...	96,000	...	...	9,676
Jhansie „	56	78	65	...	46,400	...	...	4,602
Chirgong „	36	80	68	...	35,400	...	...	4,720
Goorserai „	93	215	181	...	1,04,000	...	...	12,685
TOTAL	239	537	452	452	...	2,81,800	...	31,683
	Add 5 per cent.		for contingencies, nearly,			14,200		
						2,96,000		

ARJAR KHURREEF CANAL.—*Head at Upper Reservoir-dam above the old City of Oorcha, Left Bank of Betwa.*

Name of Canal or Branch.	Length, in miles.	Area within influence, in square miles.	Water-supply required, cubic feet per second.	Total discharge.	Probable average cost per mile.	Total.	Grand Total.	Area that will be irrigated, in acres.
					₹	₹	₹	
Main Canal,	32	128	108	...	1,000	32,000	...	7,552
Tareecha Branch,	12	24	20	...	600	7,200	...	1,416
Bomora „	10	12	10	...	600	6,000	45,200	708
Minor distribution channels, per mile of canal,	...	...	...	...	200	...	10,800	...
Extraordinary masonry-works in crossing drainage,	...	...	...	...	...	...	40,000	...
TOTAL	54	164	138	138	...	...	96,000	9,676

JHANSIE KHURREEF CANAL.—*Head at Upper Reservoir-dam above the City of Oorcha, Left Bank of Betwa.*

Name of Canal or Branch.	Length, in miles.	Area within influence, in square miles.	Water-supply required, cubic feet per second.	Total discharge.	Probable average cost per mile.	Total.	Grand Total.	Area that will be irrigated, in acres.
					₹	₹	₹	
Main Canal,	8	4	4	...	800	6,400	...	236
Burragaon Branch,	22	44	35	...	600	13,200	...	2,596
Jhansie „	16	20	17	...	600	9,600	...	1,180
Samurdha „	10	10	9	...	600	6,000	35,200	590
Distribution channels (minor), per mile of canal,	...	...	...	...	200	...	11,200	...
TOTAL	56	78	65	65	...	...	46,400	4,602

CHIRGONG KHURREEF CANAL.—*Head at Khoord Reservoir-dam, left bank of Betwa.*

Name of Canal or Branch.	Length in miles.	Area within influence, in square miles.	Water-supply required, cubic feet per second.	Total discharge.	Probable average cost per mile.	Total.	Grand Total.	Area that will be irrigated, in acres.
					₹	₹	₹	
Main Line	30	62	52	...	800	24,000	...	3,658
Baraich Rajhbuha	6	18	16	68	700	4,200	28,200	1,062
Minor distribution channels, per mile of canal	...	...	...	...	200	..	7,200	4,720
TOTAL	36	80	68	...	...	...	35,400	...

GOORSERAI KHURREEF CANAL.—*Head on Right Bank of the Betwa River, at the Betwa Canal-head Weir.*

Name of Canal or Branch.	Length, in miles.	Area within influence, in square miles.	Water-supply required, cubic feet per second.	Total discharge.	Probable average cost per mile.	Total.	Grand Total.	Area that will be irrigated, in acres.
					₹	₹	₹	
Main Canal	32	100	84	...	900	28,800	...	5,900
Lohargunj Branch	12	20	17	...	600	7,200	...	1,180
Heeranugger „	24	40	34	...	600	14,400	...	2,360
Erich „	15	40	34	...	600	9,000	...	2,360
Tigurea „	10	15	12	...	600	6,000	65,400	885
Minor distribution channels, at per mile of canal.	...	...	...	...	200	...	18,600	...
Extraordinary works crossing drainage.	...	...	...	...	...	...	20,000	...
TOTAL	93	215	181	181	...	...	1,04,000	12,685

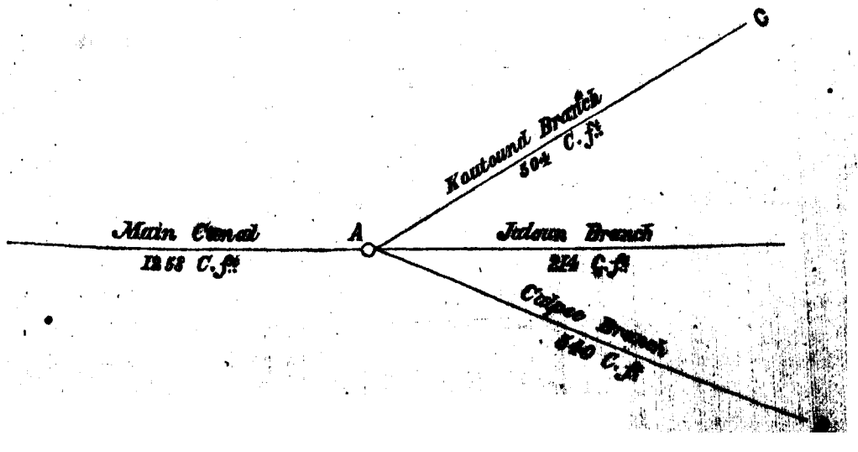
11. Thus the total outlay will be ₹76,20,000. The revenue derivable from the khurreef canals, taken at ₹2 per acre, will amount to . ₹ 64,000
That from the Betwa Canal 5,28,000
Total Revenue . 5,92,000

APPENDIX II.

BETWA CANAL.

Estimate of extra cost involved in providing for navigation down to the Jumna at Calpee, as compared with that on the construction of irrigating canals without navigation.

1. In Part X of his report, Captain Bagge adheres to his present scheme of crossing the drainage between points C and B, in consideration of its being less expensive than carrying down the supply in three separate channels from point A to the latitude of BC, the eastern or navigable line to Calpee being by such an arrangement carried down the line of greatest outfall, AB. The reductions made in the cost of crossing that drainage (₹70,000) go to strengthen this view. Further, the navigable line CB, and thence to Calpee, has but one fall in its entire length, the bed being carried down at an uniform slope of 1½ feet per mile: and if navigation is to be provided, the scheme as it stands at present appears to be the best; but in estimating the extra expenditure involved in providing for navigation over and above that which would be necessary in constructing simple irrigation lines, it would appear advisable to bring the main canal up to the point A, and there divide it into three branches:—



Canal.	Khurreef supply.	Rubbee supply.
Main Canal	1,258	440
Kootound Branch	504	176
Jaloun „	214	75
Calpee „	540	189

For the "Kootound Branch," with a section

slopes 1½ to 1, depth of water=3 feet, discharge 504, and maximum velocity=3 feet per second:—

$$\text{Area}=\frac{\text{Discharge}}{\text{Velocity}}=\frac{504}{3}=168=(b+4{\cdot}5)3,$$

or width of bed, $b=51{\cdot}5'$

And since $V=3=90\sqrt{\frac{168}{62{\cdot}3}\times\frac{h}{5{,}280}}$

Slope of bed=h=2·17 feet per mile.

When the discharge is reduced to its minimum, 176 cubic feet per second,—

The depth of the water will be=1·5 feet,

and the velocity=2·18 feet per second.

For the "Calpee Branch:"—Discharge=540 cubic feet per second, depth of water=3', maximum velocity=3' per second.

$$\text{Area}=\frac{540}{3}=180=(b+4{\cdot}5)3,$$

and $b=35{\cdot}5$ feet.

Also, $V=3=90\sqrt{\frac{180}{66{\cdot}3}\times\frac{h}{5{,}280}}$

or h=2·16 feet per mile.

The depth at minimum supply may be taken as equal, or nearly so, to 1·5 feet.

For the "Jaloun Branch:"—Discharge=214, depth of water=3', maximum velocity=3 feet per second.

$$\text{Area}=\frac{214}{3}=71{\cdot}3=(b+4{\cdot}5)3,$$

b=19·2',

$$V=3=90\sqrt{\frac{71{\cdot}3}{30}\times\frac{h}{5{,}280}}$$

h=2·46 feet per mile.

Carried down with these slopes, and a maximum depth of water = 3 feet—

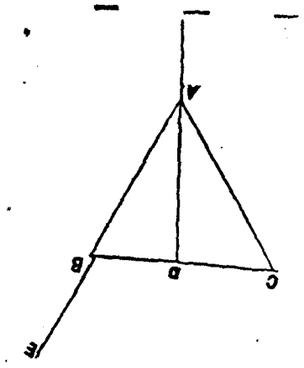
The Calpee Branch will still require six falls of 6 feet each;

The Kootound Branch will require two falls of 6 feet each;

The Jaloun Branch will require three falls of 6 feet each.

To get at the difference between the cost of the scheme with navigation and those not providing it, we have on one side—

Expenditure on Main Canal, ... AC
Ditto Calpee Branch, ... BC
Ditto Raising bridges, &c., along the line, . BE } ... N.
Ditto Kukhul Rajbuha, ... AB
Ditto Baroda „ . . . . . AD



And on the other side

Kootound Branch, ... AC
Jaloun „ . . . . . AD
Calpee „ . . . . . AB } ... I.
„ masonry works in, ... BE

Let the former be denoted by N, and the latter by I.

Under Head N, in the accompanying estimates:—

The expenditure on	AC,	=R 5,28,704
Ditto	BC,	=„ 1,46,022
Ditto	BE,	=„ 1,25,269
Ditto	AB,	=„ 21,000
Ditto	AD,	=„ 13,700
	Total cost,	R 8,34,695

Under Head I:—

The expenditure on	AC,	=R 95,810
Ditto	AD,	=„ 45,012
Ditto	AB,	=„ 1,66,990
Ditto	BE,	=„ 50,600
		R 3,58,412
Hence, difference in cost,		R 4,76,283
Add 5 per cent., contingencies,		„ 23,814
		R 5,00,097
And 20 per cent. for maintenance,		„ 1,00,000
Difference, due to navigation,		R 6,00,000

A still greater difference may be obtained by taking into consideration the diminished discharge (by 150 cubic feet navigation supply) in the main canal requiring a narrower bed, and also by taking into consideration the difference in the earthwork on the Calpee Branch and also by taking into consideration the difference in the earthwork on the Calpee Branch beyond the point B; but I think that, as it stands, 6 lakhs may be fairly taken as the extra expenditure involved in providing for navigation along the main canal and the Calpee Branch.

ESTIMATES UNDER HEAD N.—*Main Canal, from A to C.*

Nature of work.	Quantity.	Rate.	Cost.
			R
Earthwork in channel,	72,757,000	R 3 per 1,000	2,18,271
Ditto in approaches,	9,781,000	„ 3 „	80,343
Rubble masonry, in lime,	515,675	„ 15 per cent.	77,351
Plain brickwork,	609,059	„ 20 „	1,21,812
Archwork,	56,258	„ 25 „	14,064
Concrete,	369,215	„ 8 „	29,537
Granite paving,	8,000	„ 2	16,000
Cubic feet timber,	442	„ 3	1,326
Pairs of lock-gates,	10	„ 2,000	20,000
	Total for AC,		5,28,704

Calpee Branch, from C to B.

Earthwork in channel,	16,980,000	R 3 per 1,000	50,940
Ditto in approaches,	1,647,000	„ 3 „	5,541
Plain brickwork, in lime,	164,500	„ 20 per cent.	32,900
Archwork,	23,600	„ 25 „	5,900
Seetah and Kasespoora Drainage,	...	...	50,000
Cubic feet timber,	247	„ 3	741
	Total for CB,		1,46,021

Calpee Branch, Masonry-works, from B to E.

Nature of work.	Quantity.	Rate.	Cost.
			R
Plain brickwork, in lime,	421,000	R 20 per cent	84,200
Archwork,	39,000	„ 25 „	9,750
Concrete,	5,060	„ 8 „	405
Granite paving,	130	„ 3 „	390
Stone pitching,	6,600	„ 2 per cent.	132
Earthwork in approaches,	7,728,000	„ 3 per 1,000	23,184
Sleepers,	22	„ 4	88
Pairs of lock-gates,	2	„ 3,500	7,000
Sets of chains and rings,	2	„ 60	120
	Total for BE,	. . . . R	1,25,269

The estimated cost of the Kukkul Rajbuha in Appendix B.,* . . . . . R 21,000
Ditto ditto Baroda Rajbuha . . . . . „ 13,700

ESTIMATES UNDER HEAD I.—*Calpee Branch, A to B.*

Earthwork in channel—Length 19 miles—d. 6′, bed 55′,	38,530,000	R 3 per 1,000	1,15,590
Masonry-works—Falls 6′,	6	„ 2,600	15,600
Ditto Bridges,	8	„ 2,600	20,800
Branch head in main canal,	...	...	15,000
	Total for AB,	. . . . R	1,66,990

Calpee Branch, B to E.

Masonry-works—Bridges,	11	R 2,600	30,600
Ditto ditto,	11	„ 1,500	16,500
Kudowra Rajbuha-head and bridge	1	...	3,500
	Total for BE,	. . . . R	50,600

Kootound Branch, A to C.

Earthwork in channel—Length 19 miles—d. 4′, bed 51′,	23,270,000	R 3 per 1,000	69,810
Masonry-works—Falls 6′,	2	„ 2,600	5,200
Ditto Bridges,	8	„ 2,600	20,800
	Total for AC,	. . . . R	95,810

Jaloun Branch, A to D.

Earthwork in channel—Length 18 miles—d. 4′, bed 19,	9,504,000	R 3 per 1,000	28,512
Masonry-works—Falls 6′,	3	„ 1,500	4,500
Ditto Bridges	8	„ 1,500	12,000
	Total for AD,	. . . . R	45,012

APPENDIX A.

Navigation how to be provided for at the lower end of the Calpee Branch.

AFTER the Kadowra Rajbuha is taken from the Calpee Branch, the discharge is reduced to 218 cubic feet per second, and the navigation will require a minimum depth of 5 feet of water, which reduces the bed of the canal to 9 feet, with slopes of 1½ to 1.

With this width of bed it appears difficult where the falls occur, to carry out a separate lock-channel without making it in still water, thereby causing silt; and the only way in which it can be arranged is by combining fall and lock, a drawing of which is sent up.

The difficulty which arises in this plan is, how to get the boats up against the fall-water; but it is my opinion that by lengthening the lock-chamber, and giving the boatmen every assistance with chains hung at the sides of the chamber, and if necessary a set of blocks, they would be able to get into the lock-chamber: once inside, the water would rapidly rise, and get still, the lower gates being closed.

The upper gate being merely a skeleton frame, its lower portion forming a weir 2¼ feet high would be easily opened, and the boats would pass out easily when the water rose 9 feet on the lower gate.

* Not printed.

The upper and lower gates are both to be made of wrought-iron strengthened by T and L-irons.

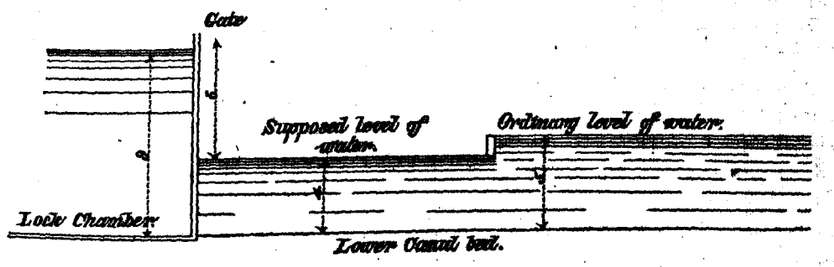
The upper one will be a skeleton frame of T-iron, with the exception of the lower portion, which will be ¼-inch plate and 2½ feet deep, which forms the weir-plate.

The lower gate is to be made exactly the same as the gate designed by Mr. Campbell for the Assuffanuggur upper gate, with the exception that the sluices must have a larger area. This gate will be 10 feet high, with six sluices each 3·66 square feet area.

The water discharging into the lock=218 cubic feet per second.

The sluice area provided will discharge, with a 5-feet head, 242 cubic feet per second.

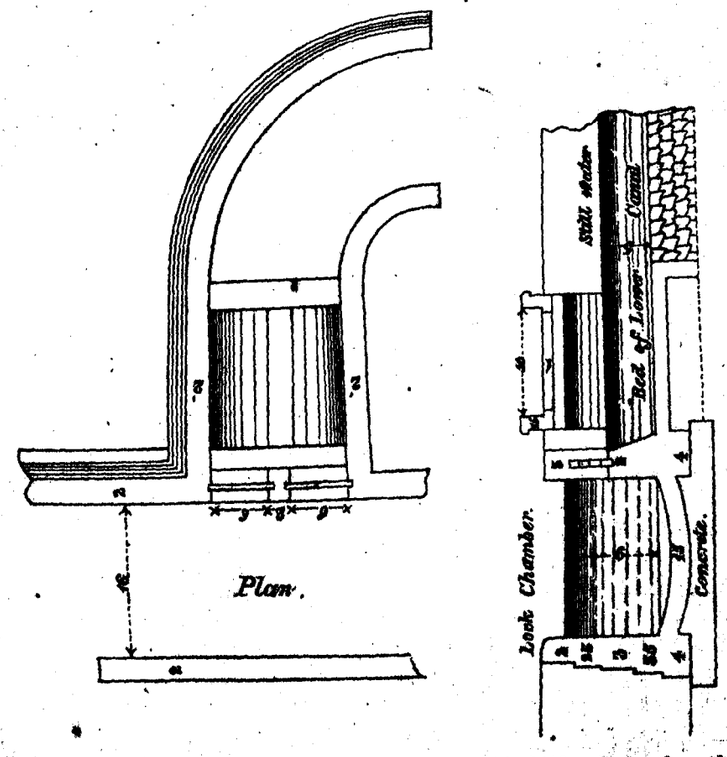
In calculating the discharge by the sluices, the pressure of the water at the lower canal-level must be taken into account, which I have taken at 4 feet deep after the boat has passed through, leaving an effective head of 5 feet, the water having lowered after the closing of the



gates during the time the boat was passing through.

The weir-gate can discharge 234 cubic feet per second with 2¾ feet on crest.

In order further to provide for safety, so that the water should not rise above 9 feet in the lock-chamber, I propose to take out an escape-channel with plank arrangement, which will, if necessary, assist the sluices if any one of them get out of order.



The extra length given to the lock-chamber in this case is 34 feet more than the Ganges Canal remodelling pattern, which, in my opinion, will be ample in the case of a 34 feet fall.

W. PELHAM RICHARDSON,
Asst. Engr., Bundelkhund Irrigation Surveys.

APPENDIX F.

Answers to questions put to District Officers, Bundelkhund Irrigation.

Question 1.—Whether irrigation from streams, jheels, or other natural sources, is now practised? If so, to what extent? Actual areas being stated if possible, otherwise an approximation to be given.

Question 2.—If irrigation is anywhere practised, do the landholders pay any rate to Government for the use of the water? If not, have they any prescriptive right to use it?

Question 3.—What is the average depth of water below the surface of the ground? State also the maximum and minimum depths, specifying the names of the places where the water is found at the greatest and least depths.

Question 4.—Do facilities exist for making (kutcha) wells? If so, are there many in use for irrigation purposes, and what is the average cost of making them?

Question 5.—Do facilities exist for making minor irrigation works from tanks, jheels, nullahs, or other sources? If so, state the portion or portions of the district which would probably be benefited, and point out which works it would be requisite to undertake first.

Question 6.—In the event of any irrigation works being carried out, state whether any special arrangement should be made with reference to charging for the water supplied, consequent on any peculiarity of the tenure of land or otherwise, and mention what would be the probable fair money-value of water to the chief crops likely to require it.

Question 7.—In what months are the "puleves" (or first waterings for breaking up and preparing the land) for the khurreef and rubbee crops required?

Question 8.—What are the more important crops of the district? Give approximate areas of cultivation.

Question 9.—What is the weight of the ordinary produce of the chief crops per acre irrigated and unirrigated?

Question 10.—Is there at present any important export of agricultural produce? If so, to what places, and what are the chief staples?

Question 11.—What are the chief marts for the agricultural produce of the district; and what are the chief lines on which water-carriage is likely to be most valuable for the purposes of inland trade, either in respect of agricultural produce or any other commodity?

Question 12.—Is there any "reh" or "oosur" land in the district? If so, specify where, and state actual and approximate areas.

Question 13.—Is there any register of the Ganges maintained showing the daily height of water in any of the rivers or streams in the district?

Question 14.—Is any protection by drainage embankment, or other works, needed for the district, or any part of it? And in the event of such protection being required, state if the flood-water brings down silt of a fertilizing description.

Answers to Question 1.

Jhansie.—No irrigation from streams, jheels, &c., that I know of.

Irrigated area at settlement 22,401, from tanks, wells, &c.

Jaloun.—The only irrigation in this district is from wells, generally near villages. The extent of such irrigation is very small. In pergunnah Madhogurh the irrigation from kutcha wells, for sugar-cane chiefly, may cover about 1,087 acres.

Humeerpoor.—No irrigation in this pergunnah is practised from streams, jheels, or other natural sources; about 140 beegahs are irrigated from wells in Humeerpoor, and 246 beegahs in Somurpore.

Mondha.—Ditto, ditto; about 566 beegahs are irrigated from wells.

Jellapore.—About 100 beegahs are irrigated from the River Betwa in mouzahs on its banks, as well as from wells.

Raat.—No irrigation from streams, jheels, or other natural sources is practised in this pergunnah.

Punwaree.—About 9,300 beegahs are irrigated from wells in pergunnah Punwaree, and 6,522 beegahs in Jeitpore; about 360 beegahs, also, are irrigated from the Bala Tal Lake in pergunnah Jeitpore.

Muhoba.—About 904 beegahs are irrigated from the lakes in this pergunnah; no irrigation from streams is practised.

Banda.—There is no irrigation from drains, jheels, or other natural sources now practised in this district. Land adjoining villages and cultivated with tobacco or vegetables is sometimes irrigated with water from wells and tanks.

Allahabad.—Irrigation is practised from jheels but not from streams, there not being any suitable for that purpose:—

	Acres.
In the Doab,	2,472
In the Trans-Ganges,	5,000
In the Trans-Jumna,	1,746

are irrigated in this manner.

Futtehpore.—There is no irrigation from streams in this district. The following statement will show roughly the extent to which irrigation is resorted to by means of jheel and tanks:—

	Jheels. Acres.	*Tanks.* Acres.
Futtehpore,	6,000	13,000
Gazeepore,	3,571	4,514
Ekdulla,	...	15,000
Khaga,	...	59,531
Kulianpore,	...	...
Kora,	..	...

Ghazeepore.—Not received.

Mirzapore.—Irrigation is partially practised in this district from wells, tanks, bunds, and not from natural sources; and the area thus irrigated is approximately 177,827 acres.

Answers to Question 2.

Jhansie.—Most of the irrigated land was assessed as such at settlement; new fields watered from Government tanks pay water-rates.

Jaloun.—The landholders pay no rate to Government for the use of the water, having a prescriptive right to the use of it.

Humeerpoor.—The only irrigation in this pergunnah is from wells, and nothing is paid to Government for it.

Mondha.—Ditto, ditto.

Jellapore.—Ditto; is from the River Betwa, besides that from wells, and nothing is paid to Government.

Raat.—No irrigation is practised in this pergunnah.

Punwaree.—The zemindars pay from 12 annas to R1-8-0 per beegah for irrigation from the Bala Tal Muhoba. The water-rates in this pergunnah vary from 12 annas to R2-1-6 for irrigation from the several lakes by canals.

Banda.—The zemindars have no prescriptive right to the use of water from streams.

Allahabad.—The zemindars, having a prescriptive right to all such water as is at present used for irrigation, do not pay any rate to Government.

Futtehpore.—Landholders pay no rent to Government for the use of the water, as they have a prescriptive right to it.

Ghazeepore.—The jheels, tanks, &c., are in their estates, and they have used the water always.

Mirzapore.—The landholders do not pay anything for the water used for irrigating their lands, as the wells, &c., are constructed at the expense of villages.

Answers to Question 3.

Jhansie.—Average depth 25 to 30 feet; maximum (north and north-east) 70 feet near river; minimum (south and south-west) 15, and ridges.

Jaloun.—The average depth of water below the surface of the ground is for surface-water between 20, 30, and 50 feet; the maximum depths 150 to 180 feet: *vide* the well in the public garden at Orai, the well at the Orai Jail, and one in Colonel Swiney's compound in Orai. At this depth an ample and inexhaustible supply of water is obtained.

Humeerpoor.—The average depth of water is 67 feet; the maximum being 90 feet, and the minimum 45 feet.

Mondha.—The average depth of water to the eastward is 100 feet, to the westward 54 feet, to the northward 65 feet, and to the southward 105 feet.

Jellapore.—The average depth of water to the north is 90 feet, to the south 60 feet, to the east 6 feet, and to the west 90 feet.

Raat.—The average depth of water in this pergunnah is 57 feet; the maximum being 90 feet, and the minimum 24 feet.

Punwaree.—The average depth of water in pergunnah Punwaree is 51 feet, and that in pergunnah Jeitpore 36 feet; the maximum of the former being 60 feet, and that of the latter pergunnah 16 feet, and the minimum 40 feet in Punwaree, and 10 feet in pergunnah Jeitpore.

Mahoba.—The average depth is 16 feet; the maximum being 20 feet, and the minimum 12 feet.

Banda.—The average depth of water below the surface is 77 feet. The maximum depth is 157 feet, in mouzah Bhawneepore, pergunnah Banda; and the minimum about 12 feet, in Busabaree, pergunnah Banda.

Allahabad.—The average depth of water below the surface of the ground is—

In the Doab	60 feet.
„ Trans-Ganges	51 „
„ Trans-Jumna	48 „

The maximum and minimum depths are—

	Maximum. Feet.	*Minimum.* Feet.
Doab	77	37
Trans-Ganges	73	31
Trans-Jumna	83	23

It is at the greatest depth near the rivers and in hilly parts—such as a portion of Khyragurh and Barra, Trans-Jumna. The nearness of the water to the surface in a large portion of the two latter pergunnahs cannot be taken as a guide regarding facilities for making wells, as owing to the soil being rocky, blasting is necessary before a well can be made, and of course the expense is much enhanced thereby. I should say that in the whole district it is at a minimum depth at Munjunpore in Mirzapore chowharee, which is the only place in this district where I have noticed the wells called "dhoklee," *viz.*, those in which water is raised by a "ghurra" at the end of a bamboo.

Futtehpore.—Average depth of water in each pergunnah—

	Feet.
Futtehpore	48
Ghazeepore	62
Ekdulla	60
Khaga	23
Kullianpore	70
Kora	90

Maximum and minimum depths—

	Maximum. Feet.	*Minimum.* Feet.
Futtehpore	63	27
Ghazeepore	120	24
Ekdulla	90	30
Khaga	20	10
Kullianpore	150	35
Kora	90	60

Ghazeepore.—Not received.

Mirzapore.—The average depth of water below the surface of the ground is 50 feet, and the maximum and minimum depths at different places are as follows:—

Sub-division.	*Maximum.* Feet.	*Minimum.* Feet.
Mirzapore	75	20
Chunar	60	22
Robertsgunj	70	30

ANSWERS TO QUESTION 4.

Jhansie.—Kutcha wells, comparatively little used in this district; cost, ₹20 to ₹30.

Jaloun.—The water in this district lies generally for kutcha wells at a depth of 30 to 50 feet, but it is only surface-water, and most of these wells run dry during the hot season, or fall in during the rains, when others are dug. The cost of such wells is about ₹25 on an average. These wells are often used for irrigation.

Humeerpoor.—The soil in this pergunnah does not admit of kutcha wells being sunk.

Mondha.—Kutcha wells, though not much in use, can be sunk for ₹10.

Jellapore.—In this pergunnah kutcha wells are used for the irrigation of sugarcane fields, and can be sunk for ₹25 each.

Raat.—Ditto ditto ₹ 5.
Punwaree.—Ditto ditto ₹ 15.
Mahoba.—Ditto ditto ₹ 20.

Banda.—No facilities exist for making kutcha wells. In pergunnah Banda there are six such wells constructed, at an average cost of ₹20; and some four or five in pergunnah Budousa—cost of construction varying from Rs. 16 to ₹35 each.

Allahabad.—Kutcha wells can be, and are easily made everywhere, except close to the rivers and those parts of Barra and Khyraghur mentioned above; they cost on an average ₹10, and last generally one year, but in some parts, *viz.*, Trans-Ganges, two years.

Futtehpore.—Every facility exists for making kutcha wells, and many exist throughout the district. The cost of making kutcha wells is from ₹10 to ₹15.

Ghazeepore.—Yes; a great many all over the district; ₹15.

Mirzapore.—Kutcha wells are easily constructed, at an average cost of ₹10 each, and are generally used for irrigation purposes.

ANSWERS TO QUESTION 5.

Jhansie.—Yes, in Mow and Garotha, along the ridges of hills between Dussan and Betwa. No facilities in Mote pergunnah.

Jaloun.—No facilities exist for making minor irrigation works from tanks, jheels, nullahs, and other sources. The district is a dead level, and much engineering science would be required to apply the drainage of the country to works of irrigation, though no doubt it is feasible. The pergunnahs of Madhogurh and Kumar, where the purwa soil prevails, would be the most benefited by well or tank-irrigation, should a canal not be available.

Humeerpoor.—Facilities for making minor irrigation works from tanks, jheels, nullahs, &c., do not exist in this pergunnah, though such might be possible from the Rivers Jumna and Betwa.

Mondha.—Still ditto; the Kane is the only stream from which this might be possible in the villages bordering thereon.

Jellapore.—Ditto, ditto; the River Betwa might admit of minor irrigation works in the mouzahs bordering on it.

Raat.—No facilities for minor irrigation works exist in this pergunnah.

Punwaree.—Canals from Bala Tal in Jeitpore do exist, and minor irrigation works might be extended from the Rivers Dussan, Birma, Keslarn, and Urjoon in pergunnah Punwaree, and the tank at Chuturwara, and nullah in Burkhers, if dammed up.

Mahoba—Canals for irrigation purposes do already exist from the Bijanuggur, Kuraree, Keerut Saugor, Mudun Saugor, and Jussrapore Lakes, and it is possible to make minor irrigation works from the tanks at Powa, Bilkher, Sijahree, and Oorwara.

Banda.—I do not think that any facilities exist for making, on the part of Government, minor irrigation works from tanks, jheels, nullahs, or other sources.

Allahabad.—I have already, in my No. 740, dated 15th December last, alluded to the facilities which exist for enabling the stream known as the Susoor Khundyrie to be improved by masonry-weirs, so as to enable the surrounding country to be irrigated. This is a work which I think might be undertaken at once; it would materially benefit the Doab, through the middle of which it runs, and I believe that it might be done at a comparatively small expenditure. I also mentioned that my predecessor was strongly in favour of a dam being made in the Tonse, by which the Barra and Arail pergunnahs might be irrigated by means of a canal, but cannot help doubting the feasibility of this, especially as the Tonse, not being a perennial stream, is likely to run dry just at the time that the water is most wanted for the canal.

Futtehpore.—Every facility exists for making minor irrigation works from nullahs, jheels, &c., provided that money is forthcoming. The water of the Rivers Rhind, Pundoo, and Noond might be used with great advantage; also the water which escapes from the high roads into the nullahs, and from thence into the Jumna and Ganges. The stream known as the Susoor Khundyrie might be banked, and its water used to great advantage. The whole of the southern portion of the district lying along the Jumna would benefit by this arrangement.

Ghazeepore.—Not received.

Mirzapore.—There is no facility for making irrigation works, owing to there being no jheels or tanks in this district, except from the River Ganges, from which a portion of the district might be benefited.

ANSWERS TO QUESTION 6.

Jhansie.—No special arrangement consequent on tenure necessary; rate somewhat high, owing to poverty of zemindars.

Jaloun.—In the event of any irrigation works being carried out, I am not aware that any special arrangements would be required with reference to charging for the water supplied. The rates prescribed by the Sudder Board of Revenue's Notifications Nos. 4 and 17, dated the 10th May and 30th August 1865, would appear to be judicious, though at first they might require to be somewhat lowered to suit a not very affluent set of farmers.

Humeerpoor.—In the event of irrigation works being carried out, a rate of from 8 annas to ₹1-8-0 would be a fair charge per beegah.

Mondha.—A rate from 6 annas to 8 annas per beegah, ditto.

Jellapore.—Ditto 6 annas to 8 annas ditto.

Raat.—Ditto 6 annas to ₹2, ditto.

Panwaree.—The existing water rate is ₹1-8-0 per beegah, and this may be continued.

Mahoba.—The existing rate of water varies from 12 annas to ₹2-1-6 per beegah, which may be allowed to stand.

Banda.—In the event of irrigation works, *i.e.*, canals, being carried out in this district, I think a water-rate varying from 4 to 6 annas per beegah might be charged for the khurreef crops, and from 8 to 12 annas per beegah for the rubbee.

Allahabad.—There is no peculiarity in the tenure of land which would render any special arrangement necessary; the rules in force in other districts regarding charge for use of water would equally apply to this. The chief crops would, from obtaining a regular supply of water, rise in value about one rupee per beegah.

Futtehpore.—Arrangements should be made for charging for the use of this water at the time of settlement of each district. The fair money-value of water would be—khurreef 5 annas per beegah, and for rubbee 8 annas.

Ghazeepore.—Not received.

Mirzapore.—If irrigation works be carried out in the district, the duty to be levied should be fixed without reference to the description or quality of the soil. The fair value of water required for the chief crops would be ₹4 per beegah.

ANSWERS TO QUESTION 7.

Jhansie.—Water for khurreef in June only wanted; however, in seasons of drought, water for rubbee in November, but usually all the land is broken up in June and July.

Jaloun.—The first waterings for the khurreef crops would be required in Jeth (June), and for the rubbee in Kooar (September).

Humeerpoor.—The rains in this pergunnah suffice for the khurreef crops, and for the rubbee water is required during the months of Aghun, Poos, and Maugh, corresponding with November, December and January.

Mondha.—Ditto, ditto.

Jellapore.—Ditto, ditto.

Raat.—For the khurreef crops water is required during July and August, and for the rubbee as above.

Punwaree.—Ditto, ditto.

Mahoba.—Ditto, ditto.

Banda.—The "puleves" are required for the khurreef crops from 15th June to 15th August, and for rubbee 15th September to 15th November.

Allahabad.—In a season of drought, the first waterings for breaking up the land for the khurreef crops would be required about July; for the rubbee about the middle of October.

Futtehpore.—For khurreef, May and June, and for rubbee, August and September.

Ghazeepore.—There is a deficiency or irregularity in the fall of rain; the waterings for the khurreef take place in June, those for the rubbee in September.

Mirzapore.—Asarh for khurreef, and Kooar for rubbee crops, are the months in which watering for breaking up and preparing land is required in case the rain is untimely or insufficient for the above purpose.

ANSWERS TO QUESTION 8

	Acres.
Jhansie.—(1) Wheat calculated at settlement,	104,295
(2) Gram	49,967
(3) Jowar	132,612
(4) Bajra	24,409
(5) Cotton	21,164

Jaloun.—The most important crops of the district are wheat, cotton, gram, jowar, bajra, urhur.

Area of Cultivation.

	Acres.	Average rate per Acre.
		₹ a. p.
	89,175	3 10 5
Mar	120,464	2 14 4
Kabur	124,629	2 7 9
Purwa		

Humeerpore.—Wheat and gram about 50,000 bighas, and in Somripore 110,000; and jowar and bajra, &c., about 23,000 bighas.

Mondha.—Wheat and gram about 46,423 acres, and jowar and bajra about 40,244 acres.

Jellapore.—Jowar, bajra, wheat and gram, in all about 100,000 bighas.

Raat.—Sugarcane 2,350 bighas, paddy about 224 bighas, cotton 4,332 bighas, wheat and barley about 57,374 bighas.

Punwaree.—Jowar, bajra, paddy, wheat, and gram, &c., about 186,000 bighas.

Mahoba.—Sugarcane, paddy, pawn, wheat, and gram about 174,000 bighas.

Banda.—The more important crops, with their approximate areas in acres exclusive of the sub-division are—

	Acres.
	146,382
Jowar and bajra	74,000
Cotton	326,500
Gram and wheat	

Allahabad.—The chief crops are wheat, barley, bajra, gram, rice, minor jowar; of which the approximate cultivated area is—

	Khurreef. Acres.	*Rubbee.* Acres.
	86,001	172,032
In Doab	94,399	159,631
Trans-Ganges	126,012	252,024
Trans-Jumna		

A great deal of sugarcane (which though not an important crop as regards sustenance, is one as to the return which it gives to the cultivator), is grown in the Trans-Ganges; a much smaller quantity in the other parts of the district.

Futtehpore.—Principal khurreef crops—rice, cotton, bajra, jowar, moong, cord, mote, til.
Principal rubbee crops—sugarcane, wheat, gram, peas, surson, urhur, masoor.

	Cultivated Area. Acres.
	110,959
Futtehpore	87,050
Ghazeepore	78,000
Ekdulla	74,942
Khaga	110,948
Kullianpore	...
Kora	

Ghazeepore.—Wheat, barley, pulses, sugarcane, rice, pool, bajra, poppy, indigo.

Mirzapore.—The important crops of the district and the approximate area of cultivation are stated as follows :—

Grain.	*Area.* Acres.
Wheat	120,060
Barley	46,536
Paddy	180,389
Gram	53,313
Urhur	48,344
Oord, or Mash	31,121

ANSWERS TO QUESTION 9.

	Irrigated. Maunds.	*Unirrigated.* Maunds.
Jhansie—Wheat	8	5
Gram	6	4
Urhur	„	4
Bajra	„	5
Cotton, uncleaned	„	5

Jaloun.—There being no irrigation in this district, the weight of the ordinary produce of the chief crops per acre, irrigated and unirrigated, cannot be given.

Humeerpoor.—There is irrigation practised in this pergunnah. The produce of wheat in unirrigated soil is 6½ maunds per acre, and gram the same.

Mondha.—Still the produce of bajra is 6 maunds per acre, jowar 7 maunds, wheat 5¾ maunds, and gram 7 maunds per acre.

Jellapore.—Irrigation is not practised here. The average produce of unirrigated fields is 6 maunds per acre.

Raat.—In irrigated and in unirrigated fields per acre—

	Mds.	Srs.			Mds.	Srs.
Sugar-cane	10	0	goor	Wheat	4	20
Wheat	9	0		Barley	5	20
Paddy	3	0		Cotton	0	15
Cotton	0	30		Indigo	0	35
				Al	5	0

Punwaree.—Gram 8 maunds, grain 4¾ maunds.

Mahoba.—Gram, barley, &c., 7½ maunds; gram, barley, 4½ maunds.

Banda.—The weight of the produce per acre is—

	Mds.	Srs.
Jowar and bajra	6	27
Cotton	5	20
Gram and wheat	8	14

Allahabad.—The ordinary produce per acre is, in the khurreef, 8 maunds in irrigated, and 6 maunds in unirrigated land; and in the rubbee 14 maunds in irrigated, and 8 maunds in unirrigated land.

Futtehpore.—Average throughout the district—irrigated, 10½ maunds per bigha; unirrigated, 7½ maunds per bigha.

Ghazeepore.—Irrigated, 10 maunds per acre; unirrigated, 6 maunds per acre.

Mirzapore.—With timely rain and a good season, the weight of ordinary produce of irrigated land is about 15 maunds, and unirrigated about 6 maunds per acre.

ANSWERS TO QUESTION 10.

Jhansie.—Chief staples; wheat goes to Lullutpore, and cotton to Mirzapore, and all goes north and north-east.

Jaloun.—The most important export of agricultural produce is in cotton and wheat. They find their way by Calpee on the Jumna (a town of this district) to the North-West Provinces, and by boat to Mirzapore and Calcutta.

Humirpore.—Al and cotton are the principal exports; the former to Calpee and Hattrass, the latter to Mirzapore *vid* Banda or Calpee.

Banda.—At present gram is largely exported to Cawnpore, Mahoba, and neighbouring Independent States, and cotton to Mirzapore.

Allahabad.—In the Doab, the chief exports are indigo towards Calcutta, and wheat, &c., towards Banda by Rajapore Ghât, and to Oudh by Kurra.

Trans-Ganges.—Goor is exported in large quantities to Banda *via* Rajapore Ghât, and to Rewah *via* Allahabad.

Trans-Jumna.—Cotton and linseed are exported for Calcutta, and opium in small quantities to Ghazeepore. A species of rice, called "lohunde," is exported from Barra into the Rewah territory.

Futtehpore.—Futtehpore, Delhi, Agra, Meerut, and Jhansie.

Ghazeepore.—Allahabad and Mirzapore.

Ekdulla.—Nil.

Khaga.—Cawnpore and Allahabad.

Kullianpore.—Delhi, Agra, Meerut, Jhansie, Mirzapore, and Calcutta.

Kora.—Western Provinces.

Ghazeepore.—Food-grains, to Cawnpore and Agra, for the supply of the famine-stricken districts in the south and west.

Mirzapore.—Agricultural produce is often exported from this district to the following places:—Wheat and barley to Furruckabad and Futtehpore; gram and til to Calcutta and Moradabad; moong and bujrie to Jubbulpore and Rewah; mustard and linseed to Azimgurh and Benares; poppy, gram, and rice to Surgooja; paddy, castor-seed, and urhur to Calcutta and Dacca.

ANSWERS TO QUESTION 11.

Jhansie.—Mow Raneepore, Bhandere, Goorsurai, Burwa Sagur, city of Jhansie (Gwalior). No canals could be made in this district fit for water-carriage. The best line would be due north-west of the Betwa.

Jaloun.—The chief marts of agricultural produce in this district are Calpee, Koonch, and Jaloun; and a canal to be useful must, starting from the Betwa in the Jhansie District, skirt the towns of Koonch, Jaloun, and Calpee, falling into the Jumna below Humeerpoor. It must have branch canals, also, towards Madhogurh and the old pergunnah of Kunnar.

Humeerpoor.—The chief marts are Raat, Koolpuhar, Mahoba, and Supolar. No line of water-carriage for inland trade exists.

Banda.—The chief marts for the agricultural produce are Banda, Narainee, Kallinger, Hurdowlee, and Gugowlee. The Jumna is the only river on which water-carriage is practicable.

Allahabad.—The chief marts of agricultural produce are:—

In Doab.—City Allahabad, Serai Akil, Daranuggur, Kurra, Munjhunpore, Kurowlee.

Trans-Ganges.—Ismailgunj, Mow, Mirzapore, Gopalgunj, Phoolpore.

Trans-Jumna.—Kurma, Bharutgunj, Sirsa.

This district is so intersected by the railroad, and has two rivers, *viz.*, Ganges and Jumna, so near to almost every part of it, that I do not think much if any inland carriage would go by means of a canal: only three of the marts mentioned above are not either on, or close to, either the railroad or one of the rivers.

Futtehpore.—Futtehpore, Huswa, Hooseingunj, Narainee, Jumrawan, Uswar, Tarapore, and Cheetusapore.

Ghazeepore.—Futtehpore Bowha, Sah, Bindkie, Kishoonpore, and Narainee.

Ekdulla.—Kishoonpore, Dampore, Kubira, and Powlee.

Khaga.—Kasimpore, Cheala, Hutgoon, Khaga, and Itailee.

Kullianpore.—Bindkee, Jafurgunj, Kora, Bindkee in Kullianpore.

Ghazeepore.—Not received.

Mirzapore.—The chief marts of the agricultural produce are Mirzapore, Chunar, Ghoruwul, Kutchwa, Bindachul, Adulpoora, Shahgunj, Robertsgunj, Ahrown, &c., but there is no market of an extensive trade in this district towards which an irrigation line could be suggested to be opened.

ANSWERS TO QUESTION 12.

Jhansie.—None to speak of.

Jaloun.—Oosur lands are often to be found in this district, particularly in the Kunnar pergunnah, now forming part of the Jaloun pergunnah, also in pergunnah Atta. These oosur lands measure about 104,320 acres.

Humeerpoor.—There is no reh in this district; the 27,637 acres are entered in the settlement records as oosur.

Banda.—Not including the Kirwee Sub-division, the area of the reh and oosur land in the district is—reh, 158 acres; oosur, 55,000 acres.

Allahabad.—The oosur land is—in Doab, 50,056 acres; Trans-Ganges, 59,937 acres; Trans-Jumna, 70,532 acres. Of the latter, the chief part is in the pergunnahs of Barra and Khyragurh.

	Reh. Acres.	*Oosur.* Acres.
Futtehpore.—Futtehpore	...	10,000
Ghazeepore	21	1,336
Ekdulla	...	...
Khaga	...	17,546
Kullianpore	...	60,219
Kora	3,208	70,000

Ghazeepore.—Not received.

Mirzapore.—Area of oosur land in the district is approximately as follows:—Mirzapore Tehseel, 2,500 acres; Chunar Tehseel, 3,000 acres. And net land in Mirzapore Tehseel, 700 acres; Chunar Tehseel, 415 acres.

ANSWERS TO QUESTION 13.

Jhansie.—No register kept.

Jaloun.—A register is kept of the rise and fall of the Jumna, but of no other rivers.

Humeerpoor.—No register of the height of water in stream is kept up in this district.

Banda.—No register showing the daily height of water in any of the rivers or streams in the district is kept up in this office.

Allahabad.—No such register as is here described is here kept up.

Futtehpore.—No.

Ghazeepore.—No.

Mirzapore.—A register of daily rise and fall of water of the River Ganges is kept by the Police Department.

ANSWERS TO QUESTION 14.

Jhansie.—No such protection required.

Jaloun.—This question does in no way apply to this district.

Humeerpoor.—No protection by drainage or embankments is needed in this pergunnah. The Rivers Jumna and Betwa when they rise bring down silt on their banks.

Mandha.—No protection as above mentioned is needed, nor are there any streams which bring down silt.

Jellapore—No protection is needed; the Rivers Betwa and Birma bring down silt on their banks.

Banda.—Protection by drainage embankment or other works is not needed.

Allahabad.—I am not aware of any portion of the district bordering on either the Ganges or Jumna where protection by way of embankment is needed. I have already, in paragraph 5, and in my No. 740, dated 15th ultimo, alluded to a system of weirs or dams for the Susoor Khundeyree.

Futthehpore.—Embankments and other works are needed for the rivers mentioned in question No. 5, in order to utilize the immense quantity of water which at present wastes itself in the River Jumna and Ganges.

Ghazeepore.—Not received.

Mirzapore.—No protection is required for any part of the district.

Extract paras. 82 to 85, from a Report on the Average Rent Rates for Assessing Pergunna Koonch of the Jaloun District, dated 25th September, 1869, by MR. P. J. WHITE, *Settlement Officer.*

"82. Before concluding, some remarks may be, I think, appropriately ventured on the subject of irrigation in connection with Koonch. I am aware in a general way that the whole question is under the consideration of Government, and I also believe that a survey has been made and levels taken, but I have no exact official information on the point, and do not know how the several parts of this district are likely to be affected by whatever scheme may be in contemplation. If the extraordinary variableness of the monsoons was neutralized by irrigation, the immediate effect of our present figures would be a revenue of about ₹1,85,000, or the recovery of an annual loss for the next thirty years of ₹27,000. Not only that, but with the higher rents it would create, an absolutely higher revenue would be secured. However, these benefits are yet shadows in the future; but in the present temper of the times their realization is not so fanciful as it would have seemed a generation or two ago. Irrigation in Bundlekhund has been always thought a hopeless undertaking, and if you ask the people, they will with one accord tell you that the peculiar texture of the soil makes general irrigation impossible; yet their empirical knowledge in the matter ought to induce them to modify this belief. Though in small quantities, no doubt, nevertheless they *do* artificially irrigate for garden-produce both mar and kabur, which are the reputed impracticable soils. In all 1,031 beegahs are irrigated from wells in Koonch, of which 107 impracticable soils. In all 1,031 beegahs are irrigated from wells in Koonch, of which 107 beegahs are mar, 492 kabur, 421 purwa, and 11 rakur. So, also, in reporting the Jaloun settlement, I showed that of the 11,438 *acres* there irrigated, 484 acres were mar, 3,138 kabur, 7,752 purwa, and 64 rakur. The alleged obstacle offered to irrigation by mar and kabur consists in their cracking into great fissures when dry, which is therefore the natural feature they present for six or seven months in the year; but the successful experiments represented in the above detail *have* overcome this difficulty, and so its insuperable character disappears. The truth is, that the labour required is comparatively considerable, the means are insufficient, and agriculture must come a little out of its present groove before the full value of irrigation can be felt. The crops now grown on the different soils are these:—

Soils.	Rubbee (Acres), Wheat.	Wheat and Gram mixed.	Gram.	Barley.	Urese.	Dye-plants.	Garden-produce.	Total.	Khurreef (Acres). Cotton.	Joosr.	Bajra.	Indigo.	Kodo.	Garden-produce.	Other crops.	Total.	Grand Total.
Mar	689	34,785	100	...	79	115	46	35,813	1,665	573	11	35	3	...	...	2,287	38,100
Kabur	998	29,092	1,625	104	275	1	150	32,245	2,401	1,806	173	58	62	11	5	4,516	36,761
Purwa	...	2,832	2,735	89	159	31	157	6,003	1,251	1,331	578	...	31	59	21	3,321	9,524
Rakur	...	840	575	21	...	8	47	1,491	215	109	211	...	10	...	6	551	2,042
Total	1,687	67,549	5,035	214	513	155	400	75,552	5,532	3,869	973	93	106	70	32	10,675	86,227

"With the produce just now quite at the mercy of the seasons, this distribution of crops is perhaps the best that could be devised; but under a system of irrigation some obvious changes suggest themselves. Mar is intrinsically humid for the crop now devoted to it, *viz.*, wheat, mixed commonly with gram. All that is wanted is a fair average rainfall; indeed, it is the one essential condition to a maximum outturn from this soil, and any excess of moisture injures its produce. Under present circumstances, then, no soil can be naturally so independent of irrigation as mar, and what is more, it seems at first sight that irrigation would be positively hurtful to it; but alter the staple from wheat to rice, and the prospect clears. Rice, as a wet crop, would have an affinity for the humidity of mar, and would flourish on all the further irrigation that could be given it. Rice would be a far more valuable crop than wheat, and physically there would appear to be nothing in the soil noxious to its growth. As an instance in proof, I may refer to the examples of returns in rice cultivation cited by Colonel Greenaway, M.S.C., in his book on "Farming in India." At page 38, he alludes to red rice grown under irrigation on the ordinary black earth in the Nellore District, called "black cotton-soil," and states that the yield of this rice, fully irrigated, averaged 1,800lb; and pretty well, but not perfectly irrigated, 1,600lb of paddy per acre. This black cotton-soil, which is known by the

same misnomer throughout Malwa, the Nerbudda Territories, Gwalior, and Bundlekhund generally, is no other than our mar land. Now, against the above outturn, contrast that which has been stated for wheat in para. 54, *viz.*, 528lb per acre, and then judge if it is an overstrained expectation that with irrigation at command the people might be not very tardily brought to see the advantage of making rice the staple of mar, instead of wheat. I have already remarked of kabur that a heavy rainy season benefits it extraordinarily; so, by a parity of reasoning, irrigation would be of immense use to it, probably doubling its present yield of the wheat crop. The culture of sugarcane, evidently once an active industry in the pergunnah, but now wholly extinguished, might be revived. There are no less than 157 solid stone (? hornblende) mills for pressing canes to be counted now in the pergunnah; but, according to tradition, it is more than a century ago when this crop was a good deal cultivated here, and that, too, without irrigation. The inherent moistness of the mar soil was, it is said, eked out by protecting the young plants from the sun's rays with a covering of the broad cool leaves of the *dhak* tree which was plentiful in those days; and I am told that even at the present time this expedient is employed in the Raat pergunnah of Humeerpoor.

"83. I shall briefly trace out my ideas of the facilities Koonch possesses for irrigation; and first, one necessary word on its physical geography. Though divided by a distance of some thirty-five or forty miles, Koonch is a part of the great basin of the Jumna. If to the unaided eye it is a perfectly level tract of country, yet the run of the rain-water proves it to have a sufficiently decided slope from south to north. Its boundaries are all artificial; the lands of different pergunnahs of the district merge into its own all around; but the Pahooj River is about eight miles from its western boundary, while the Betwa, flowing northwards through the Jhansie District, comes to within some three miles of its southernmost point, Mouzah Jugwee, and then abruptly turns off eastwards at right angles to its former course. It is just this bend, or rather a little below it at Mouzah Kureela in Sumpther, which seems the most effective site for a weir, from which an irrigation channel might enter the pergunnah at Jugwee, and, passing on to Jumrohee, Busobe, &c., shape its further course along the higher lands of Koonch, as its general scope in reference to the other pergunnahs might regulate.

"84. The Koonch possesses, to my thinking, another especial facility. It has an annual rain-flood called the *pouh*. My remarks on it will be easily understood by referring to the accompanying Map No. 3,* on which I show the points at which the *pouh* enters the pergunnah, its proper regular waterspread, and the points at which its feeding-channels pass out of Koonch. The *pouh* enters principally from the Sumpther Territory by three channels at Mouzah Kishunpore and Soonao, on the south-west of the pergunnah, and secondarily at Khukul from Dutteea on the west. The eastern of the former three channels causes little or no flooding; its chief office is that of draining off the incoming waters. The middle and the western streams are those which largely inundate, but inundation does not begin until they have traversed half the length of the pergunnah; for all that, these streams are of no serious depth. This inundation is, after the best enquiries, exhibited on the map* by an encircling band of mixed green and blue colours. It spreads, with any permament effects, through thirty villages in all; in eighteen it passes over the whole area, and only partly over the other twelve. The total area it covers approximates 29,400 acres. It occurs twice or three times during the height of the rains, continuing variously from three days to a week each time. It injures the mar soil, often rendering any khurreef in it impossible; and sometimes, if it happen to be brought down by high freshes late in the season, blighting the wheat from excessive dampness imparted to the land. It generally benefits the kabur and purwa lands. Unfortunately, it comes usually at a time when the lands are receiving their own needful share of rain. Supposing, then, irrigation to be in view, the idea which at once strikes one is to intercept all this waste at its sources by constructing large tanks of the concave or horse-shoe form to store up the waters of the *pouh* streams. Three such reservoirs suggest themselves to me, namely, two at the three south-western channels coming from Sumpther, and the third at the brook which enters from Duttea. Of course, the reservoirs must be placed at the highest levels consistent with the requisite of ensuring a full supply of water; but with the scientific details bearing on the execution of the measure I do not pretend to deal. If the suggestion should seem such as to carry any recommendation with it, its further elaboration will properly rest with professional hands.

"85. A third—and if the humblest, also the readiest, available—means for extending irrigation in the pergunnah is to encourage the construction of wells by grants of *tuccavee* under

* Not printed.

simple contracts to repay by fixed instalments, realizable in default by the processes for collecting arrears of land revenue, *without requiring other collateral security*, as is now done in this district. Such a demand generally does that from which it is one of the objects of *tuccavee* to save the landholder, it throws him into the hands of the money-lender; at any rate he has always to pay in some way or other for getting another to stand his surety. In connection with this point, I submit Map No. 4,* which charts out the water-bearing strata, according to actual measurement of the depth of all wells, from village to village.

"The different depths have been classified as below; and in the first two classes at least, which embrace half the pergunnah, the sinking of wells should be a comparatively simple matter. I strongly believe that the experiment would succeed if encouraged on our part with some zeal, and if *tuccavee* were granted free from hampering conditions."

Class.	Depth of water-bearing strata.	Number of Villages.	Colour in Map.
I.	Under 20 feet	11	Red.
II.	From 20 to 35 feet	37	Light blue.
III.	„ 36 to 50 „	37	Orange.
IV.	„ 51 to 60 „	5	Green.
V.	Above 60 feet	1	Dark blue.
VI.	Villages without wells	4	Yellow.
	TOTAL	95	

APPENDIX G.

Opinion of Local Officers in reply to No. 1159I—C, dated 7th September, from Joint Secretary to Government, North-Western Provinces, Irrigation Branch.

From LIEUTENANT-COLONEL B. P. LLOYD, Commissioner of the Jhansie Division, to LIEUTENANT A. H. BAGGE, R.E., Executive Engineer, Bundelkhund Irrigation Works, Jhansie, No. 798, dated Jhansie, 22nd September 1869.

IN REPLY to your docket No. 193, dated 18th instant, forwarding copy of No. 1159I—C, dated 7th idem, from Secretary, Government, North-Western Provinces, Public Works Department, Irrigation Branch, requiring "opinions of Local Officers on the probable return to be derived by the State if the canals are made perennial, or nearly so, by the construction of reservoirs," I beg to state that I am at a loss to see how such an opinion can be given without full information as to course of the proposed canals, and the area it is intended they should be capable of irrigating.

2. It appears to me that you have the means of forming a much truer estimate of probable returns than any Civil Officer can do. You know the amount of water it is proposed to supply, and the rates it is intended to charge. You have also, I believe, full information as to the nature of the soils along the course of the canals. The only doubtful point, then, would seem to be how far the zemindars may be willing to avail themselves of the water. It may, I think, be assumed that for the *khurreef crops*, except in dry seasons, very little canal-water would be used; for the rubbee crops, I have no doubt that, with LOW RATES at first, it will be eagerly sought after for all soils except the mar, and in time, possibly, for this last also.

3. If detailed information on the point is necessary, the best way to obtain it will be for an intelligent officer to march along the course of the canals, and endeavour to ascertain the feeling of the zemindars, after carefully and clearly explaining the proposed system of issuing the water-supply to them. I shall be glad of further information from you if it is wished that this enquiry be made by District Officers.

4. I need not say it is my wish to afford every assistance in obtaining the information required by Government.

From E. B. THORNHILL, Esq., Officiating Collector of Humeerpoor, to LIEUTENANT A. H. BAGGE, R.E., Executive Engineer, Bundelkhund Irrigation Survey, No. 459, dated Humeerpoor, the 19th October 1869.

IN REPLY to your docket 193, dated 18th September 1869, asking for my opinion regarding the probable outturn to be derived by the State if the Dussan Canal were made perennial or nearly so, I have the honour to state that I am of opinion that a canal for irrigation purposes only would not pay expenses, in consequence of the quantity of mar soil through which

* Not printed.

the line of the canal would pass. Water would only be taken in purwa soil, unless the rates were very low indeed. An immense deal of water runs to waste, no doubt, and is emptied into the Jumna, and a great deal sinks into the sandy beds of the rivers. If the Dussan Betwa, and Tank Canals could be formed into a system of navigable canals, however small, if irrigation could be carried on from them as well, I believe it would be a great boon to Bundelkhund, and would open up its resources; but of course I can offer no opinion as to the feasibility of such a scheme. As I have only been a short time in the district, I have not had time to make myself very well acquainted with it. I annex a note by Mr. Adams, the Officiating Deputy Collector, who has been in the district for the last two years and a half. The Raat Pergunnah benefits greatly by irrigation, and so would parts of the Jellalpore Pergunnah.

MEMORANDUM—By Mr. Adams.

I think that the return which will be derived by the State from the proposed Dussan Canal will be very small. If the water-supply be not constant throughout the year, the best-paying crop, sugarcane, will not be grown, while this crop alone would hardly give a fair return for the extra cost required to ensure the supply of water needed. I believe that a large portion of the irrigable area consists of black soil, no kind of which is irrigated save in exceptional seasons. The chief khurreef crops are cotton and joar, and I imagine that it would require a very long time to induce the cultivators here to take water for them. Barley, and to a less degree wheat (less because it is much grown on the unirrigable black soil), would be the only crops of importance irrigated; and these alone would not, I suppose, pay expenses.

I think, however, that the artificial lakes and tanks in the district might, under careful professional supervision, be made profitable at a small cost. Water could be given from them to a large proportion (with reference to the cost) of the irrigable purwa and rakur soils, and nothing should prevent a constant supply throughout the year for the sugarcane.

From R. D. Spedding, Esq., Officiating Collector of Banda, to Lieutenant A. H. Bagge, R.E., Executive Engineer, Bundelkhund Irrigation Works, Jhansie,—No. 1606, dated 22nd September 1869,

In reply to his No. 193, dated the 18th instant, forwards copy of a report No. 310, dated the 22nd February last, from the Collector of Banda, which contains the only opinion which can be given in the absence of any information as to the line of country through which it is proposed to make canals.

From the Officiating Collector of Banda, to the Junior Secretary to Government, North-Western Provinces, Irrigation Branch, P. W. D., Allahabad,—No. 310, dated Banda Collector's Office, the 22nd February 1869.

In reply to your No. 32, without date, I have the honour to state that at present there is no land in this district. Levels have been taken for a canal from the River Kane, and I have no knowledge as to whether the scheme has been found to be practicable or not, and until I am aware of the probable line of the country to be traversed by the canal, I am unable to venture an opinion as to the expediency of constructing khurreef, or enlarging public canals for the purpose of carrying on an enhanced supply.

Rice cultivation on the kabur soil in pergunnahs Budousa, Ongasee and Leonda, would greatly expand on an abundant khurreef supply, and the water would be in great demand in a season like the last for the cotton and joar crops on the above-mentioned soils. But in the land—mar soil—in pergunnahs Banda, Pylanee, and Ongasee, though the embankments or channels might be kept moist by a constant flow, yet if the rains were so scanty as to render it advisable to have recourse to artificial irrigation, the lands adjoining the channels would, I am of opinion, be so full of fissures as to be unfit for irrigation.

From the Superintending Engineer, 2nd Circle, Irrigation Works, N.-W. Provinces, to the Chief Engineer, Irrigation Works, North-Western Provinces,—No. 782, dated Delhi, the 25th March 1870.

I have the honour to forward the under-noted plans and papers relating to the Betwa Project, received under cover of Executive Engineer's No. 289, dated 27th November 1869:—

(1) Executive Engineer's No. 289, dated 27th November.
(2) Report on the Betwa Project.

(3) *Appendix A.*—Fall and lock calculations.
(4) *Appendix B.*—Estimates.
(5) *Appendix C.*—Estimate masonry-works.
(6) *Appendix D.*—Designs masonry-works.
(7) *Appendix E.*—Designs for rajbuha bridges.
(8) *Appendix F.*—Answers from District Officers to certain questions relating to irrigation in Bundelkhund.
(9) *Appendix G.*—Opinions of Local Officers on the subjects noted in No. 1159, dated 7th September, from Joint Secretary, North-Western Provinces.
(10) *Appendix H.*—Longitudinal sections of canals and rajbuhas.

2. As Captain A. H. Bagge, R.E., the Executive Engineer who had prepared the project, was about to leave India on furlough, I proposed that he should meet you at Allahabad, *en route* to Bombay, and discuss his plans with you.

3. The result of this meeting is contained in the following papers, received under cover of your No. 88 I., dated 7th January 1870, which are now returned:—

I.—Appendix No. 1.—Modification and reduction in Captain Bagge's design.

II.—Appendix No. 2.—Estimate of extra cost involved in providing for navigable connection with the Jumna.

4. In returning Captain Bagge's plans and papers, I was called upon to "analyse and consider the project carefully; to report whether in my opinion the scheme is practicable; and whether I am of opinion that advantage will be derived from carrying it out as proposed, or from any modifications of it."

5. Captain Bagge divides his report into ten parts:—

Part I.

6. Captain Bagge describes carefully the nature of the country and soil, and gives some interesting data.

Part II.

7. Captain Bagge shows that the irrigable area on the high land between the three rivers—Betwa, Pahooj, and Jumna—is 1,492 square miles, or 954,880 acres. He also states that in Zillah Jaloun, which contains four-fifths of the entire area, 354 acres in every square mile are cultivated. He considers that one-third of the cultivated area will only be irrigated, that is, one-sixth in each fusl. Hence 354÷6=59 acres per square mile is the area to be provided for.

8. For the khurreef he allows 0·84 cubic feet per second per square mile, and for the rubbee 0·295 cubic feet.

9. With this data the supply needed will be for an area of 1,492 square miles—

Khurreef	1,492 × 0·84	= 1,253 cubic feet per second.
Rubbee	1,492 × 0·295	= 440 „ „

10. For navigation purposes a supply of 150 cubic feet per second is allowed.

11. The monsoon-supply is distributed proportionally throughout all the canals.

Part III.

12. Captain Bagge gives six different methods by which he calculates the flood-discharges.

13. The results of these calculations are:—

	Cubic feet.
(1) Mean of four discharges calculated from four sections taken below Burwa Sagur Ghât	1,013·375
(2) Discharge calculated from the mean of the areas, &c., &c., of the four sections of No. 1	1,008·600
(3) Discharge calculated from three sections of No. 1, Burwa Sagur Section being thrown out (co-efficient 90)	293·034
(4) Same as No. 3, co-efficient being 92·5	301·200
(5) Discharge calculated from a measured discharge taken on the 10th September	388·290
(6) Discharge calculated by applying the results of the measured discharge of 10th September, to the means of area, &c., of the four sections of No. 1	421·400

14. Discarding the results of Nos. 1, 2, 3, and 4, and working with the result of No. 5, which he takes in round numbers as 500·000, and to which he adds 50,000 cubic feet as the amount that may drain into the Betwa between Pareecha and Ghusgowan, he prepares his designs and calculations for a flood-discharge at 550·000 cubic feet.

15. Lieutenant Home's calculations gave 715·000 as the flood-discharge.

Part IV.

16. Captain Bagge's table of discharge of the Betwa shows the perennial supply that may be expected.

17. On the 21st December, 1869, Lieutenant Home found by measurements that the Betwa was discharging 1,028 cubic feet. On the 4th December, 1859, Captain Bagge's observations give the discharge as 816 cubic feet.

Part V.

18. Captain Bagge, discarding Lieutenant Home's site of the weir, chooses Ghusgowan, as thus the storage capacity of the reservoirs is greatly increased.

Part VI.

19. Captain Bagge, calculating with a flood-discharge of 550·000 cubic feet, fixes the level of crest of weir at Ghusgowan at 600·00, and finds the afflux to be 14·0 feet. Tne reduced level of the flood of June, 1866, was 605.00. The highest flood-level due to the weir would, therefore, be 619·00—about the level of country.

20. The canal-head is fixed at reduced level 591·0, and the depth of water in canal at 9 feet.

21. In his calculation for afflux, Captain Bagge omits the quantity V. a. (velocity of approach). He considers it dangerous to arrange for keeping up the supply by temporary means, such as boards or shutters.

Parts VII and VIII.

22. Captain Bagge states that, owing to the peculiar shape of the rocky barriers on which the work will be built, the weir must be designed with the smallest possible base.

23. Working with a flood-discharge of 550·000 cubic feet, present reduced level of floods 605·00, reduced level of crest 600·00, afflux 14 feet, reduced level of river-bed 550·0, Captain Bagge designs his weir with the following dimensions:—

Width of crest	20′
„ base	70′
Height, maximum	50′
Up stream face	vertical.
Length of weir	2,289′

In these calculations the weight of masonry has been taken at twice the weight of water.

24. The probability of the bed of the Betwa being raised in front of the weir is noticed by Captain Bagge, who, however, considers this would not interfere with the working of the canal, as high floods would remove any deposits left by small freshes. To allow of the removal of any silt deposits in the canal, he states that an escape in the Seipoora Aqueduct may be provided.

Part IX.

25. To supplement the supply of the Betwa, Captain Bagge proposes two reservoirs, both formed in the bed of the Betwa. One reservoir extends from the Lower Khoord Section to Burwa Sagur Ghât, a length of twelve miles. The second reservoir he proposes somewhere above Oorcha, which town is six miles above Burwa Sagur Ghât.

26. The first reservoir has only been worked out by Captain Bagge. It is formed by a dam 5,500′ in length and 50′ in height, built at the Lower Khoord Section.

27. The section of the dam is similar to that of the Ghusgowan weir. The dimensions are—

Width of crest	12·5
Height	50
Base	62·5

28. Calculating with a flood-discharge of 550·000 cubic feet, reduced level of crest 635·00, present reduced level of highest flood above site 641·00 and below site 636·00, Captain Bagge gives the afflux at 6·00, or 2 feet above level of country. Small embankments will, therefore, be needed.

29. The capacity of the Khoord Reservoir is 4,013,930,900 cubic feet. The amount allowed for evaporation between October and February is 307,792,400 cubic feet; or, as the surface exposed is 101, 247,500 square feet, $\frac{307,792,400}{101,247,500}$ = 3·03 feet vertical measure.

30. The amount available for irrigation during the months from October to February is—

$$\frac{4,013,930,000-307,792,400}{152\times60\times60\times24} = 282{\cdot}2 \text{ cubic feet per second.}$$

Part X.

31. Captain Bagge carries the water in one channel to a point near the town of Koonch. He then divides the supply into three streams, one called the Khokund Branch, taken along the high bank of the Pahooj; the second, the Calpee Branch, which is navigable, taken along the high bank of the Betwa; and the third, the Jaloun Branch, taken in the middle of the Delta.

32. In the first portion of the Calpee Branch considerable drainage is crossed. Captain Bagge explains that this alignment was chosen in preference to another in which little or no drainage was met, but which ran through a country with a considerable slope, because he considered the cost of the drainage works in one line would be less than that of the necessary falls and locks on the other.

33. In the letter accompanying the report, Captain Bagge (*vide* para. 3), estimates the return at 5·86 per cent., thus:—

(1) Capital, 90 lakhs.
(2) Cultivated area, 528,000 acres.
(3) Yearly irrigated area, one-third of cultivated, or $\frac{528,000}{3}$=176,000.
(4) Rate per acre, Rs. 3.
(5) Gross income, Rs. 528,000.
(6) Return $\frac{528,000\times100}{9,000,000}$=5·86 per cent,

34. Captain Bagge states, also, that if certain khurreef canals were taken out from the Oorcha Dam, the return would be greatly increased.

35. Having summarized Captain Bagge's report, it will be as well, before giving an opinion, to state briefly the nature of the work.

36. The works consist of—

	R
(*a*) A masonry-weir at the village of Ghusgowan (with crest, 50 feet above lowest point of river-bed), 2,680 feet in length, with subsidiary works: estimated cost	9,96,287
(*b*) A reservoir-dam across the Betwa near the village of Khoord (with crest 50 feet above lowest point of river-bed), and subsidiary works; length of dam, 5,500 feet: estimated cost	24,47,904
(*c*) A reservoir-dam at Oorcha, details not worked out: estimated roughly to cost	19,37,404
(*d*) Irrigation channels:—	
(1) Main canal, length 36¾ miles, cost	11,24,405
(2) Calpee Branch „ 61 „ „	6,04,000
(3) Kolund „ „ 39 „ „	95,100
(4) Jaloun „ „ 31 „ „	56,000
Total, 167¾ miles, cost	18,79,505
(5) Main distribution channels, length 287 miles, cost	3,16,834
(6) Minor distributive channels, length 196 miles, cost	2,42,279
(7) Canal escapes, length 13½ miles, cost	35,133
(8) Chowkees	41,500
(9) Land	1,33,704
Total cost of irrigation channels and subsidiary works	26,48,955

37. I will divide my review of Captain Bagge's project into seven sub-heads:—

(1) Discharge of Betwa.
(2) Site of weir.
(3) Section and cost of weir.
(4) Site and number of reservoirs.
(5) Section and cost of reservoir-dams.
(6) Alignment of the canals, their cost, and provision for navigation.
(7) Estimated income.

38. *Betwa Discharge.*—Captain Bagge's calculations of 550,000 cubic feet as the maximum flood-discharge are, I am of opinion, erroneous. His calculations are based on fall in bed, while fall in surface is entirely lost sight of. Now, no doubt in a river like the Jumna at Delhi, or Ganges at Ghurmooktesur, the fall in bed might be taken as a quantity in the equation for determining the flood-discharge. In a river like the Betwa, where the bed consists of rapids or falls, with deep pools between, the surface-fall should be the quantity adopted and not the fall in bed. In Appendix Z, I have given the calculations of flood-discharge as deduced from Captain Bagge's data. The result is 741,000 cubic feet, agreeing fairly with Lieutenant Home's discharge.

39. In Appendix Y are given :—

(*a*) The monthly discharge of the Betwa from January 1868 to February 1870.

(*b*) The quantity, drawn monthly from the Khoord Reservoir.

40. *Weir Site.*—I consider that the site selected by Captain Bagge for his weir is the best that could be chosen. A site higher up the river would make the construction of reservoirs next to impossible, while no site lower down would afford rock for foundation, nor would the canals taken therefrom get command of the country rapidly.

41. *Weir Section.*—I am of opinion that the section adopted by Captain Bagge for his weir is far stronger than is needed. In Appendix X, I have given the section of a weir 50 feet in height, calculated to bear a pressure of 70 feet, prepared from the profile of a masonry-dam 165 feet high, built in 1866, at Furens in France. Two papers on large masonry-dams—one by M. Graeff, and the other by M. Delocre—were published in the *Engineer* of 1869. M. Graeff enters into the method of constructing the dam at Furens, while M. Delocre writes on the economical form of profile, under circumstances similar to that which we have to deal with on the Betwa, excepting that floods will pass over the Betwa works, while the work at Furens was purely a dam.

42. I consider that the crest, and rear-face to a depth of 20 feet below crest, should only be faced with ashlar, and that this facing should be two feet thick.

43. I am of opinion that the crest of the weir might be 2·00 lower than that fixed by Captain Bagge, and that this 2·00 could be maintained by planks. I do not anticipate any danger in this plan, and consider Captain Bagge's fears groundless.

44. The cost of my weir is 5½ lakhs less than Captain Bagge's. The reason that a pressure of 70 feet is calculated for, is that in heavy floods the surface of water will stand 20 feet above crest of weir, which is 50 feet high.

45. *Dam Site.*—I consider that the site of the Khoord dam is well chosen, as far as relates to the storage capacity of the reservoirs, but would have preferred a site which would have given a less length of dam than 5,500 feet, which is nearly double the length of the Ghusgowan weir.

46. *Dam Section.*—In Appendix W, I have given a section of the Khoord dam, modified according to the profile of M. Delocre, and calculated to bear a pressure of 70 feet. In my estimate for this work I have given the same width of ashlar facing as for the Ghusgowan weir.

47. The cost of this dam is less than Captain Bagge's by 11⅛ lakhs.

48. *Oorcha Reservoir.*—I consider that it would not be advisable to construct a reservoir between Burwa Sagur Ghât and Jirror Ghât, the former being the upper limit of the Khoord Reservoir, and the latter the point at which the Betwa enters British territories.

49. From the surveys made by Mr. Richardson, it appears that the most favourable site of the reservoir near Oorcha is nine miles above it.

The capacity of this reservoir is—

$5{,}280' \times 7{\cdot}5'' \times 1{,}000' \times 25' = 990{,}000{,}000$ cubic feet;

equal to $\frac{990{,}000{,}000}{365 \times 60 \times 60 \times 24} = 31{\cdot}4$ cubic feet per second perennial supply,

or for five months, October to February, $\frac{31{\cdot}4 \times 365}{151} = 75{\cdot}9$ cubic feet.

50. The cost of the reservoir-dam would be—with a length of 1,000 feet, and a mean section of 412—3 lakhs, thus :—

$1{,}000 \times 412 = 412{,}000$ cubic feet

	₹
Say ¼ ashlar, thus 103,000 at Rs. 2	2,06,000
¾ rubble 309,000 at Rs. 15	46,350
Sluices	47,650
TOTAL	3,00,000

51. At Eastern Jumna Canal rates the gross value of 31·4 cubic feet of perennial supply would be $31{\cdot}4 \times 500 = ₹15{,}700$.

Allowing 10 per cent. for working expenses, the net returns would be—

$$15{,}700 - \tfrac{15{,}700}{10} = ₹14{,}130.$$

and the percentage on the capital of ₹3,00,000 $= \frac{14{,}130 \times 100}{300{,}000} = 4{\cdot}71$.

52. In these calculations no allowance has been made for absorption or evaporation. The returns must, therefore, be accepted as the maximum theoretical amount.

53. *Navigation.*—Considering the small extent of country commanded by the Betwa Canals and the uncertainty of a perennial supply, I would not advise any provision being made for navigation.

54. Captain Bagge's estimate for navigation works amounts to ₹4,61,454, as will be seen from Appendix V. At 7·5 per cent. the net returns from navigation must be ₹34,609; and, allowing 15 per cent. for establishment charges, the gross return must be ₹39,800, or ₹5,000 more than the navigation returns of the Ganges Canal for 1867-68.

55. *Alignment of Canal.*—I do not approve of Captain Bagge's alignment of the Calpee Branch. I would carry the water in one channel to about the 17th mile of the canal, at which point I would fix the heads of the Calpee, Jaloun, and Kootound Branches.

56. By this arrangement, not only would the heavy drainage crossed in the first few miles of Captain Bagge's Calpee Branch be uninterruped, but, as will be seen by reference to Appendix T, there would be a saving of 5¼ lakhs nearly, supposing navigation was provided for.

57. *Distribution of Supply.*—Captain Bagge distributes his rubbee supply proportionally to all rajbuhas and branches. I would recommend two distinct kinds of works; one to carry water during the khurreef, with few, if any, masonry-works, and the other to carry a perennial supply, constructed in a manner similar to the existing canals in Upper India.

58. From Appendix S, it appears that by separate works for monsoon and perennial supplies, there will be a saving of over ₹42,000 on Captain Bagge's estimate.

59. Summarizing the modifications, I propose—

(1) Abandonment of the Oorcha Reservoir.

(2) Reduction in section of Ghusgowan weir and Khoord dam, and reduction in thickness and width of ashlar facing.

(3) Lowering the Ghusgowan weir two feet, and maintaining this supply by boards.

(4) Abandonment of provision for navigation.

(5) Carrying the supply in one channel for 17 miles, from which point would be led three branches; two of which—the Calpee and Jaloun—would carry a perennial supply, and the third—the Kootound—a monsoon supply only.

Appendix R. gives the cost of the works as modified by me. The modifications show a saving of ₹53 lakhs over Captain Bagge's estimate.

60. I have not taken up each and every design of Captain Bagge's, considering that such could be better done by a special officer. The general opinion I have formed from the works that I have examined is, that Captain Bagge's designs are far more costly than necessary, and that even greater reduction than I have made could safely be carried out. For instance, the general rate for earthwork is Rs. 3, though some of the channels are less than four feet in width.

61. In my estimates I have adopted Captain Bagge's rates, as in most cases, no doubt, his local knowledge would allow of his opinions being more trustworthy than mine.

62. From Appendix P, it will be seen that, with a capital of ₹36,88,412, a perennial supply of 440 cubic feet (valued at Rs. 500 per foot), a monsoon supply of 946 cubic feet (valued at ₹150 per cubic foot), and a charge of 40 per cent. for maintenance and repairs, the returns are 6·2 per cent. on capital.

63. Captain Bagge, in paragraph 4 of his letter No. 289, dated 27th November, gives the returns on 90 lakhs of capital at 5·86 per cent. This figure is obtained by a charge of ₹3 per acre on the total irrigable area, and with an allowance of 70 acres per cubic foot for the

khureef, and 200 acres for the rubbee. No allowance is made for maintenance and repairs. I need scarcely remark on the probability of returns estimated in such a manner being ever obtained.

64. In paragraph 4, Captain Bagge notes the possibility of making monsoon canals from the Oorcha dam. My opinion, from actual inspection of the country, is, that above Pareecha it would be impossible to lead canals from the Betwa from which the returns would pay one per cent. on their cost. Mr. Richardson, in his No. 347, dated 8th January, written after completing the survey of the Betwa to Jirror Ghât, says:—"To take out khurreef canals is impossible, because, from observations, I note that the jungle-trees do not grow larger than three inches in diameter, after which they die off, thereby showing that the soil is very shallow—I should think two feet at most. All the cultivation that exists in the few wretched villages are jheel beds The other portion of the country is a wilderness of jungle, with primary rocks close to the surface."

65. In conclusion, I beg to remark that, although differing in many points from Captain Bagge, and criticising unfavourably the manner in which certain calculations have been made, I consider that he and his assistants are deserving of commendation. The labour bestowed in the preparation of the designs and estimates, in the collection of data for calculating the discharge of the Betwa, in the surveys necessary to elucidate the subject, can only be ascertained after careful examination of all the papers submitted by Captain Bagge.

66. Whatever may be the result of this report, I would recommend strongly that no work be taken in hand for at least a twelve-month. In that time the Betwa discharge data will be more perfect, and more satisfactory estimates than those we have already will have been prepared. I would also propose that on completion of the surveys ordered in Chief Engineer's No. 2915I., dated 13th December 1869, Mr. Richardson be ordered up to Nynee Tal or Delhi, and in conjunction with Chief or Superintending Engineer, further investigate the subject.

APPENDIX P.

Statement of Capital, Income, &c., &c.

	R
Capital	36,88,412
Perennial supply, 440 cubic feet @ R500	2,20,000
Monsoon supply, 968 " " 150	1,45,200
Miscellaneous Revenue	14,800
Gross Revenue	3,80,000
Net Revenue, 60 per cent. of Gross	2,28,000

Then percentage on Capital is $\frac{2,28,000 \times 100}{36,88,412} = 6{\cdot}2$ nearly.

APPENDIX R.

Mr. Anderson's Project, Betwa Canal, prepared from Captain Bagge's data.

	R	R
I.—Ghusgowan Weir, Captain Bagge's Estimate	9,96,287	
Saving, *vide* Appendix X.	5,54,080	
		4,42,207
II.—Khoord Reservoir Dam, Captain Bagge's Estimate	24,47,904	
Saving, *vide* Appendix W.	11,11,184	
		13,36,720
III.—Perennial canals not available.		

	Rubble.	Brick Masonry.	Arch Masonry.	Concrete.	Excavation.	Ashlar.	Stone Pitching.	Timber.	Gates.
Main Canal, 17 miles:—									
Excavation	...	...	...	...	97,288,000	...	...	...	...
6 Bridges, Design No. 1	85,284	...	16,830	...	720,000	...	153,600	...	...
Calpee and Kootound Heads	...	55,893	3,575	...	52,000	...	51,600	442	...
	85,284	55,893	20,405	...	98,060,000	...	205,200	442	...
Calpee Branch—Perennial—Captain Bagge's line of Kukhul Rajbuha, 19 miles:—									
Excavation	...	...	...	...	26,835,600	...	...	...	...
6 Bridges, Design No. 3	...	78,210	13,284	...	600,000	...	110,000	...	...
3 Falls 8 ft. " " 3	...	51,912	...	...	10,400	...	123,000	...	...
	...	130,122	13,284	...	27,446,000	...	233,000	...	...
Calpee Branch—From Mile 11 to Tail:—									
Earthwork	...	...	...	...	36,006,000	...	...	...	...
3 Bridges, Design No. 3	...	39,111	6,642	...	300,000	...	55,000	...	...
11 " " " 4	...	106,491	14,653	...	1,100,000	...	159,000	...	...
11 " " " 5	...	118,074	9,702	...	1,100,000	...	66,000	...	...
1 Fall " "	...	17,304	...	...	3,500	...	41,000	...	...
Kadowree Head	...	18,890	1,740	...	1,100,500	...	...	12	...
14 Tail Falls	...	28,000	...	...	...	...	...	...	...
	...	327,870	32,736	...	39,612,000	...	321,000	12	...
Jaloun Branch—Perennial—Captain Bagge's line of Banoda Rajbuha, 15 miles:—									
Excavation	...	...	...	...	3,601,600	...	...	...	...
5 Bridges, Design C	...	15,155	2,380	...	110,400	...	...	...	...
3 Falls, 4 ft. " C	...	5,616	...	...	...	...	...	...	...
	...	20,771	2,380	...	3,912,000	...	...	...	...
Kootound Branch—Monsoon—Captain Bagge's line of Main Canal, 19½ miles:—									
Excavation	...	...	...	...	3,893,000	...	...	...	...
5 Falls	12,346	78,018	...	...	85,000	169,000	...	...	...
	12,346	78,018	...	...	3,978,000	169,000	...	...	...

	Rate.	Main Canal.		Calpee Branch.		Calpee Branch.		Jaloun Branch.		Khotund Branch.	
Excavation	3 0 0	98,060,000	294,180	27,446,000	82,338	39,612,000	118,836	3,912,000	11,736	3,978,000	11,934
Brick Masonry	20 0 0	55,893	11,179	130,122	26,024	327,879	65,576	20,771	4,154	78,018	15,602
Arch Masonry	25 0 0	20,405	5,101	13,284	3,321	32,736	8,184	2,380	595	...	...
Rubble	15 0 0	85,284	12,793	...	...	...	...	...	...	12,346	1,852
Stone Pitching	2 0 0	205,200	4,104	233,000	4,660	321,000	6,420	...	...	16,900	3,380
Timber	8 0 0	442	1,326	...	...	12	36	...	...	...	...
	...	...	328,683	...	116,343	...	199,052	...	16,485	...	32,768

	R	R	R
Then: 1. Ghusgowan weir	...	4,42,207	
2. Khoord dam	...	13,36,720	
3. Main Canal	...	3,28,683	
4. Calpee Branch	1,16,343		
Ditto	1,99,052		
		3,15,395	
5. Jaloun Branch	16,485		
Captain Bagge's Estimate	56,000		
		72,485	
6. Kootound Branch	32,768		
Ditto Appendix S.	73,551		
		1,06,319	
7. Monsoon Rajbuhas	...	...	
Appendix S.	...	74,595	
8. Perennial Rajbuhas	...	...	
Captain Bagge's Estimate	...	1,86,936	
9. Escapes	...	...	
Captain Bagge's Estimate	...	35,133	
10. Canal Land	...	1,33,704	
11. Chowkies	...	41,500	
			30,73,677
Add for Establishment and Contingencies @ 20 per cent.		...	6,14,735
TOTAL			R36,88,412

APPENDIX S.

Comparative cost of Canals carrying proportionally Perennial and Monsoon Supply, and of separate Canals for each Supply.

CAPTAIN BAGGE'S ESTIMATE.

Perennial and Monsoon supply, proportionally distributed :—		₹	₹
Kootound Branch, Appendix B.		95,100	
Bara Khera, Rajbuha		10,200	
Sumpther	„	4,600	
Beora	„	5,830	
Seekree	„	14,457	
Hudruck	„	17,567	
Madhogurh	„	15,348	
Jursoli	„	27,193	
			1,90,395
Monsoon Canals.			
Kootound Branch :—			
23,278,000 cubic feet Excavation, at ₹ 3		69,834	
17,759 „ „ Brick masonry „ 20		3,552	
660 „ „ Arch „ „ 25		165	
			73,551
Bara Khera Rajbuha :—			
2,742,000 cubic feet Excavation, at ₹ 3		8,226	
4,899 „ „ Brick masonry „ 20		980	
182 „ „ Arch „ „ 25		45	
			9,251
Sumpther Rajbuha :—			
983,000 cubic feet Excavation, at ₹ 3		2,949	
4,540 „ „ Brick masonry „ 20		908	
182 „ „ Arch „ „ 25		45	
			3,902
Beora Rajbuha :—			
1,543,000 cubic feet Excavation, at ₹ 3		4,629	
2,733 „ „ Brick masonry „ 20		547	
182 „ „ Arch „ „ 25		45	
			5,221
Seekree Rajbuha :—			
3,478,000 cubic feet Excavation, at ₹ 3		10,434	
4,315 „ „ Brick masonry „ 20		863	
49 „ „ Arch „ „ 25		12	
			11,309
Hudruck Rajbuha :—			
4,491,000 cubic feet Excavation, at ₹ 3		13,473	
3,278 „ „ Brick masonry „ 20		655	
			14,128
Madhogurh Rajbuha :—			
3,951,000 cubic feet Excavation, at ₹ 3		11,853	
			11,853
Jursoli Rajbuha :—			
6,571,000 cubic feet Excavation, at ₹ 3		19,713	
977 „ „ Brick masonry „ 20		195	
91 „ „ Arch „ „ 25		23	
			19,931
TOTAL			1,48,146
Or a saving of ₹			42,149

CAPTAIN BAGGE'S PROJECT.

	Rubble.	Brick Masonry.	Arch Masonry.	Concrete.	Ashlar.	Earthwork.	Stone Pitching.	Timber.	Gates.
Main Canal, miles 36¾ :—									
Masonry Works	681,677	609,059	77,294	369,215	8,000		6,12,60	...	10
Earthwork	...	...	...	...	...	10,801,000			
						170,047,000			
					Total	180,848,000			
Calpee Branch from Head to Miles 13·4 :—									
Masonry Works	...	594,678	14,541	6,572	130	16,980,000	...	281	2
Excavation	...	...	...	...	...	3,950,000			
						20,940,000			

MAIN CANAL.			CALPEE BRANCH.		TOTAL.	
Contents.	Cost.		Contents.	Cost.	Cost.	
	₹	₹		₹	₹	
681,677	1,02,252	15	...	...		
609,059	1,21,812	20	594,678	1,18,936		
77,294	19,323	25	14,541	3,635		
369,215	29,537	8	5,672	454		
80,000	16,000	2	130	260		
180,848,000	5,42,544	3	20,940,000	62,790		
612,600	12,252	2	...	843		
... ... 10	...	3	281	4,000		
	20,000	2,000	2			
	8,62,720			1,90,918	10,54,638	
					Captain Bagge's Project . . ₹	10,54,638
					Mr. Anderson . . . „	5,34,770
					Saving . ₹	5,19,868

APPENDIX T.

Comparative Cost of Captain Bagge's Project of Main Canal and Calpee Branch to Mile 13-4, and Mr. Anderson's Line of Main Canal to Mile 17; and thence three Branches—Calpee, Jalaun, and Kootound—Main Canal, and Calpee Branch Navigable; Rubbee Supply distributed proportionally throughout all Channels.

	Rubble.	Brick Masonry.	Arch Masonry.	Concrete.	Ashlar.	Earthwork.	Stone Pitching.	Timber.	Gates.
Main Canal, 17 Miles :— MR. ANDERSON'S PROJECT.									
Excavation	...	...	...	...	...	97,288,000	...	...	...
6 Bridges, Design No. 1	...	21,036	...	...	...	1,020,000	153,600	...	...
Calpee and Kootound Heads	166,002	4,567	...	...	...	52,000	...	442	...
Total	1,66,002	25,603	...	...	...	98,360,000	153,600	442	...
Calpee Branch—Along Captain Bagge's Line of Kukkul Rajbaha, 19 Miles :									
Earthwork	...	...	...	...	...	26,835,600	...	...	...
3 Falls	...	...	...	...	10,200	...	123,000	...	...
3 Locks	51,912	5,954	...	147,696	3,200	3,187,000	...	...	6
6 Bridges, Design No. 3	114,306	17,284	...	...	...	1,583,000	...	...	...
Total	166,218	23,238	...	147,696	13,400	31,605,600	123,000	...	6
Jalaun Branch—Captain Bagge's Line of Banda Rajbaha 15 miles :—									
Earthwork	...	...	...	...	...	3,801,600	...	...	...
5 Bridges, Design E.	15,155	2,380	...	...	...	110,400	...	...	...
3 Falls, 4 feet, Design E.	5,616	...	...	...	...	...	...	...	...
Total	20,771	2,380	...	...	...	3,512,000	...	...	...
Kootound Branch— Captain Bagge's Line of Main Canal :—									
19½ Miles Earthwork	...	...	...	...	...	3,898,000	...	...	...
5 Falls, Designs Nos. 1, 2, 3,	78,018	...	...	...	...	85,000	169,000	...	...
7 Bridges, Design A.	33,951	7,560	...	...	...	204,000	...	...	...
Total, Kootound Branch,	1,17,969	7,560	...	...	...	4,182,000	169,000	...	...
Total, Jalaun Branch.	20,771	2,380	...	...	...	3,512,000	...	...	...
Total, Calpee Branch.	166,218	23,238	...	147,696	13,400	31,605,600	123,000	...	6
Total, Main Canal.	1,66,002	25,603	...	...	...	98,360,000	153,600	442	...
Total	3,40,207	...	...	2,34,336	...	16,485	...	43,242	5,34,770

	Main Canal.		Calpee Branch.		Jalaun Branch.		Kootound Branch.		Total Cost.
	Contents.	Cost.	Contents.	Cost.	Contents.	Cost.	Contents.	Cost.	
		R		R		R		R	R
Then : Rubble	166,000	24,900	3,19,264	47,890	...	...	12,346	1,852	...
Brick Masonry	67,145	13,429	1,66,218	33,244	20,771	4,154	1,17,869	23,574	...
Arch ditto	25,603	6,400	23,238	5,809	2,380	595	7,560	1,890	...
Concrete ditto	...	...	147,686	11,815	...	595	...	...	...
Ashlar	...	...	13,400	26,800	...	...	...	...	...
Earthwork	98,360,000	2,95,080	31,605,600	94,818	391,200	11,736	4,182,000	12,546	...
Stone Pitching	153,600	3,072	123,000	2,460	...	...	169,000	3,380	...
Timber	442	1,326	...	...	...	...	...	...	...
Gates	...	...	6	12,000	...	...	...	...	...
	Contents.	Cost.							
		R							
R	166,000	15							
15	67,145	20							
20	25,603	25							
25	...	8							
8	98,360,000	2							
2	153,600	3							
3	442	2							
2	...	3							
3		2,000							
2,000									

APPENDIX V.

Cost of Navigation,—Captain Bagge's Project.

	Rubble.	Brick Masonry.	Arch Masonry.	Concrete.	Paving.	Gates.	Earthwork.	Stone Pitching.	Timbers.
Main Canal :—Locks, . . .	3,19,264	4,63,896	14,885	3,69,215	8,000	10	79,67,000	33,000	...
6 Bridges, Design No. 1; Towpaths, &c., &c.	50,718	...	4,206	...	...	...	5,00,000	...	...
7 Bridges, Design No. 2; Towpaths, &c., &c.	48,125	...	5,166	...	...	...	5,50,000	...	...
Total .	4,18,107	4,63,896	24,257	3,69,215	8,000	10	86,17,000	33,000	...
Calpee Branch.—Tail, Falls, and Locks	...	4,41,574	3,444	70,840	1,820	28	14,51,000	92,400	140
7 Bridges, Design No. 3; Towpaths, &c.	...	42,112	15,498	...	...	...	3,50,000	...	...
11 Bridges, Design No. 4; Towpaths, &c.	...	95,898	7,920	...	...	...	11,00,000	...	...
11 Bridges, Design No. 5; Towpaths, &c.	...	48,995	4,752	...	...	...	11,00,000	...	...
	...	6,28,579	31,614	70,840	1,820	28	40,01,000	92,400	140
Deduct.—Tail Falls	...	28,000	...	...	...	...	...	...	...
	...	6,00,579	31,614	70,840	1,820	28	40,01,000	92,400	140

Thus—

Main Canal :—

				R	R
418,107	cubic feet	Rubble	@ . . .	15 =	62,715
463,896	„	Brick	„ . . .	20 =	92,779
24,257	„	Arch	„ . . .	25 =	6,064
369,215	„	Concrete	„ . . .	8 =	29,537
8,000	„	Ashlar	„ . . .	2 =	16,000
10	Gates		„ . . .	2,000 =	20,000
8,667,000	Cubic feet	Earthwork	„ . . .	3 =	26,001
38,000	„	Stone-pitching	„ . . .	2 =	760
					2,53,856

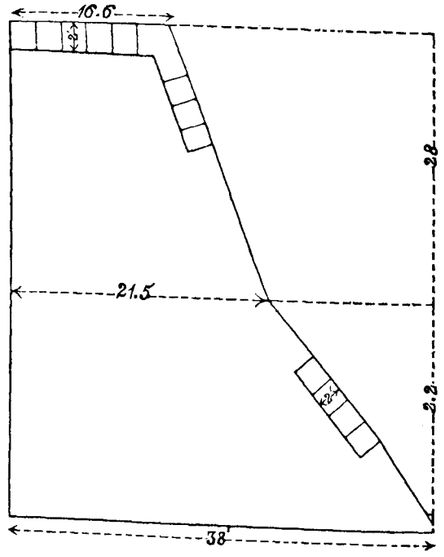
Calpee Branch :—

				R	R
600,579	cubic feet	Brick masonry	@ . . .	20 =	1,20,116
31,614	„	Arch masonry	„ . . .	25 =	7,904
70,840	„	Concrete	„ . . .	8 =	5,667
1,820	„	Ashlar	„ . . .	2 =	3,640
28	Gates		„ . . .	2,000 =	56,000
4,001,000	cubic feet	Earthwork	„ . . .	3 =	12,003
92,400	„	Stone-pitching	„ . . .	2 =	1,848
140	Sleepers		„ . . .	3 =	420
					207,598
			Total cost of Navigation . .		461,454

APPENDIX W.

Khoord Dam—M. Delocre's Profile.

Dam or Weir, 50 feet high, but calculated to bear a pressure of 62·0 feet.



Quantity Calculations.

Height.	Area of Section.	Length.	Contents.	Height.	Area of Section.	Length.	Contents.
					Brought forward .		947,040
15	262	270	70,740	13	226	150	33,900
20	357	30	10,710	20	357	150	53,550
14	244	130	31,720	12	208	50	10,400
30	560	70	39,200	24	436	50	21,800
20	357	160	57,120	37	710	150	106,500
44	915	180	164,700	46	998	50	49,900
42	856	270	231,120	39	772	50	38,600
9	154	970	149,380	50	1,111	30	33,330
5	84	100	8,400	33	625	210	131,250
5	84	100	8,400	30	560	120	67,200
4	67	50	3,350	25	456	100	45,600
8	136	100	13,600	27	497	50	24,850
14	244	650	158,600	18	319	1,260	491,940
	Carried over .		947,040		Total .		2,055,860

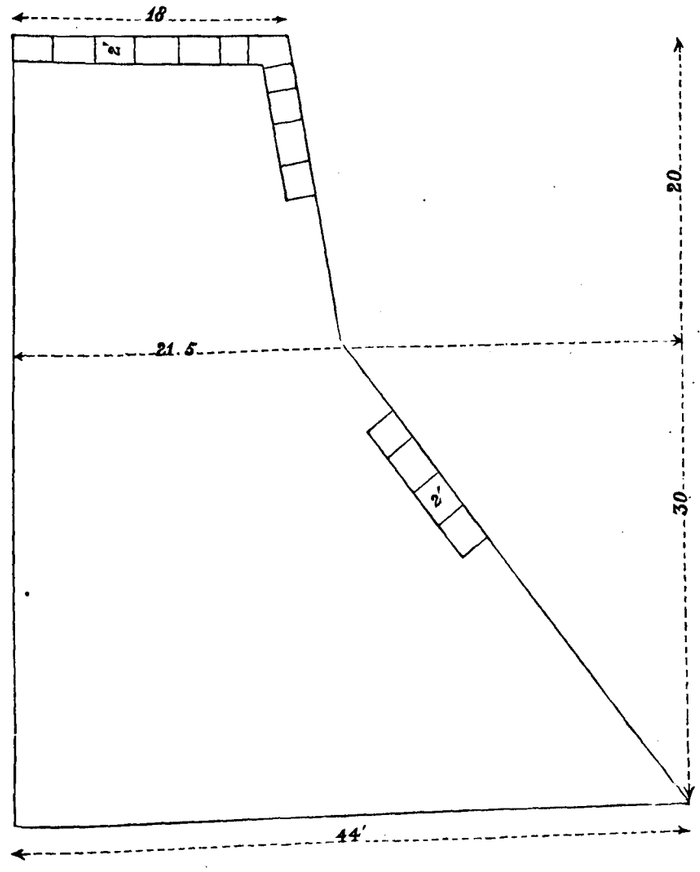
Thus—

Ashlar . .	(16·6+18) 1,670×2=1,16,232 45,568×2= 91,136	
		2,07,368
Rubble		18,48,492
	Total .	20,55,860
Captain Bagge's Estimate of Ashlar	7,59,000	
Mr. Anderson's ,, ,,	2,07,368	
Difference . . .	5,51,632 @ R2=11,03,264	
Captain Bagge's Estimate of Rubble	19,01,290	
Mr. Anderson's ,, ,,	18,48,492	
Difference	52,798 @ R15=7,920	
Total Saving		R11,11,184

APPENDIX X.

Ghusgowan Weir—M. Delocre's Profile.

Weir 50 feet high, but calculated to bear a pressure of 70 feet.



Quantity Calculations.

Height.	Area of Section.	Length.	Contents.	Height.	Area of Section.	Length.	Contents.
					Brought forward .		586,592
28	591	73	43,143	15	290	60	17,400
34	790	20	15,800	25	512	70	35,840
42	1,049	20	20,980	17	331	30	9,930
43	1,088	30	32,640	16	310	120	37,200
40	975	60	58,500	10	189	20	3,780
28	591	20	11,820	13	249	30	7,470
29	619	50	30,950	7	130	44	5,720
34	790	20	15,800	27	564	100	56,400
36	835	30	25,050	6	111	120	13,320
38	903	30	27,090	16	310	80	24,800
34	790	40	31,600	25	512	30	15,360
44	1,049	20	20,980	24	487	37	18,019
31	677	40	27,080	12	229	33	7,557
35	802	30	24,060	16	310	20	6,200
48	1,291	10	12,910	6	111	17	1,887
27	564	60	33,840	3	55	23	1,265
14	269	30	8,070	22	440	39	17,160
16	310	30	9,300	16	310	146	45,260
2	36	130	4,680	30	648	20	12,960
18	352	210	73,920	22	440	90	39,600
21	417	140	58,380	27	564	50	28,200
	Carried over .		586,592		Total .		991,921

Thus—

Ashlar .	(18+18) 1,157 × 2 = 83,304		
	32,699 × 2 = 65,398		
			1,48,702
Rubble			8,43,219
			9,91,921
Captain Bagge's Ashlar estimate		3,91,590	
Mr. Anderson's " "		1,48,702	
Difference		2,42,888 @ R2	= 4,85,776
Captain Bagge's Rubble estimate		14,20,715	
Mr. Anderson's " "		8,43,219	
Difference		5,77,496 @ R15	= 86,624
TOTAL .			5,72,400
Deduct cost of planking for upper two feet,			
2,290 × 2 × ½ = 2,290 cubic feet, @ R3			= 6,870
450 Iron Standards @ R25 each			= 11,450
			18,320
Balance Saving .			5,54,080

APPENDIX Y.

Discharge of Betwa River from January, 1863, to January 1870, with amount drawn monthly from Reservoirs.

1		2	3	4	5	6	7	8	9	10	11	12	13
Month.		Less than 100 cubic feet.	From 100 to 250 cubic feet.	From 250 to 500 cubic feet.	From 500 to 1,000 cubic feet	Over 1,000 cubic feet.	Maximum.	Minimum.	Mean.	Canal Discharge.	Volume in Reservions.	Quantity drawn by Reservoirs.	Balance in Reservoirs end of each month.
January,	1868,	...	...	...	31	...	1,028	741	869	440	1,410	...	...
February,	"	...	..	12	17	..	741	435	592	...	...	...	...
March,	"	.	13	18	...	...	325	208	276	...	...	164	1,246
April,	"	...	30	...	...	..	208	99	151	...	...	289	957
May,	"	31	..	...	...	...	99	70	85	...	...	355	602
June,	"	30	..	...	...	...	66	64	62	...	...	378	224
July,	"	18	...	...	1	12	12·8F.	17	...	...	Supply for half month.		
August,	"	1	4	3	5	18	19·2F.	99	...	...	Canals full.		
September,	"	10	8	...	...	12	28·8F.	54	...	...	...	...	...
October,	"	1	8	8	8	6	5·9F.	89	...	...	...	...	...
November,	"	30	...	...	...	...	79	46	62	...	..	378	1,032
December,	"	31	...	...	...	...	70	39	54	...	...	386	646
January,	1869,	31	...	...	...	...	33	33	33	...	...	407	239
February,	"	28	...	...	...	...	33	33	33	Supply for the month.			
March,	"	31	...	...	...	...	49	39	45	...	Canals dry.		
April,	"	31	...	...	...	...	Dry			...	...	...	...
May,	"	31	...	...	...	...	"			...	...	...	...
June,	"	8·	...	...	...	...	"			...	...	...	...
July,	"	...	...	...	...	23	39·7F	1,028	...	...	...	...	...
August,	"	...	...	...	...	31	16·3F.	6·1F.	...	...	Canals full.		
September,	"	...	...	...	...	30	26·66F.	8·4F.	...	...	...	...	...
October,	"	...	...	...	...	31	18·22F.	6·0F.	...	...	...	...	...
November,	"	...	...	...	...	31	6·0F.	5·0F.	...	...	...	...	...
December,	"	...	...	...	31	...	815	677	764	...	...	...	...
January,	1870,	...	...	...	31	...	767	594	703	...	...	...	...
February,	"	...	15	13	...	...	260	228	218	...	...	212	1,198

NOTE.—In 1867-68 the rubbee would have beeen recured, and water would have been available for sugar and early rice; 1868-69 the rubbee would have barely been saved; 1869-70, water would not have been drawn from the Reservoirs till February.

APPENDIX Z.

Flood Discharge and Afflux Calculations.

By measurement on 10th September, 1869 :—

Gauge		618·41
Sectional Area	(A.)	14,492 square feet.
Perimeter	(P.)	1,440
Discharge,	(D.)	45,150 c. ft. per second.

Flood Discharge, June, 1866.

Gauge, ...		669·10
Sectional Area	(AI)	88,018 square feet.
Perimeter,	(PI)	1,564
Discharge	(DI)	741,200

The flood discharge is calculated thus :—

$$D : DI :: A.\sqrt{A.} \div P. : AI\sqrt{AI} \div PI$$

$$DI = \frac{A\sqrt{A} \div P}{A.\sqrt{A,} \div P,} D$$

$$\frac{\sqrt{88{,}018^3} \div 1{,}564}{\sqrt{14{,}492^3} \div 1{,}440} \cdot 45{,}150 = 741{,}200$$

AFFLUX CALCULATIONS.

Ghusgowan Weir.

Flood Discharge		750,000
Betwa Bed	Red. L.	550·00
Present Flood	"	619·00
Crest of Weir	"	598·00
Length of Weir	2,600′	
Afflux, ...	14′	

Khoord Dam.

Betwa Bed	Red. L.	589·00
Present flood level above Dam	"	641·00
Ditto ditto below Dam	"	636·00
Crest of Dam	"	635·00
Length of Dam		5,500 ft.
Afflux		11·0 ft.

Formula by which afflux is determined is :—

$D = c_d\ l.\ \sqrt{29\ d.}\ (d_s + \frac{1}{3}\ d)$.

D = Discharge.

Cd = Co-efficient = 0·625.

L = Length of Weir.

d = Afflux.

d_s = Crest of Weir below—Present Flood level.

At Ghusgowan the reduced level of floods after the wir ise built will be

598 + 5 + 14 = 617·0

At Khoord the flood level after construction of dam will be

635 + 1 + 11 = 647·0 or six feet above present floods, which rise to a level of 641·0 on the up-stream side of dam.

From the Superintending Engineer, 2nd Circle, Irrigation Works, N.-W. P., to the Chief Engineer, Irrigation Works, N.-W. P.,—No. 796, dated Delhi, the 26th March, 1870.

IN continuation of my No. 782, dated 25th March, I have the honour to forward the Betwa plans and sections, consisting of 27 sheets, received under cover of your No. 559 I, dated 19th March.

Plans, 9 sheets.
Cross Sections, 14 sheets.
Ditto of Site of Weir, 2 sheets.
Longitudinal Section, 2 sheets.

2. In paragraph 46 of my No. 782, I remarked that while approving of Khoord site for the Reservoir dam, I should have preferred a site which allowed of a shorter length of dam.

3. On examining the Betwa river maps, I found that Captain Bagge had fixed the Reservoir dam at a point where the width of the river was much greater than it is for miles above or below.

4. Thinking that a considerable reduction in cost would be the result of adopting Pureecha, which is above Khoord, as the site for the dam, I prepared the accompanying Estimates: my anticipations were not realised.

5. The following is a comparison of the two works:—

	Length.	Contents.	Cost.	Saving.
Khoord dam . .	5,500	2,055,860	R13,36,720	
Pureecha . . .	2,650	1,465,253	„11,01,886	R2,34,834

6. Against this saving of R2,35,000 must be placed the loss of revenue due to the 37 cubic feet per second of supply which is contained between the Pureecha site and the Khoord Dam. The revenue from this 37 cubic feet, calculated at R500 per cubic foot, represents at 7·5 per cent. a capital of R2,60,000.

7. The advantage of the two sites are pretty fairly balanced; but if the afflux due to each dam is considered, the Khoord site has the preference, for at Pureecha the afflux is 11·23 feet while at Khoord it is only 6·00 feet.

PUREECHA SITE.

Reservoir Dam.

Profile of Dam similar to that of Khoord Dam.

Height.	Area.	Length.	Contents.	Height.	Area.	Length.	Contents.
					Total Brought over, .		808,530
14	244	13	3,172	26	476	24	11,424
18	319	27	8,613	29	539	26	14,014
16	281	70	19,670	27	497	30	14,910
10	172	20	3,440	29	539	20	10,780
15	262	30	7,860	25	456	50	22,800
12	208	50	10,400	26	476	16	7,616
26	476	25	11,900	21	377	14	5,278
33	625	75	46,875	25	456	170	77,520
37	710	130	92,300	31	591	70	41,370
38	741	100	74,100	27	497	60	29,820
39	772	160	123,520	24	436	23	10,028
45	944	40	37,760	29	539	47	25,333
42	856	50	42,800	26	476	80	38,080
39	772	20	15,440	24	436	120	52,320
41	821	30	24,630	27	497	100	49,700
45	944	30	28,320	21	377	250	94,250
43	888	100	88,800	28	518	100	51,800
39	772	56	43,232	30	560	100	56,000
37	710	28	19,880	27	497	50	24,850
27	497	44	21,868	22	397	10	3,970
31	591	100	59,100	14	244	20	4,880
27	497	50	24,850				
	Total Carried over .		808,530		Total, ...		1,456,773

Thus:—

		R
Ashlar	(16·6 × 18) 2,398 × 2 = 1,65,941	
	6,676 × 2 = 13,352	1,79,293
Rubble	... ...	12,85,960
		14,65,253
Mr. Anderson's Estimate of Khoord Dam Ashlar . .	...	2,07,368
Mr. Anderson's Estimate of Pureecha Dam . . .	...	1,79,293
	Saving	28,075

		R
Mr. Anderson's Estimate of Khoord Dam Rubble .	18,48,492	
Mr. Anderson's Estimate of Pureecha Dam . .	12,85,960	5,62,532
Add contents of Piers, 205 in number—		
Mr. Anderson's Estimate of Khoord Dam Piers, Rubble .	7,27,100	
Ditto ditto Pureecha	98,400	6,28,700
Total Saving		11,91,232

Thus:—		R
28,075 cubic feet Ashlar @ R 2		56,150
11,91,232 ditto Rubble @ „ 15		1,78,684
Total .		2,34,834

RESERVOIR SUPPLY.

Supply with Dam at Khoord	4,013,930,000
Deduct quantity stored between Khoord and Pureecha . .	531,960,000
Contents of Reservoir with Dam at Pureecha . . .	3,481,970,000

LOSS BY EVAPORATION.

Area with Dam at Khoord	101,247,500
Ditto between Khoord and Pureecha	13,710,000
	87,537,500

Then loss is $87{\cdot}537{\cdot}500 \times \frac{3{\cdot}03 - \frac{3,481,970,000 - 265,238,652}{152 \times 60 \times 60 \times 24}}{3{\cdot}03} = 265,238,652$ cubic feet, and supply is 245 cubic feet per second.

Volume in Reservoir with Dam at Khoord is	. 282	ditto	ditto.
Difference	. 37	ditto	ditto.

COMPARATIVE RESULTS.

Khoord Reservoir contains 37 cubic feet per second more than Pureecha Reservoir. Then—37 × 500 = 18,500 is the yearly revenue that will be lost by adopting the Pureecha site. This at 7·5 per cent. represents a capital of

$\frac{18,500 \times 100}{7{\cdot}5}$ = Rs. 2,60,000

while saving in cost of Pureecha Dam . Rs. 2,35,000.

AFFLUX CALCULATIONS.

		Cubic Feet.
Flood Discharge		750,000
Length of Dam		2,650
Crest of Dam, Red. Level		645·0
Present Floods		645·0
Surface of Country		649·0
Afflux		11·23

Then D. = 750,000 l. = 2,650
C.a. = 0,625 d. = 0

$D_s = c.l. \sqrt{29d, (d) + \frac{2}{3} d,)}$

$750{\cdot}000 = 0{,}625 + 2{,}650 \times 8{\cdot}02\frac{2}{3} \sqrt{d,^3}$

$\sqrt{d,^3} = \frac{750{\cdot}000 \times 3}{0{\cdot}625 \times 2{,}650 \times 8{\cdot}02 \times 3} = 37{\cdot}64.$

$d, = 11{\cdot}23.$

and reduced level will be	.	645 + 1,123 =	656·23
Ditto of country	.	...	649·00
Height of Embankment	.	...	7·23

CLINTON ANDERSON,
Supdg. Engr., 2nd Circle, Irrigation Works, N.-W. P.

Extract from a Note by the Chief Engineer of Irrigation, North-Western Provinces, No. 233 $\frac{I}{C}$ of 2nd February 1872.

BETWA CANALS.

IX.—The Betwa River was first examined, with a view to irrigation, by Captain F. Home, R.E., in 1867-68. On this officer going to England, the late Captain Arthur Bagge, R.E., took up the enquiry on a wider basis, and acquired the valuable knowledge of the character of the soil in the field of this canal, which is the basis of the present scheme.

After deducting the area of mâr soil it is found* that 228,000 cultivated acres of loam† and sandy soils requiring water, are irrigable from these canals. Those lands lie on the borders of the Betwa and Pahooj Rivers, and can be served by the two canal branches (see) above specified, which are shown in the map, page 1, of Appendix B.

* Paragraph 9 of Captain Bagge's report.

† *Kabur*—rich loam; *Purwa*—sandy soil; *Rakur*—coarse grit, detritus of kunkur quartz and gravel.

X.—The project of Captain Home, the result of a single season, was not sufficiently complete, or that of Captain Bagge sufficiently encouraging, to justify their adoption; but all the *data* on which we are now working were obtained by the laborious researches of these two officers, and it is certain that if either had been able to continue their enquiries, the conclusions now arrived at would have been determined three years ago. In the interval, the Government has lost in Captain A. Bagge one of its most devoted and valuable officers.

XI.—We now propose to take out a canal from the left bank of the Betwa at Pureecha, the point selected by Captain Home, 13 miles below Jhansie.

The canal, after passing through the Sumpther State, divides into two branches, which will terminate in the Jumna,—one near Kootound in Jaloun, the other near the station of Humeerpoor; leaving the mâr soil which lies in a basin between the two rivers for the present untouched.

XII.—Lieutenant-Colonel Brownlow, who has examined the subject, finds‡ that a volume of 600 feet a second in the Betwa may be counted upon in September and October, which dwindles to 50 cubic feet in February.

‡ Appendix C.

XIII.—This volume will afford a first watering to 120,000 acres, the total lands annually under rubbee cultivation, of which two-thirds, or 80,000 acres, may be fully watered, and the remainder will get started at any rate, and may get further help.

XIV.—For calculation of returns, the 80,000 acres only are taken into account, and the 50,000 which, when requisite, can be watered in khurreef, are also disregarded. There can be no doubt that these returns are moderate and reliable.

XV.—It is proposed to raise a weir at Pureecha to the level proposed by Captain Home for the sill of his masonry structure R. L. 622·66; making the weir thick enough to allow 3 feet more masonry being added, if found practicable, so as to bring it to the level 625·66, which Captain Home proposed to attain by the use of planks. The violent stream of the Betwa renders the use of planks undesirable. Proceeding thus tentatively, there is no fear of accident or mischief, and every prospect of our being able to increase the duration of rubbee supply ultimately by forming a reservoir above the weir.

XVI.—Reducing the capacity of the canal so as to carry 600 cubic feet during rubbee, and 700 during the monsoon, when the river is running full, it is found practicable to reduce the depth of digging proposed by Captain Home 2 feet. This arrangement fixes the sill of canal head at R. L. 619·66.

XVII.—The reduction of depth of canals, and a modification of alignment in the first 16 miles, bring the rough estimate of the cost of the scheme to Rs. 17,25,000, on which a net return of Rs. 1,71,000, or 10 per cent., may be fairly expected.

Note by LIEUTENANT-COLONEL BROWNLOW, Officiating Joint Secretary to Government, Irrigation Branch, on Betwa project, No. 674 I. C., dated Allahabad, the 1st April 1872.

IN 1868, Captain (then Lieutenant) Home* recommended construction of a canal carrying a maximum khurreef supply of 1,000 cubic feet per second, with a depth of 8½ feet, to be taken out from river near village of Pureecha, where an admirable site for a weir exists.

* Pros., Govt., N.-W.P., Vol. $\frac{A}{W}$—, Feby. 1869, Nos. 9—39.

The length of weir crest to be 2,426 feet, height above bed in lowest part 25 feet.

Roughly estimated cost of whole scheme Rs. 19,29,246, giving an estimated return on capital of 7·9 per cent., after deducting cost of maintenance and repairs.

2. His Honour the Lieutenant-Governor, North-Western Provinces, in his minute on project, stated his disinclination to favour any project that did not include ample rubbee supply, doubting willingness of people to take water in khurreef except during years of drought, as effect of irrigation on the black ("mâr") soil was uncertain.

3. Colonel Greathed suggested establishment of reservoirs for regulating in some measure the floods, and supplementing canal supply, when water in river should be low.

4. Colonel Strachey, in commenting on project as Inspector-General of Irrigation Works, leaned towards immediate construction of a khurreef canal before attempting to deal finally with the storage of water to supplement the rubbee volume of canal, considering that there was no solid ground for apprehension that the black soil might prove unsuited to irrigation, and believing that khurreef irrigation would largely develope if water were once supplied.

Generally approving of project, he suggests an alteration of alignment between the proposed head of canal and town of Mote, to save the heavy excavation entailed by line adopted by Captain Home.

5. Sir W. Muir adheres to his opinion as to inexpediency of setting on foot any purely khurreef project, and Colonel Greathed points out that opinion of agricultural community, as represented by civil officers of Jaloun, Jhansie, and Humeerpoor, is opposed to that of Colonel Strachey's in the matter of irrigating the black soil. Lieutenant Arthur Bagge, R.E., then submitted a project in November 1869, the cost of which, including that of reservoir dams (which amounted to one-half of sum) was close upon 90 lakhs of rupees. Omitting the estimated cost of head weir and of two reservoir dams, Lieutenant Bagge's project amounted to 36 lakhs—nearly double the cost of Captain Home's, which (omitting cost of head weir) amounted to 18¼ lakhs. The difference was attributable to a more complete development of the project, to necessity of providing for navigation, and to heavy expenditure in crossing drainage.

6. Having in view the desire to use the channel of river itself as a storage reservoir, Lieutenant Bagge placed the head of his proposed canal at Ghusgaon, the lowest of the four rocky barriers which cross the channel of Betwa between the Burwa Saugor Ghât, where it debouches from hilly country, and a point 17 miles lower down. Fifteen miles from Ghusgowan the line regained general watershed of country at an obligatory point, laid down by Colonel Greathed.

7. Lieutenant Bagge submitted with his report a very interesting soil chart,* in which tracts containing 75 percent of black soil are coloured grey, those containing nearly the same proportion (70 per cent.) of loamy and sandy soils are coloured sepia, and the sandy soils are coloured burnt sienna. Out of 528,000 acres of cultivated land embraced by the project, he estimates 300,000 acres as black soil, and from the measured areas of the Jaloun district he obtains the following percentages which he considers fairly applicable to whole area under consideration:—

* See map opposite to page 4, Appendix B.

Cultivated lands	54 Per cent.
Culturable	10 „ „
Barren and ravines	35 „ „
	100

8. If we now take up the project with the object of supplying as much water as may in ordinary years be available to the rubbee crops on the loamy and sandy soils, leaving all black soil tracts out of the scheme, and omitting also to provide for navigation, we shall have roughly the following data to go upon. After studying the table of measured discharges in the river, extending more or less continuously over a period of four years, I think we may fairly rely on starting the rubbee crops during the end of September and October of ordinary years with 600 cubic feet per second, dropping to 350 cubic feet in January and 200 cubic feet in February. In dry years, we shall be able to start the crops with very nearly the same volume (600 cubic feet) obtained in ordinary seasons; but this will only be available during end of September and early part of October. The supply of water in river falls rapidly to 160 cubic feet in end of October, and to only 50 cubic feet in February; allowing for the very great decrease in the volume of canal between the commencement and the end of rubbee, I think we

should only calculate on full-water rates being realised on two-thirds of area irrigated at commencement of the season. Taking 200 acres per cubic foot per second as duty ultimately obtainable in irrigation of rubbee crops, we have :—

	Rs.
Cubic feet 600 × 200 = 120,000 acres irrigated in September and October, two-thirds of which = 80,000 acres @ Rs. 2 . = Rs.	1,60,000
Add 12 annas per acre for enhancement of land revenue . . .	60,000
Add 5 per cent. of water-rate miscellaneous revenue . . .	8,000
Total ultimate returns .	2,28,000
Deduct 25 per cent. for working expenses	57,000
Balance net revenue . .	1,71,000

9. These will be, of course, ultimate returns, but as they take no account whatever of khureef irrigation (which it is hard to believe will not be carried on more or less when the water is available), I think the estimate cannot be called excessive. Rs. 1,71,000 return 7 per cent. on 24½ lakhs of rupees, so that I think we have good grounds for recommending such a project for serious consideration. Cutting the black soil tracts out of Lieutenant Bagge's scheme, we should have to irrigate from main channel

Kootound Branch	222·59 miles.
Calpee Branch	467·00 „
	375·00 „
Total .	1,064·00 „
Deduct 35 per cent. barren .	372·00 „
Balance cultivated aud culturable, 692 square miles . .	= 442·880 acres.

of which we should fully irrigate 80,000 acres, or 18 per cent., during the rubbee, and could, if required, irrigate 700 × 70 = 50,000 acres, say, between July 15th and September 15th of a dry khureef. This would be 11 per cent. of the whole area, so that on an emergency we should be able to protect very nearly one acre out of every three.

10. Captain Home's proposed site for a weir is decidedly the best, and should be adopted. I think we can keep the masonry sill at same height as designed by him, but the reduction in volume discharged by canal will allow of our raising the bed two feet above the level originally proposed. This raising of bed level, together with a modification of alignment of the first 16 miles, will materially diminish the excavation on this portion of line.

Cutting out of Captain Home's estimate the branches of rajbuhas intended for irrigation of black soil, and allowing for a reduction in excavation of first 16 miles, we get Rs. 17,25,000 as a rough estimate of cost of modified project.

11. The calculations of maximum flood discharge of such rivers as the Betwa by the application of ordinary formulæ are quite unreliable.

With reference to that on page 8 of report,* I may observe that these formulæ are derived from experiments made in small channels of regular section and slope, and give results much in excess of the truth when applied to channels of irregular section and slope. Lieutenant Bagge, too, apparently includes the areas of deep holes above rocky barriers in his sections of flood volumes, which will at once account for a portion of the excessive volume obtained by him in his calculations under consideration. In such calculations, too, the slopes of surfaces of floods should be regarded, and not the slopes of *river beds*. Further, the deduction that velocities will vary as square roots of hydraulic mean depth is only true when surface slopes remain constant; the very first effect of an increase of flood volume in a channel like that of the Betwa at this point being to increase markedly the surface slope. Were the formulæ employed correct in other respects, both these sources of error would give results very much below the mark, and they account for the comparatively low volumes obtained in calculations at top of pages 9 and 10. Failing any better means of arriving at the truth, we must obtain a maximum flood volume from calculation of water running off catch-water basin after heaviest known fall. The Surveyor-General has supplied area of catchment basin, and a calculation of maximum flood on that basis is appended.

* Appendix B.

12. I think the measurement of volumes in river should be continued, especially of the volumes during October to February.

13. Having regard to the volume of river between November and June, I do not think it possible to maintain navigation during those months in the irrigating channel, except on an insignificant portion of its length; and owing to the small capacity of the terminal irrigating channels, any scheme of through navigation will, in my opinion, entail an expenditure on still water channels quite out of proportion to any advantages derivable from them.

From the Government of India, to the Secretary of State for India, No. 121, dated 16th September 1872.

WE HAVE the honour to report for the information of Her Majesty's Government, the measures in progress towards the development of irrigation in Bundelkhund, regarding which the Lieutenant-Governor of the North Western Provinces, in a Minute dated the 4th September 1868, recorded the following opinion :—

"There are few parts of the country in which canal irrigation would prove a greater blessing than in that territory. The rainfall there is generally more scanty, irregular and uncertain than in the Doab and the Trans-Gangetic Provinces. At the approach of drought, the people are in the habit of emigrating for the time to more favoured localities. The tenure of land is consequently far less valuable and fixed than where the production is tolerably certain. There is less accumulation of capital and less ability to tide over seasons of difficulty, and so, when drought and famine do occur, the miseries of want and depopulation are experienced with an intensity and duration quite unknown in the more favoured tracts to the north of the Jumna and Ganges."

2. This Minute was written on the occasion of the submission of two preliminary canal schemes roughly projected for the Province. These, after being reviewed, were returned to be properly worked out and matured.

3. In January last a third scheme was projected and submitted, and last April the previous two were re-submitted.

4. The first of the projects provides for a canal for spring irrigation from the left bank of the Betwa river, and is intended to irrigate portions of the Jaloun and Humeerpoor districts in a triangle contained between the Betwa, Pahooj, and Jumna rivers. The cost has been approximately estimated at 17¼ lakhs of rupees, and the returns at Rs. 1,71,000, or 10 per cent.; but these calculations cannot as yet be relied on.

5. The second provides for a canal, also for spring irrigation, from the right bank of the River Dussan, to irrigate part of Humeerpoor. It is calculated to cost about 12½ lakhs of rupees, and to yield a clear return of more than 1¼ lakhs, or 11¼ per cent. on the outlay.

6. The third scheme consists of, as modified by the Chief Engineer and recommended for adoption, a weir on the River Keyn, with canals leading therefrom, for the irrigation of the Banda District, and has been roughly estimated to cost Rs. 13,33,099, including working expenses and establishment, and to return a profit of Rs. 90,392, or 6·8 per cent. This scheme is capable of extension hereafter, if found necessary.

7. Your Grace will see from the papers forwarded, that we have accorded our general approval to these projects, and authorised their being prepared in proper detail for final submission for sanction. An expenditure of nearly Rs. 1,25,000* has been, with our permission, incurred in their preparation, from Local Funds, which is, however, to be refunded from "Ordinary" in the event of conclusive evidence not being ultimately adduced in proof of the schemes being eventually remunerative.

* Including establishment.

8. In addition to these projects, proposals have been submitted, and have received our sanction, for the management, improvement, and further development of tank irrigation in the southern and hilly tracts of Bundelkhund, the works embraced in which promise to be very profitable.

9. We shall not fail to apprise Your Grace, from time to time, of our further proceedings on the subject of our present despatch.

From—The Secretary of State for India, To—The Government of India,—No. 12, dated 20th February, 1873.

I HAVE had before me in Council your letter No. 121 of 16th September last, reporting measures in progress towards the development of irrigation in Bundlekhund, with a view to

which, an expenditure of Rs. 82,050 on the repair and improvement of certain tanks has been sanctioned, and general approval accorded to three separate projects for leading off canals from the Rivers Betwah, Dussan and Keyn.

2. The cost of these projects has been approximately estimated at 17¼, 12½, and 13½ lakhs; and the annual returns thereon at 10, 11¼ and 6·8 per cent. respectively; but these estimates would seem to have been regarded with some distrust, as the order of your Government sending them back to be "prepared in proper detail for final submission for sanction," was accompanied by an intimation that "an expenditure of Rs. 1,25,000 incurred, with permission, in their preparation from Loan Funds," should "be refunded from Ordinary, in the event of conclusive evidence not being ultimately adduced in proof of the schemes being eventually remunerative."

3. The caution with which your Excellency's Government is proceeding in this matter is plainly not greater than the circumstances require. So far as can at this distance be readily judged, the proposed works have been planned, and the estimates of expenditure framed, with adequate care, but in regard to probable pecuniary returns, recorded opinions differ very materially. On one side it is confidently asserted of the Bundlekhund territory generally, that "water is very much wanted during the rubbee or winter harvest, and will be taken with avidity in all but the most unusually favourable seasons;" that Zemindars will gladly welcome the introduction of canal irrigation, and willingly "pay the usual water-rates;" and also that, although "at present water is not taken, where available, for the *mar* or black cotton soil," which chiefly prevails, "save in very unusual droughts," * * * the "provision of a rubbee supply for as many acres as possible of the loamy (or *kabur*) soils" is a genuine requirement. But, on the other hand, of the local Officers speaking for particular Districts, one represents the cultivators as "unwilling to avail themselves of the water" already obtainable; another, even while advocating the construction of canals, admits that, "as to the readiness of cultivators to make use of canal water, the results will not at first be encouraging," and that the growth of such readiness is likely to be "slower in Bundlekhund than in the Gangetic Doab, on account of the backward condition of the country and the natural indolence of the people; a third expresses his fear that "a canal for irrigation only would not pay expenses," for that water "would be taken only in *purwa* (or sandy) soil, unless the rates were very low indeed; and a fourth gives it as his opinion that "barley, and, to a less extent, wheat, will be the only crops of importance irrigated, and that these alone will not pay expenses."

4. The prudent inference from these conflicting statements is that, if the practice of irrigation do in Bundlekhund follow extensively on the construction of irrigation works, it will, at any rate, follow only very deliberately, so that, in order to estimate with any approach to accuracy the percentage upon cost which the pecuniary returns will eventually represent, it will be indispensable to take into account the additions to original outlay to be made by reason of deficient revenue during the many years which may elapse before the canals become fully remunerative.

5. Your Excellency will observe that these remarks apply only to the Canal schemes still awaiting final orders, and have no reference to the measures which have been already sanctioned for the improvement of existing tanks. It seems tolerably certain that the money so expended will be speedily, as well as abundantly, remunerative.

No. 02557 I. C., dated Nynee Tal, the 18th September 1878.

Report by the Chief Engineer of Irrigation in the North-Western Provinces, upon the droughts which have visited Bundelkhund.

THE Government of India has been pleased to call for—

"Particulars of droughts of former years, their results on the people as well as on the Government land-revenue receipts, and the expense incurred by Government for the relief of distress."

Accordingly the following compilation has been made.

Following the arrangement prescribed, the subject is divided into—

I.—The results of drought on the people.

II.—The results on the land-revenue receipts.

III.—The expense incurred by Government in the relief of distress.

I. Concerning the effects of drought on the people, we are limited, in the absence of a local press of any consideration, to the information afforded from time to time by officers engaged in the administration of the country in their reports to Government.

No description can be found in documents to which we have access, of the effect of famines previous to that of 1830, but the *Calcutta Gazette** of 1803 informs us that a bounty of 15 to 30 rupees per hundred maunds was paid by Government on importations of food-grain from Bengal to Allahabad, Benares, Cawnpore, and Futtehgurh. And what a world of suffering and woe lies buried under that announcement!

In 1842 Mr. C. Allen, the Settlement Officer of Humeerpoor, writes† :—

"The season of 1834 was one of unparalleled distress to the people of this district and of loss to Government. The miseries of famine, pestilence and exile, which denuded this district of nearly one-half its population, are too well known to the world to need recapitulation here.

"In Humeerpoor, in the pergunnahs under report, the drought of 1838 was felt less heavily than that of 1834, and the balances were less heavy;" * * * "but in no year has the whole revenue been realized, (this was partly due to over-assessment)."

In the same year, speaking of the famines of 1830, 1834, and 1838, Mr. W. Muir, the Settlement Officer of Calpee, says:—

"No one who has not toiled through the details of each village can conceive the extent of alienation of property, or the misery attendant on the depopulation of villages, and the disruption of society which has prevailed in this unhappy country. * * * By the drought of 1834, thirty-five villages were totally desolated in Jullalpore; and in 1834 and 1838 seventy-two villages in Calpee and Humeerpoor were laid waste, and left without an inhabitant.

"The frequent injury which failure in crops inflicts upon an estate, reduces its value in two distinct respects, first, by the actual losses they occasion; and second, by depreciating, as they render uncertain, the returns actually obtained: the losses to which I allude are not those of severe and extraordinary famines, but of such unfavorable seasons as are of common occurrence. The calamities of over-assessment and famine have prostrated many estates so completely, that it is almost impossible to tell what their ultimate capabilities may prove."

The suffering of the people in 1868-69 are thus described:—

BANDA AND HUMEERPOOR.—*Commissioner of Allahabad.*

"I found the poorer classes reduced to the lowest extremity: their cattle sold, their fields bare, and without means of existence other than that found from wild berries or than that furnished from the few stunted plants which had not actually withered: the better classes were reduced to want and brought into debt."

Again—

"The total loss (in that famine) was computed at 85,335 head of cattle, or 20 per cent. of the whole stock; of these 20,000 were plough-cattle, which represents the power of cultivating 50,000 acres."

JHANSIE AND LULLUTPORE.—*Commissioner of Jhansie.*

"The grain-dealers, in the hopes of still larger profits, withheld their stores from market. Seeing no prospect of a harvest from which to recover their loans, they stopped advances, whether of cash or grain, to their cultivating constituents, and left them to do the best they could for themselves. The inferior grains were not procurable. From this state of things great distress was beginning to be felt: people began to flock into the city for relief; cultivators with their cattle and families left their homes, to wander they knew not whither, in search of food or employment. Children are reported to have been sold by their parents in the city of Jhansie. Small-pox raged during the first six months of 1869. Sun-stroke carried off numbers of enfeebled wretches: men came in weary and weak, and fasting, took a long draught of water and died. Cholera appeared with the rainy season, and fever of a malignant type, the usual attendant of scanty and inferior food, doubled the tale of victims: 20,300 died in the district of Jhansie in 1869, while in 1868 only 3,180 died.

"In Lullutpore also, of 233,000 cattle, about 95,000, or 41 per cent., died. Some were sent off to the jungles, others were driven to shift for themselves in the barren fields. The change to abundance of grass and and water upon the setting in of the rains in 1869 is said to have destroyed numbers. The stench arising from thousands of carcases polluted the air, and contributed to the outbreak of cholera, which was the last visitation. ₹88,000 were advanced for useful works and ₹70,000 for seed and cattle. *But the advances went to buy bread and preserve life, consequently wells have not been sunk, cattle have not been replaced; want of men and cattle prevents cultivation: 60 per cent. of the land revenue demands were suspended.*"

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* See *Calcutta Gazette*, III., 136.

† Reports on the Revenue Settlement of the North-Western Provinces, Volume II., Part II.

Let us now see the contrast afforded by a description of the irrigated portion of the North-Western Provinces, in the scarcity of 1868-69:—

"The canals, where they existed, were the life of the country; unhappily, however, there were considerable tracts within the area of drought which possessed no such advantage, but the benefits conferred will be apprehended from the following plain statement of facts. The produce saved by canals has been estimated at half a million tons, but the estimate of the District Officers is still higher, and their valuation amounts to five millions sterling. In former famines there was no food within possible reach of the afflicted districts. In 1868-69 the development of irrigation created a surplus stock in the plains of the North-West, which an arterial railway carried east and west with great facility: but other means of transport were insufficient to carry the entire food of a population, and unfortunately Bundelkhund and Ajmere, the provinces most remote from railways, were also dependent entirely on the rainfall for their sustenance.

"The irrigated tracts of the Doab (or central portion of the plains included between the rivers Ganges and Jumna), says another reporter, were the heart of the province from which surplus food flowed out by railway westward to the Cis-Sutlej States, in which there was no harvest to reap; and southward by never-ending trains of carts and camels to Bundlekhund, Ajmere, and Rajputana, where no grain was ever sown. Under Providence a famine was averted in the Cis-Sutlej States and the Doab by the combined action of railways and canals.

"But besides producing food for the support of human life, canal irrigation created sustenance for cattle which was producible by no other means; and at a crisis when wells failed in well-irrigated districts, and herbage and fodder depended on abundant water, the cattle of the Doab were saved strong to labour in the work of the following harvests; whilst elsewhere those harvests also were reduced by the want of cattle which had been swept off by the drought.

"And, lastly, canal cultivators became rich whilst others suffered, because they realised both large crops and high prices; the payment of land-revenue was assured; the breaking up of communities, the unsettlement of the social system of the country, the loss and dispersion of property, which famine entails, were averted; and a vast sacrifice of life prevented, which, but for the extension of canal irrigation, must have occurred in 1868-69, as it had occurred in the same districts in 1837-38."

It has been requisite to introduce a narrative of the condition of Lullutpore, which comes indirectly under the influence of the Bundelkhund Canals, because it illustrates with harrowing intensity what must happen to an isolated country, dependent for food on the rain of heaven, when in the course of nature the supply fails. Lullutpore suffered in 1868-69 as much from isolation as from drought, for it is humanly impossible to transport the food of a population many miles by any agency but railways or canals: and Bundelkhund, from its position and its poverty, has no prospect of enjoying benefit of railways.

Had Bundelkhund possessed canals in 1868, the condition even of Lullutpore would have been far less terrible, for food would then have been procurable within a distance which available means of transport would probably have sufficed to bridge.

And until Bundelkhund has canals, the people not only of that province, but of neighbouring countries, must die by thousands in future periods of drought as their fathers have died by thousands under past visitations.

II.—Effects on the land-revenue.

First in necessitating light assessments.

In the Settlement Report published in 1842, the Settlement Officer of Calpee suggested in view of the frequency of famine, a fixed graduated scale for remissions on the report of the Collector of the district as to the result of the season.

"I beg to suggest whether it would not be more politic in a country so liable to severe drought, to adjust remissions according to the following scale:—

Class of village.	Demand per cent. of Jumma.		
	In moderate drought.	In great drought.	In extreme drought.
Kachar	84	50	22
First	80	50	18
Second	70	35	12
Third	60	24	7

"A total suspension of rain should be followed by a total suspension of demand."

Further, in the Settlement Report of Jhansie—

"The settlement during the last three or four years (previous to 1871), though a fairly light one, has been severely tried, owing to failure of rain and flight of cultivators."

In urging the necessity for a light assessment the Commissioner of Jhansie writes:—

"The calamity of drought may be truly said to be of by no means uncommon occurrence. It has been stated by a very high authority (Sir W. Muir) in regard to the neighbouring District of Humeerpoor, that one out of every four or five years is certain to be more or less of a failure, and the remark is, I believe, quite applicable to the Jhansie District. The rains are sometimes remarkably partial; and while one portion of a pergunnah may be flourishing well, another may be suffering from a failure of rain, and as a consequence from a failure of crops. The importance of irrigation works in this part of the country cannot be over-estimated."

The statistics regarding the actual remissions and suspensions of balances for the earlier famines, are too meagre to admit of a complete statement being drawn up: and in many cases the returns for Bundelkhund are mixed up with those for other districts.

From Mr. Girdlestone's Report the following figures are taken:—

	Remission of revenue.
	₹
1812-13	11,105
1813-14	3,504
1814-15	3,448
	Suspended balances.
	₹
1818-19	55,231 6,435
1819-20	31,428 15,069
	74,095
In 1820, the revenue fell off by	4,53,386
For years the suspended balances were increasing, and in 1836-37 were remitted in Banda alone—	3,94,777
1837-38	
were remitted in Humeerpoor.	8,87,724

For the famine of 1860-61 the Bundelkhund statistics are not separated. These figures show a direct loss in remission of revenue of nearly nine lakhs, independent of the falling off in its amount and of other evil results, and the probability is that the amount is far short of the real loss.

In the famine of 1868-69 the balances of revenue uncollected at the close of the year were:—

	₹	Per cent.
Jaloun	2,57,256	29·4
Jhansie	1,90,347	39·0
Banda	48,412	3·6
Humeerpoor	73,083	6·7
Total	5,69,098	

Of this amount, about ₹1,05,168 was actually remitted, and the remainder held over to be recovered by instalments.

The following statement shows the remissions of Land Revenue made in Bundelkhund in each of the last 12 years:—

Return of remissions of Revenue in Bundelkhund compiled from the Board's Administration Reports.

Year.	Jaloun.	Jhansie.	Lullutpore.	Banda.	Humeerpoor.
	Remitted.	Remitted.	Remitted.	Remitted.	Remitted.
5 months of 1860	3,770	.....	.....	6,53,388	2,128
1860-61	1,94,034	76,398	66,701	1,01,389	18,492
1861-62	1,92,102	50,521	58,251	58,602	5,58,793
1862-63	2,275	1,77,631	15,187	868	21,773
1863-64	2,56,190	11,817	.....	418	229
1864-65	19,149	8,535	9,255	8,102	96,494
1865-66	2,816	4,921	.....	4,218	13,814
1866-67	61,474	.....	35,052	781	10,864
1867-68	2,900	.....	1,81,688	.....	1,139
1868-69	1,832	.....	1,81,714	.....	229
1869-70	59,173	2,324	62,680	.....	443
1870-71	473	.....	79	42,731	24
1871-72	318	23,659	3,553	3	2,595
	7,96,506	3,55,806	6,14,160	8,70,500	7,27,017

Grand Total ₹33,63,989, or more than thirty-three and a half lakhs.

These figures include total remissions of Land Revenue for all causes. A large amount is due to revisions and reductions of assessment, some is due to the mutiny, to hail, and other causes, the balance is on account of famines. The details cannot now be separated without ruinous loss of time; but as the revision of the assessment would in all probability never have been necessary had not the ravages of famine deprived the country from time to time of large proportions of its cultivating powers in the shape of both men and bullocks, it may be assumed that by far the greater proportion of this severe loss is due directly or indirectly to famine.

III.—Under the third head, "amount disbursed by Government in the relief of distress," the records are very imperfect. The following are taken from the famine reports :—

	Labour relief.	Charity.	Tuccavee advances.	Bullocks and seed advances.
	₹	₹	₹	₹
1833-34	.....	20,150	... ..	.....
1837-38	46,694	1,677	.....	.....
1868-69 Goverment	27,662	4,370	1,73,774	38,723
Local Funds	2,01,364	83,331	.....	.....
Total	2,75,720	1,09,628	1,73,774	38,723

or taking the last famine only, in which alone the account is in detail, ₹5,97,745 were expended in addition to remissions of revenue. Including the latter, the actual net loss at the time was ₹11,66,843. These figures do not include the loss in Lullutpore, which district though not to be brought directly under canal irrigation, will still benefit by it indirectly. The loss in Lullutpore should therefore be brought into account.

That loss in 1868 was as follows :—

	₹
Labour relief, local	10,910
,, ,, Government	2,09,578
Charity, local	61,443
Suspended revenue or 59·8 per cent. of total demand	87,659
Tuccavee	87,785
Bullocks and seed	68,439
	5,25,814

making a grand total expenditure in Bundelkhund on account of that one famine of ₹13,19,185, of which ₹4,28,457 were absolutely given away, the remainder being recoverable on easy terms by instalments, and this it should be remembered is in addition to the loss of life and property which cannot be estimated.

W. H. GREATHED, Col., R.E.,
Chief Engineer of Irrigation,
North-Western Provinces.

Report by James Hair, Esq., *Superintendent, Bundelkhund Irrigation Works.*

Irrigable Area.

The country proposed to be irrigated is bounded by the Betwa, Pahooj, and Jumna rivers, and the line of latitude 25° 42′30,″ where flow irrigation is possible. The accompanying index map shows accurately the boundary of the mar soil as obtained from a soil map prepared by Colonel Ternan, the Deputy Commissioner of Jaloun, and published by the Board of Revenue.

2. The country, excluding the low lands of the river, which do not require irrigation, has a total area of 1,492 square miles, of which 518·42 are barren, leaving a balance of 973·58 to be irrigated. It would appear, however, from Captain Bagge's report, and the opinions of the officers recorded in the appendices thereto, that no irrigation is required for the mar or black cotton soil which is included in this area, and occupies 35 per cent. of it. I think therefore that in estimating the amount of land for which irrigation is necessary the mar soil land should be excluded, when the balance requiring irrigation would become 632·83 square miles. The area to be irrigated is coloured green on the index map.

3. As the culturable land in a village is considered to be highly irrigated from a canal when one-third of it receives water in a season, the actual area requiring water will become $\frac{632·83}{3}$ = 210·94 square miles, or 135,000 acres; water will therefore be required for 135,000 acres; but it will be seen from what follows that the supply of water carried by the canal will not be sufficient for such an area.

4. From a careful study of the river discharges, the discharge of the canal has been fixed at 600 cubic feet per second. This 600 cubic feet per second would be the supply at the commencement of the irrigating season in the rubbee, but as it dwindles down to 300 cubic feet by the end of the irrigating season, which is about the end of January, I estimate that only 450 cubic feet per second will yield revenue.

5. No reason appears why we should not ultimately get as much duty out of a cubic foot of water in Bundelkhund during the rubbee as in other parts of the North-Western Provinces, seeing that the country proposed to be irrigated is very much like the Ganges-Jumna Doab.

6. The average duty for four years obtained on the Ganges Canal for the rubbee, shown in Table N, page 19, in the Revenue Report for 1872-73 is 96·07.

7. Table N in the same report gives the average duty obtained on the Eastern Jumna Canal for the rubbee for three years as 123·8 acres, and I think it will be fair to assume that we will ultimately get 100 acres on the Betwa Canal.

8. With 450 cubic feet per second, we will therefore be able to irrigate 450 × 100, or 45,000 acres. It will be observed that this area is only one-third of 135,000 acres, the total area calculated to require irrigation in the rubbee.

9. In addition to the rubbee irrigation, Colonel Brownlow, in his note No. 0949I.C., dated 12th April 1873, calculates on irrigating 21,000 acres of rice in the khureef. The revenue therefore will be as follows :—

	₹
45,000 acres rubbee at ₹2	90,000
21,000 ,, khureef at ,, 3	63,000
Total water-rate	1,53,000
Enhancement of land revenue, 66,000 acres at ₹1	66,000
Miscellaneous revenue, 5 per cent. of water-rate	7,650
Total	2,26,650
Deduct 25 per cent. on gross revenue for working expenses	56,662
Probable net revenue	1,69,988

10. It is not unlikely that in most years water could be supplied for a little cultivation of sugarcane and gardens, but no credit has been taken for this.

Alignment of Canal and Distribution of Supply.

11. The main canal runs a very direct course from the head at Pureecha to the village of Reo, on the parallel of latitude where flow irrigation will commence.

Here it bifurcates into the Hamirpoor and Kootound branches.

The Hamirpoor branch goes off to the right, and follows the watershed, which is on the high land bordering the Betwa river, and along which most of the land requiring irrigation lies.

12. The Kootound branch goes off to the left in a north direction, and follows the watershed on the high land bordering the Pahooj and Jumna rivers, along which line the land requiring irrigation also lies. There are therefore two main watersheds in the Doab, the great mar soil basin between the branches being drained by the nullahs shown in the map.

13. The land requiring irrigation has a pretty uniform width along the branches, and I think, for purposes of design, I was justified in allotting so much water per mile.

14. The boundaries of Native States are coloured yellow on the map, and so small a portion of the branch canals lies within them, that even supposing these States to be admitted to the same advantages as our own territory, the proportion of water due to them would be very trifling, and would not affect the designs.

15. The map of country now submitted shows every drainage line, so that the best alignment can be seen at a glance. The total length of distributaries is 220 miles. Where the lines of canal pass through the mar soil, the beds will be kept as near as possible at the depth of full supply below the surface of ground.

Masonry Works on Main Canal and Branches.

16. There being no navigation, these works are very simple in character, and no engineering difficulty is anticipated. It is probable that no well foundations will be required anywhere. The drainage syphons are of the same pattern as the Buriah nullah syphon on the Agra Canal.

17. All the bridges on the branches have been provided with grooves, so that they may be used as regulators during a low supply in the canal. The position and description of each masonry work is shown on the map.

Driving Road.

18. The road will be on the left bank. On the main canal, where there is deep digging, it may be inside the spoil bank, but where the digging is not deep, and on the branches, it will be outside the bank on the surface of ground.

The Weir.

19. The line of weir is shown accurately on sheet No. 11. It follows the highest point of the rocky barrier which crops up in the bed of the Betwa a little below Pureecha. The whole of the weir, under-sluices, head-sluices, and left flank walls will be founded on solid rock, but a portion of the right flank wing walls may not be on solid rock. The weir on the left flank meets the edge of the river at an acute angle, so if the head-sluices were to be placed at right angles to the under-sluices, they would be to a great extent out of reach of a good scour along their face, and they have accordingly been designed at an angle of 75°.

20. The under-sluices have been increased from 4 bays of 6 feet, as in original design, to 6 bays of 10 feet, which, I think, will be ample, especially as the flooring is 2 feet below that of the head-works.

21. Cast-iron grooves have been provided in piers of head and under-sluices, but I would like to have an opportunity of seeing how those at Okla work before submitting designs for the gates and lifting apparatus. A lump sum has, however, been allowed in the estimate to cover the cost.

22. The design is in exact accordance with the rules for stability laid down by Weisbach[s] who is the only author I know of who writes on weirs of this description. No credit was taken, however, for any counterbalancing pressure on the down-stream side. I have estimated for taking up all the land within the afflux bund above the weir.

Cost of Project and Estimated Return.

23. It will be seen from the general abstract of estimates that the total cost of works, including tools and plant and 5 per cent. for contingencies, is . ₹ 18,45,423
Add 25 per cent. for establishment, &c. . . . . „ 4,61,356

Total cost, . „ 23,06,779

The ₹23,06,779 will be gradually spent in three years, and supposing we spend ₹7,06,779 the 1st year, ₹8,00,000 the 2nd, and ₹8,00,000 the 3rd year, the interest for the 1st year will be ₹7,06,779 at 2½ per cent., for the 2nd ₹7,06,779 at 5 per cent. + 8,00,000 at 2½ per cent., and for the 3rd year, ₹15,06,779 at 5 per cent. + 8,00,000 at 2½ per cent.

24. Assuming, also, that irrigation will be fully developed in three years, and that the canal will pay 1 per cent. the 1st year, 2 per cent. the 2nd year, 3 per cent. the 3rd year, 4 per cent. on ₹23,06,779 will be added to the capital for the 1st year, 3 per cent. for the 2nd, and 2 for the 3rd year. The total cost of the project will then be as follows :—

	₹
Cost of works, tools and plant, contingencies, and cost of establishment	23,06,779
Interest for 1st year	17,669
Ditto 2nd year	55,338
Ditto 3rd year	95,338
Ditto 4th year	92,271
Ditto 5th year	71,971
Ditto 6th year	49,420
Total .	26,88,786

The probable net revenue was shown in page 7 to be Rs. 1,69,988, so that the probable return will be 6·33 per cent.

Material.

25. Kunkar is procurable all along the line of canal and its branches. Firewood is scarce and costly north of the boundary of the Jhansie district, where rubble stone is also scarce. Rubble stone (quartz or granite) is to be had in any quantity in the Jhansie district and near the site of weir, but the only good ashlar quarry within a reasonable distance from weir (43 miles) is at Tapkin Mohal, in the Gwalior State. It is a very hard and durable red sandstone, of fine grain, capable of being neatly dressed. It is the only ashlar used by the Department of Public Works in these parts. Clay for brickmaking will generally be found close to the line of canal and its branches, where there is no mar soil.

Escapes.

26. There will be two or three small escapes on each branch of the canal. They will be very simple and short, as the canal passes close to a number of nullahs. Their cost will be met from the allotment for minor rajbuhas. Their position will be best determined where the rajbuhas have been lined out.

Appendices.

27. Appendix page 12A. shows the time for sowing and reaping the various crops in the district through which the canal passes.

28. Appendices 25A. give the calculations for flood discharges through the two large drainage syphons at mile 16-4 on the main canal, and at mile 39-2 on the Hameerpoor branch.

29. I do not consider that the two inlets for which a design is given in sheet No. 16 will be found necessary, but they have been estimated for.

30. In conclusion, it will be seen from the Appendices, page 16A. and page 6A. *et seq.* that material for the weir is to be had at a convenient distance, and Mr. White's opinion, whose district will most benefit, is entirely in accordance with mine.

JAMES HAIR,
Superintendent of Works, Bundelkhund.

OPINIONS OF REVENUE OFFICERS.

From J. Hair, Esq., Superintendent, Irrigation Works, Bundelkhund, to A. R. Pollock, Esq., Commissioner Jhansie Division, dated Jhansie, the 18th June, 1874.

I was sorry I could not see you yesterday, as I wished to show you the enclosed correspondence about the Betwa Canal, which is the latest out. Will you kindly read it over and make any remarks you see fit which I can quote in my report? There are a few points which it may be necessary for me to explain to you, as I am still feeling too ill to call upon you.

1st.—We do not in the present scheme contemplate khureef cultivation, except to a very small extent: to wit, 21,000 acres of rice.

2nd.—The total area which can be irrigated by the Betwa Canal, as shown on the accompanying index map, and coloured green, is 66,000 acres, whereas the area which can be irrigated theoretically by the whole of the lakes in the Jhansie district is only 17,134. You may thus imagine what an extent of lakes, as proposed by the Secretary of State, would be required to do the same duty as the canal from a small perennial supply in the river. Besides, as you know, there are few sites for lakes remaining, and even if they could be found, which I doubt, the expense of carrying water from them to the far end of the Jaloun district would far exceed the cost of the Betwa Canal. The mar soil is coloured sepia on the map, and was taken from Colonel Ternan's map.

Please return the map and enclosure.

From Commissioner, Jhansie Division, to Superintendent, Irrigation Works, Bundelkhund, dated Jhansie, the 19th June 1874.

I am much obliged to you for sending me the papers connected with the canal project. I will send you a letter on the points noticed by you and the Secretary of State in a day or two, when I receive it from the Deputy Commissioner.

Other information I have called for; the thing has been left out of sight. They refer to years of drought—that is, years when the rain is shown to be considerably less than in ordinary years. But they do not allude to those seasons when the rains may have been plentiful but owing to the rains ceasing altogether in September, the khureef crop, which otherwise would have been flourishing, turns out a miserable failure. This happened in 1872, and I expect I shall be able to show that owing to uneven rains in several years crops have failed which would otherwise, with a steady water-supply, have been good. The argument that the river would not supply sufficient water to serve the canal in years of drought is absolutely a strong one at first sight, but if the canal answers its purpose in nine seasons of short rain, and fails completely in one year of absolute drought, the work will be well worth the expenditure.

The idea of building large lakes at intervals along the course of the canal is a grand one, but utterly impracticable. Between this and the Jumna you must have your lakes of considerable depth to store water in throughout the hot weather, and a dry bottom, and without hills you cannot get such lakes I fancy.

From Commissioner, Jhansie Division, to Superintendent, Irrigation Works, Bundelkhund, dated Jhansie the 22nd June 1874.

COLONEL DAVIDSON has returned me the canal papers which I received from you, with a memorandum showing the rain from 1859 to 1872, and the harvest results therefrom. From this memorandum it is apparent that in 1859-60, 1863, 1864, 1868 and 1872 the rains ceased early and caused loss to the khureef crop, and that if those crops had had canal water to fall back upon they would have been saved. The rainfalls for those years were—1859, 32·8; 1863, 25·1; 1863, 46·9; 1864, 20·6; 1868, 12·3; and 1872, 32·5, which would have sufficed to fill your reservoir, I dare say. But as you only propose to give water to fifteen villages in Jhansie, we must look to White for argument, and I will therefore take the papers and map to Orai with me to-day and put them before the district officers, and see what they have to say.

From Deputy Commissioner, Jhansie Division, to Commissioner, Jhansie Division, dated the 22nd June 1874.

I RETURN you the papers about the Betwa Canal received with yours of the 17th, with a memorandum showing the amount of rainfall in each year and month from 1859 to 1872, and also a memorandum about the failure of crops of late years. It appears to me, after giving the subject my best consideration, that, as regards the Jhansie district, it would be an utter fallacy to suppose that the canal would prove any "real security against famine." Of what benefit it would prove to the Jaloun district I don't know, not having the detail of the estimated irrigable area of 66,000 acres; but, as far as I am aware, the Jaloun district is not really in need of any such costly scheme, the benefits of which would necessarily be extremely partial.

But to go back to this district. Mr. Dubus tells me that some sixteen villages in Mote pergunnah would get water from the canal. Therefore nearly all that pergunnah and the whole of pergunnahs Mhow and Garotha would not benefit at all. Mr. Hair says the scheme only contemplates khureef cultivation to a very small extent. In a year of drought, therefore, the people being dependent on the khureef for their food, would, as far as the canal is concerned, starve before deriving any benefit from it. Large expensive lakes would be equally useless, except in their immediate neighbourhood.

Something might be done to utilize the rain water, and I cannot help thinking that the most practicable scheme in every point of view would be the formation of numerous low earthen bunds. In ordinary years the water would be drained off, and the beds would grow excellent rubbee; in years of drought, whatever rain fell (and even in 1868 there were 12 inches) would render the soil fit to bear a khureef crop. This is the general plan in some villages, and it answers well. A lakh of rupees might perhaps be profitably spent in this way. The people are too poor to carry out such works themselves, but perhaps they would pay at irrigated rates for all such lands.

P. S.—The maps referred to by Mr. Hair were not sent by you. Regarding the small shallow tanks in the Bhander villages, let me refer you to section 74 of Jenkinson's Settlement Report, page 71.

Memorandum of Rainfall, Zila Jhansie.

Years.	Rainfall in inches.					Total rainfall.	Remarks.
	June.	July.	August.	September.	October.		
1858,	...	...	...	...	...	...	No record.
1859,	6·5	6·2	17·4	2·4	·3	32·8	Loss of khureef.
1860,	4·8	8·2	11·	1·1	...	25·1	Ditto.
1861,	15·	16·2	5·7	6·2	...	43·1	Good khureef.
1862,	2·	9·6	6·8	5·9	·6	25·9	Khureef failure from worms.
1863,	5·3	30·5	9·	2·1	...	46·9	Loss of khureef.
1864,	·5	6·3	10·1	3·7	..	20·6	Ditto.
1865,	3·3	9·4	15·3	9·	...	37·	Good khureef.
1866,	10·	8.8	8·5	1·5	...	28·8	Good.
1867,	8·	16·7	11·5	5·4	2·3	43·9	Too much rain.
1868,	1·8	8·2	·2	2·1	...	12·3	Total failure of khureef.
1869,	...	30·1	7·9	9·3	3·6	50·9	Excellent.
1870,	6·1	8·1	10·1	5·6	·2	30·1	Ditto.
1871,	6·8	12·2	15·9	6·1	...	41.	Too much rain.
1872,	3·8	12·1	14·8	1·8	...	22·5	Poor khureef.

Memorandum showing the state of crops since 1858-59 to 1872-73.

Years.	Remarks.
1858-59,	Both crops good.
1859-60,	Khureef partial failure first by heavy fall of rain, and second by drought.
1860-61,	Khureef partially failed in pergunnahs Karara and Pachor on account of drought.
1861-62,	Both crops good.
1862-63,	Khureef below average on account of maggots.
1863-64,	In Garotha and Mote khureef suffered from want of rain.
1864-65,	Partial failure of khureef on account of want of rain in August and September.
1865-66,	Khureef good; partial failure of rubbee from blight.
1866-67,	Both crops good.
1867-68,	Partial failure of rubbee and khureef: the latter from excessive rain.
1868-69,	Total failure of khureef over great part of the district; rubbee very poor.
1869-70,	Both crops above average.
1870-71,	Ditto ditto.
1871-72,	Khureef below half the average, owing to excessive rain; rubbee below average.
1872-73,	Partial failure of both crops from too early cessation of the rains.

NOTE BY SETTLEMENT OFFICER, JALOUN.

Betwa Canal.—The Secretary of State's despatch of 23rd April last, paragraph 2, noting that the Betwa Canal project is said to be intended mainly as a safeguard against famine in exceptionally bad years, doubts if in such years of scanty rainfall there would be rain enough to fill the canal. But local drought, the evil to be conquered, would not disable the canal. The Betwa rises in latitude 23° 14″, longitude 77° 22″, about two miles south of a large lake near the town of Bhopal, and runs a course of 360 miles before its junction with the Jumna at Hameerpoor, adjoining our district; about half of this total length is outside the province of Bundelkhund. In all the extensive tract of country simultaneous drought is extremely improbable. For all but the most extraordinary calamity, therefore, the Betwa for us is likely to be filled with the periodical rains, and the canal to serve its purpose of saving our produce even in seasons that locally may be exceptionally bad.

2. Again, as regards the local rainfall, our unfavourable seasons are oft times owing to a great burst of the monsoons in the beginning, and then either an unduly long dry interval, or an unequal distribution of the remaining rains. The canal would be at hand to prevent the loss of crop, and the consequent hardship to the agriculturist more frequently occurring through these common causes.

3. Another signal benefit that must accrue from the canal is the absolute security it will give to the sowing of the rubbee. In the great majority of cases our bad rubbee harvests are due *to the failure of the latter rains*. The rainfall may show no deficiency in the tally of inches usually denoting a full supply; yet it may be that the September and October showers have been entirely absent or quite insufficient, and if so, the rubbee is jeopardized. Mar might yield some kind of a crop notwithstanding, but the kabar soil, which is nearly 30 per cent. of the whole cultivated area, remains untilled and barren for the season, and is only gradually taken up again. This not uncommon source of danger would be completely nullified by the canal, which must always be brimful of water in those months.

4. Then as to good years, when it is thought that the canal water will run to waste without any call for it during the khureef; this assumes that the present system of agriculture will make no improvement, that the *juar* and *bajra* millets, which form the food of the poorer classes, and which never will be ordinarily irrigated, will continue the staples of the khureef, together with cotton. I altogether differ from this view. Let water but pass the doors of the people and the irrigable khureef staples, rice, sugarcane, and perhaps indigo (cotton we already have), will speedily come into vogue; they are not now grown simply because it is impossible to grow them without water. Within the last few years subsequent to the settlement, whenever kucha wells could be economically dug they have been constructed, and the sugarcane crop introduced. Although, therefore, the present scheme is said not to contemplate khureef cultivation to any extent, the strong probabilities are that, before long, the force of circumstances, induced by the operation of the most natural motives, will invest it chiefly with the character of a khureef canal, and its utility in the rubbee in almost all years is indisputable.

5. Paragraphs 3 and 4 of despatch refer to engineering questions. But as it is said that the canal, as at present devised, will only control the irrigation of 66,000 acres, and this district on the lines of the canal and its channels can easily find double that quantity of irrigable land, the expedient of storage reservoirs on the affluents of the Betwa would supply the means of increasing the power of the canal to an important degree. As to a system of gorge tanks or reservoirs, this district does not possess the physical facilities for it.

6. It is venturesome to say so without data, but my belief is that the return from the canal, when once it is fully developed, has been much too cautiously calculated.

7. In every view we sadly want the canal. In the words of Government—"it will, if completed according to its present design, cause an improvement hardly at present to be imagined, and make the wilderness to blossom as a rose."

Orai, the 30th June, 1874.

From the Commissioner, Jhansie Division, to the Superintendent, Irrigation Works, Bundelkhund, dated Jhansie, the 7th July, 1874.

I RETURN you the correspondence you sent me on the Betwa Canal project with many thanks.

I have had no leisure to think of it, even much less to write about it, and moreover the information at my disposal is so meagre, that I really have no grounds on which to base an opinion as to the probability of the area which will benefit by the canal water being in excess of what has been estimated.

The two questions are—will the canal always have a sufficiency of water in years of drought? and will the project be justified by the results, direct and indirect? You cannot reply to the former question without having data gathered from the results of 20 or 25 rainy seasons, and that we do not possess. There is no record, that I am aware of, showing the volume of water in the river in any time in any year of drought; nor can we gather information from any reliable source as to the rainfall between Jhansie and the place where the Betwa rises for a series of years, and therefore, as far as I can see, we can only conjecture whether there will or will not be a sufficient supply of water in the canal in a year of drought to ensure a khureef crop to the villages within reach.

As to the beneficial results of the canal, supposing water always to be procurable there, they will be next to none in the Jhansie district, and I leave Jaloun to speak for itself through its Settlement Officer, Mr. P. White, whose memo. I enclose.

The only decided opinion that I have formed on the subject is, that if you can ensure a supply of water in all years, the canal will be most valuable to Jaloun; but if in years of drought water fails, the project had better be abandoned.

Docket from the Superintendent, Irrigation Works, Bundelkhund, to the Deputy Commissioner, Jhansie Division, No. 538, dated Jhansie, the 7th July, 1874.

HAS the honour to enquire whether any information can be obtained in his office of the rainfall at Jhansie for the months of July, August, and September of the years 1830, 1834, and 1838.

From the Deputy Commissioner, Jhansie Division, to the Superintendent, Irrigation Works, Bundelkhund, No. 172, dated Jhansie, the 7th July, 1874.

IN REPLY to his docket No. 538 of to-day's date, has the honour to state that no such information as the above is procurable for this district.

Table of Discharges of the Betwa River.

Year.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
1866	...	...	...	...	...	...	...	...	...	...	...	†649·01	...	...	...	...	...	...	...	...	...	...	21	1,028
1868	18	878	5	740	6	343	5	196	6	100	6	70	6	120	22	4,072	30	1,500	...	...	81	674	71	
	24	807	17	590	18	250	17	145	18	89	19	68	18	914								1,028		
	30	741	29	427	30	220	29	109	30	74	30	68										538		
1869	12	62	...	53	...	44	...	15	...	...	...	...	...	22,000	28	11,144	...	45,000	...	...	23	340	4	815
																					21	535		
1870	...	400*	17	228	27	77	18	13	...	...	...	...	2	2,375	...	...	...	...	...	...	23	215	29	215
							23	12					23	55,953										
1871	26	344	...	*250	...	*70	*10						31	29,997										
1872	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	27	415
1873	24	223	28	217	26	110	26	15	...	...	24	15	...	...	...	†640·81	3	46,446	18	4,114	27	1,037	27	891
1874	...	...	1	578	...	...	...	...	...	...	...	...	...	†632·79	9		18	1,457·68						
			26	354																				

* These figures are reduced from the average gauge reading for the month.

† These are the reduced levels of water surface at time of observation.

Table showing rainfall during Monsoon months, in connection with irrigation in Bundelkhund.

Station.	Month.	1862.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869	1870.	1871.	1872.	1873.	Means.
SAGAR	June		...	...	...	...	...	...	...	...	3·0	...	...	...	...	0·0	...
	July		...	...	...	...	...	...	...	...	10·4	...	...	...	...	6·4	...
	August		...	...	...	...	...	...	...	...	3·3	...	...	...	...	13·2	...
	September		...	...	...	...	...	...	...	...	14·3	...	...	...	...	16·2	...
	October		...	...	...	...	...	...	...	...	0·0	...	...	...	...	0·0	...
	TOTAL		...	...	...	...	...	...	...	...	31·0	...	...	...	...	37·8	...
INDORE	June		13·0	...	...	...	...	...	...	...	3·1	...	...	...	...	4·8	...
	July		11·8	...	...	...	...	...	...	...	12·3	...	...	...	...	3·8	...
	August		2·8	...	...	...	...	...	...	...	10·8	...	...	...	...	6·3	...
	September		1·7	...	...	...	...	...	...	...	5·9	...	...	...	...	9·0	...
	TOTAL		29·3	...	...	...	...	...	...	...	32·1	...	...	...	...	23·9	28·4
BANDA	June		...	...	...	...	...	1·6	·6	8·0	2·6	0·0	2·5	3·5	·7	0·0	...
	July		...	...	...	...	...	4·1	14·6	16·1	5·4	15·1	12·4	9·7	11·6	20·9	...
	August		...	...	...	...	...	6·7	4·6	15·9	1·4	4·0	16·7	10·8	15·9	4·5	...
	September		...	...	...	...	...	1·0	12·3	18·2	11·1	9·6	11·5	9·6	1·7	6·7	...
	TOTAL		...	...	...	...	...	13·4	36·9	58·2	20·5	28·7	43·1	33·6	29·9	32·1	32·8
JHANSI	July		24·4	32·4	21·1	42·8	20·1	32·7	18·8	39·0	10·5	43·3	28·8	37·0	29·7	42·9	30·2
	August		...	...	...	...	...	...	...	...	14·0	...	...	...	34·9	...	...
	September		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Whole year		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
HAMEERPOOR	July		24·3	32·4	29·6	33·5	12·7	26·6	30·4	42·5	15·0	30·7	40·9	34·9	33·5	34·7	30·1
	August		...	...	...	...	...	...	...	...	...	...	...	...	39·8	...	...
	September		...	...	...	...	...	...	...	...	18·6	...	...	...	28·7	26·7	27·86
	Whole year		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Ditto		...	...	...	...	...	...	...	...	32·67	...	...	...	...	...	...
	Ditto		...	...	...	...	...	...	...	...	74·1	...	...	...	...	...	...
DECCAN*	Whole year		...	...	...	...	...	...	...	...	49·8	...	...	...	...	...	...
BOMBAY	Ditto		...	...	...	...	...	...	...	...	31·5	...	...	...	...	...	...
BELGAUM	Ditto		...	...	...	...	...	...	...	...	88·0	...	...	...	...	...	...
DHARWAR	June		...	...	...	...	...	...	...	...	162·5	...	...	...	...	...	...
	July		...	...	...	...	...	...	...	...	166·5	...	...	...	...	...	...
	August		...	...	...	...	...	...	...	...	49·6	...	...	...	...	...	...
	September		...	...	...	...	...	...	...	...	4·9	...	...	...	...	...	...
	October		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
MATHERAN	TOTAL		...	...	...	...	...	...	...	...	471·5	...	...	...	...	...	...

Mean 24·8 31·3

* Obtained from Sanitary Commissioner, Bombay.

CORRESPONDENCE ABOUT RAINFALL.

From the Reporter on Meteorology, North-Western Provinces, to the Joint Secretary to Government, North Western Provinces, P. W. D., Irrigation Branch,—No. 199, dated Roorkee, the 29th June 1874.

IN REPLY to No. C.537W. of the 20th instant, I have the honour to state that there are no records of any rainfalls in this office previous to the year 1863; but with a view of answering, if I could, the questions put, I have consulted all the records of Government of the North-Western Provinces which are to be found in the library of the Thomason College, but I can find none going so far back as the years in question. I have also consulted Mr. Girdlestone's report on "Past Famines" in the North-Western Provinces, and although he mentions the occurrence of famines in Bundelkhund in 1834 and 1838, yet he does not quote any measured rainfalls. Mr. Girdlestone alludes frequently to the reports of Mr. (Collector) Rose on the state of the crops in these years in Bundelkhund; if access to these can be had, possibly the information wanted may be obtained, but beyond this, and a reference to the records of the Revenue Board, I regret my inability to suggest anything further.

From the Deputy Commissioner, Sagar, to the Assistant Secretary to Government, North-Western Provinces, P. W. D., Irrigation Branch,—No. 2109, dated the 7th July 1874.

I HAVE the honour to acknowledge the receipt of your letter No. 767A. of the 24th ultimo, and in reply beg to enclose herewith a statement showing the rainfall in Sagar during the monsoon months of 1868.

2. I regret, however, that I cannot report whether the rainfall in 1834 or 1838 has been more or less than that of 1868, as no papers are forthcoming from which the information can be obtained. It appears that no statistics used to be kept up at that time.

From the First Assistant Agent to the Governor-General for Central India, to the Joint Secretary to Government, North-Western Province, P. W. D., Irrigation Branch,—No. 1101, dated the 18th July 1874.

I HAVE the honour, by desire of the Agent, Governor-General for Central India, in reply to your No. C.557W. of 26th ultimo, to forward a statement of rainfall at Indore for the seasons of 1860 and 1868.

There are no records extant of the rainfall of 1830-34-38.

From the Under-Secretary to Government of Bombay, Irrigation Branch, to the Joint Secretary to Government, North-Western Provinces, P. W. D., Irrigation Branch,—No. 292 I., dated Bombay Castle, the 27th July 1874.

IN REPLY to your letter No. C.534W., dated 20th ultimo, I am directed to forward herewith a statement prepared by the Sanitary Commissioner showing the rainfall in the Konkan and Deccan, and one station within the Ghâts, Matheran, for the year 1868.

2. I am to express regret at being unable to furnish you with any information for the years 1830, 1834, and 1838. Every enquiry has been made, but no trace of the records can be found.

Statement showing the time for sowing and reaping the various crops in the Districts through which the Betwa Canal passes.

1		2	3	4	5	6	7
No.	Fasl.	Name of crops or cultivation.	Date of sowing crops.	How much sown per acre.	How sown.	In what kind of soil sown.	How the fields are prepared.
1	Khureef	Kapas (cotton)	Middle of June	10 seers	After twice ploughing the fields the seed is sown.	In all kinds of soil	By ploughing the fields twice.
2	Ditto	Juar	Middle of June to middle of July.	5 ditto	Ditto ditto	Ditto	Ditto ditto.
3	Ditto	Bajra	Middle to end of July	4 ditto	Ditto ditto	Pandwa, kachar, parwa, and rakar moti.	Ditto ditto.
4	Ditto	Dhan (paddy)	July	1 maund	Ditto. The seeds are sown in a separate place, whence they are transplanted to the fields.	In all soils except kabar and mar.	Ditto, and making bunds around to confine the water in the fields.
5	Ditto	Mung, mas	Middle of June to middle of July.	5 seers	After twice ploughing the field's seed is sown.	In all kinds of soil	By ploughing the fields twice.
6	Ditto	Moth	Ditto	5 ditto	Ditto ditto	Ditto	Ditto ditto.
7	Ditto	Indian-corn	Ditto	5 ditto	Ditto ditto	Ditto	Ditto ditto.
8	Ditto	Roets	Ditto	3 ditto	Ditto ditto	Ditto	Ditto ditto.
9	Ditto	Kodo	Ditto	3 ditto	Ditto ditto	Ditto	Ditto ditto.
10	Ditto	Kakan, sama, phekar, rali, kutki, and kotka.	15th June to 31st July	4 ditto	Ditto ditto	Pandwa and rakar	Ditto ditto.
11	Ditto	Sesamum (pahli)	1st to 30th August	3 ditto	Ditto ditto	Banjar fit for cultivation	Ditto ditto.
12	Ditto	Sugarcane	January to middle of April	.....	The cane is cut into pieces and put into a soft soil, which is transplanted after budding.	In all soils except kabar and mar.	The fields are first irrigated and then ploughed from three to six times, and after cleaning and again irrigating the soil it is transplanted.
13	Ditto	Ginger, gwinyan, yam, turmeric, Sakarkand, zaminkand, and muli.	15th June to 15th July	6 maunds ginger, 3 maunds others.	They are put 6 inches under the surface of the ground and covered with leaves.	Ditto	After spreading the manure the land is twice ploughed.
14	Rubbee	Wheat, barley, gram, peas, masur, alsi, and mustard.	10th October to 30th November. Gram requires to be sown a little earlier.	1 maund wheat; 20 seers alsi, mustard; 30 seers others.	The seeds are spread in the furrows made by the plough.	In all soils which require irrigation except kabar and mar.	The fields are ploughed four times in the rainy season and twice in October, and after softening the soil by irrigation they are furrowed.
15	Ditto	Dhan, sati, balta, chena, mung, mas, water-melon, melon, and Ajwain.	1st March to 15th April	3 maunds 10 seers dhan; 1 seer sati; ¼ seer melon and water-melon; 5 seers others.	Dhan and sati on well-tilled lands; water-melon and melon on the sandy banks of rivers and streams; the others similar to bajra and maize.	In all soils except kabar and mar.	The fields are ploughed twice or thrice.
16	Ditto	Arhar	15th June to end of July.	4 seers	After twice ploughing the field the seed is sown.	In all kinds of soil	Ditto ditto.

Statement showing the time for sowing and repairing the various crops in the districts through which the Betwa Canal passes—continued.

8		9	10	11	12	13	14
No.	From what time to what time irrigation is carried on, and in case of drought from what period.	By what diseases the crops are affected, and how removable	When crops are cut.	How crops are cut.	How crops are threshed.	Yield per acre.	Rate of grain.
1	No irrigatition required; but in the case of drought it is required once in the beginning of the months of July, August, and September.	Should it rain in October the seeds fall off	The cotton is gathered from 15th October to 15th January.	Gathered	Cleaned by country machines.	1 maund 10 seers	3 seers per rupee.
2	Ditto Ditto	The crops are blighted and destroyed by the October rains, but they are bettered again if the wind blows from the west.	October	The ears only cut	By bullocks	4 to 6 maunds	20 Ditto.
3	Ditto Ditto	The October rains are destructive	Ditto	Ditto	Ditto	2 to 4 Ditto	20 Ditto.
4	The fields must be filled in with water from time of sowing till cutting.	The north wind does great harm, but the west wind improves.	October and November	Cut from the root	Ditto	12 Ditto	21 maunds dhan and 12 seers rice.
5	Similar to barley and bajra,	If west wind blows it is attacked with smut	October	Ditto	Ditto	5 Ditto	20 seers.
6	Ditto Ditto	Ditto Ditto	Ditto	Ditto	Ditto	5 Ditto	Ditto.
7	Ditto Ditto	Attacked by no disease,	September	The ears are only cut.	By striking with lathis on charpais.	8 Ditto	30 seers.
8	Ditto Ditto	Ditto	October	Cut from the root	By bullocks	5 Ditto	1 maund.
9	Ditto Ditto	The east wind withers this crop,	15th September to 15th October.	Ditto	Ditto	12 Ditto	30 seers.
10	In case of drought it is required to be irrigated every week in June and July.	Attacked by no disease,	Middle of August to 30th September.	Ditto	Ditto	6 Ditto	Ditto.
11	No irrigation required,	East wind destroys and west wind improves	15th October to 30th November.	Ditto	Crushed when dry	3 Ditto	12 seers.
12	Every fortnight from beginning to end	Attacked by no disease, but when it blossoms and then withers, the cane comes to no perfection.	15th November to end of March.	Ditto	The juice is extracted by native machinery.	...	1 seer of gur per rupee.
13	.....	Attacked by no disease,	15th November to 31st January.	By digging up the bulbs.	Cleaned by washing in water.	45 maunds ginger; 25 seers others	20 seers ginger, 1 maund others.
14	Irrigation required in all soils except mar and kabar, and in case of drought, irrigation is required every month till the 28th February.	Rain in February does great harm to the wheat crops, but the west wind soon restores them; grain is destroyed by blight, and wheat and gram are destroyed by frost and mist.	1st March to 15th April	Cut from the roots,	By bullocks	8 maunds	16 seers wheat, mustard, alsi; 20 seers others.
15	Dhan, balta, and chana require weekly irrigation from beginning to 15 days previous to cutting; others require none, except in case of drought, when twice is quite sufficient.	Attacked by no disease,	15th May to 15th June	Cut from the roots. Except water-melon and melon.	Ditto, except water-melon and melon.	Dhan, chana, and balta 10 maunds, mas, mung and ajwain 4 maunds.	Sati, dhan, chana 30 seers balta 1 maund, ajwain, 8 seers, mas, mung 20 seers, melon and water-melon 2 maunds.
16	In case of drought irrigation is required once only in the end of February.	Frost proves destructive to this crop	1st March to 15th April	By cutting the roots.	By striking with lathis.	10 maunds	30 seers.

N.B.—No special date can be assigned to the sowing and cutting of the crops, as the former is commenced on rainfall, and the latter when full ripe and ready.

Statement of Distribution of water and Dimensions of Channels.

Number of mile.	Height of banks from bed.	Breadth of bank at top.	Outside slope.	Slope of bed one in.	Breadth of bed.	Side slopes inside.	Depth of water.	H. M. D. or R.	Mean velocity.	Discharge.
					MAIN CANAL.					
1 to 19½ .	all deep	digging.	...	2,877	20	1 to 1	7	4·749	3·25	600
					HAMEERPOOR BRANCH.					
0 to 10½ . .	8	10	1½ to 1	3,009	15	1 to 1	6	3·94	2·75	342
10½ to 20½ . .	7·5	8	ditto,	2,891	15	ditto,	5·5	3·65	2·70	300
20½ to 30½ . .	7	7	,,	2,785	15	,,	5	3·45	2·57	257
30½ to 48⅝ . .	6·5	6	,,	2,796	14	,,	4·5	3·28	2·50	214
48⅝ to 58½ . .	6·5	6	,,	5,280	12	,,	4·5	3·00	1·66	120
58½ to 68½ . .	6·5	6	,,	5,280	8	,,	4·5	2·71	1·51	80
68½ to 78½ . .	6	5	,,	5,280	6	,,	4	2·21	1·37	40
					CALPEE BRANCH.					
0 to 11 . .	6	5	1½ to 1	5,280	5	1 to 1	4	2·21	1·37	40
					KOTOUND BRANCH.					
0 to 10½ . .	8	10	1½ to 1	2,509	10	1 to 1	6	3·56	2·75	257
10½ to 20½ . .	7·5	8	ditto,	2,847	10	ditto,	5·5	3·34	2·50	121
20½ to 30½ . .	7	7	,,	2,890	10	,,	5	3·12	2·30	375
30½ to 40½ . .	6·5	6	,,	3,515	10	,,	4·5	2·87	2·00	113
40½ to 50½ . .	6	5	,,	4,611	10	,,	4	2·63	1·60	87
50½ to 58½ . .	6	5	,,	5,280	5	,,	4	2·21	1·37	49

NOTE.—Bazin's coefficients for obtaining mean velocity have been used.

Afflux due to proposed weir across the Betwa at Pureecha.

Adopting the formula given by Neville—

$D = cl\sqrt{2gd_1}\,(d_2 + \frac{2}{3}d_1)$

When D is discharge

c a co-efficient of velocity.

l is length of weir.

2g the force of gravity.

d_1 height of afflux.

d_2 submerged depth, or depth of water above sill of weir.

And taking for c the value 0·625—

an afflux of 6·5 feet will give at the Pureecha weir a discharge x.

$x = 0{\cdot}625 \times 2{,}400\sqrt{64{\cdot}4 \times 6{\cdot}5}(20 + \frac{2}{3} \times 6{\cdot}5)$

$= 1{,}500 \times 2{,}049 \times \frac{73}{3}$

$= 500 \times 20{\cdot}49 \times 73 = 748{,}005$ cubic feet

which is nearly the estimated dischage of Mr. Anderson. Lieutenant Home's discharge is 715,000 cubic feet. Further experiments during the next rains will verify these results.

NOTE.—In accordance with Colonel Brownlow's pencil note the velocity of approach was taken into account, but as it made no appreciable difference in the height of afflux it has been omitted.—J. HAIR.

GENERAL SPECIFICATION.

WEIR AND HEAD-WORKS.

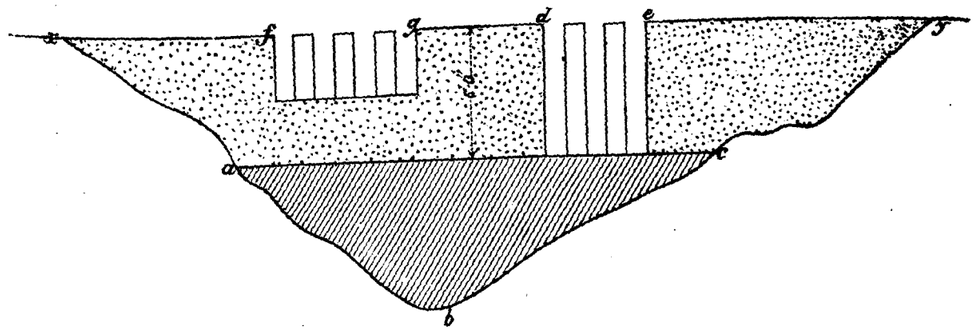
The weir itself will be of rubble masonry, coursed on both faces. The coping of weir will be of ashlar as shown in the section.

2. The steps leading from both flanks down to weir will be of ashlar three feet on bed, of the same thickness as the steps, as shown in the sketch.

The piers and abutments of head-works and under-sluices will be of solid ashlar to a height of 10 feet from bed. The grooved portions of the piers will also be of ashlar, and so will the arches and floorings. The grooves will be lined with cast-iron to a height of 20 feet from bed. The parapet will be of first-class brickwork, and all the other parts of the work will be of rubble masonry coursed on both faces.

3. Both faces of weir and spandrils of head and under-sluices to be pointed with Portland cement in the proportion of one of cement to one of sand, after the rubble joints have been raked out to a depth of two inches and the face well wetted. The ashlar coping of weir will be set in Portland cement. For the foundations of weir the rock will be blasted away to the level shown in the longitudinal section on sheet No. 11, and the whole brought to level surfaces with chisels or picks.

4. The work will first be commenced on the lowest portion of the bed, and there will be no difficulty in diverting the stream with earthen bunds until the work is six or seven feet high. It must then pass over the portion of the weir already built, and to enable the work to proceed until the weir is two or three feet above level flooring of under-sluices, the following mode of construction must be adopted :—



The shaded portion *a b c* on sketch shows the work completed to a height of six or seven feet. The next six feet in height will be built as shown in sketch by the dotted area, leaving the gap *d e* for the water to pass. Small temporary piers about six feet long being built on the up-stream side of the gap to receive sleepers. By the time the work has reached the level *x y*, the whole of the supply, assuming it three feet deep, will be able to pass through the new gap *f g*. The sleepers will then be dropped into the piers in gap *d e*, and the work brought up to the level *x y*. This process will be repeated until the whole of the supply in the river can pass through the under-sluices.

5. Before the end of each working season the masonry of weir must be brought to a uniform level and pointed on upper surface with Portland cement, and to prevent a running joint through the weir, this surface, before commencing work the next season, must have two or three longitudinal channels cut in it five feet wide and one foot deep.

6. The stone from excavation of foundations for weir and head-work will become the property of Government.

7. All the work on the canal will be executed according to the following specifications :—

EARTHWORK.

8. Before work is commenced the ground must be cleared of all jungle, roots, and trees. The cuttings and embankments to be made according to the profiles and levels given on sheets 1 to 7, and no work will be commenced until profiles of the banks, 10 feet wide at each 1,000 feet in length of the canal have been made. Spoil banks need not be rammed, but must be dressed to the proper profile; all other banks will be built in 9-inch layers, slightly concave in the centre; each layer to be well rammed before another is laid on it. No mar soil will be allowed in any bank that has to retain water.

MORTAR.

9. All mortar will be of good wood-burnt kankar lime only, with no admixture of surkhi, sand, or bajri : to be well ground first dry, and then wet in mortar pans at the head-works, and in the common native mortar mill at the other works.

M.

Concrete.

10. To be of the mortar described under that head, and broken stones or hard-burnt broken bricks in the proportion of one of mortar to two of stones and broken bricks, $\frac{3}{4}$ inch gauge. To be well rammed in 6-inch layers, and to be kept wet until the full thickness of the bed is completed.

Brickwork.

11. The bricks to be hard-burnt, of the best clay procurable within a reasonable distance, and to be sand-moulded on tables. They must be of uniform size, well shaped and square, with sharp and regular arrises, and they must ring clearly when struck; when burnt to measure $10'' \times 4\frac{7}{8} \times 2\frac{3}{4}''$.

Report on the stone and kankar quarries and earth suitable for brick-making in the vicinity of the head-works of proposed Betwa Canal.

Stone.

An unlimited quantity is procurable from the Pureecha and Golara hills, which are situated at an average distance of about one mile from the head-works. It is estimated that these hills will together yield about 5,000,000 of cubic feet of excellent stone, the greater part of which is stratified and easily split or chipped into blocks of convenient size and shape for coursed rubble masonry. The rock is gneissoid, a kind of igneous granite, is very hard, and evidently possess in the highest degree the valuable property of resisting the action of water. This was easily ascertained by examining that portion of the Pureecha dyke which abuts on the river. The water has, of course, been flowing over these rocks for countless ages: yet they exhibit no sign whatever of disintegration, and very little even of erosion. There remains no doubt whatever that the supply of stone is unlimited, and that it is of a kind remarkably suited for hydraulic works.

Kankar.

Mr. Mackinnon having been directed to finish his work in four days, had not time to make any exacavation for the purpose of discovering new kankar beds. But he examined and measured three very extensive and well-known beds. The first of these is situated at the site of the proposed weir itself. But, unfortunately, the lime appears to be of very inferior quality, as frequently is the case in quarries on the banks of large rivers. Mr. Mackinnon's estimate of the quality of this kankar is confirmed by the fact that it is never used by the villagers, who procure the limited quantity they require at a greater distance.

The other two beds are situated at the villages of Jijjora and Upara. The Jijjora bed (in Urcha State) is bisected by the Bhabar at about a mile from the mouth of that nala, and is about nine miles south-west of the weir site. The kankar is carted into Jhansie in large quantities, and this would lead to the opinion that the quality is good. It has all the appearance of hydraulic lime. The yield will probably be about 2,000,000 of cubic feet; according to surface measurements the quantity is about 4,000,000 cubic feet. Half this quantity is taken for safety.

The Upara bed is about the same distance from Pureecha, but in the opposite direction, north-east. It is about three miles south of Chirganw, and lies between the villages of Upara and Ghusgowan. The kankar is extensively used by the villagers for well building, and the "steenings" appear to last for upwards of a hundred years, a tolerably safe test of the hydraulic properties of the lime. It is not easy to estimate with precision the quanity of kankar in a bed upwards of a mile long, and of variable or unascertained depth and breadth. But the yield may safely be put down at 40,000,000 cubic feet. Although this bed is not nearer to the proposed head-works than that at Jijjora, it is nearer to the general line of canal, and for this reason, besides the fact that the supply is actually unlimited (of hydraulic lime), is far preferable as a field for permanent works.

These are the only beds large enough to require special description, but there is a small bed near the village of Rhond about half a mile from the head-works; but, like all riparian beds, the kankar appears to Mr. Mackinnon to be very inferior.

It is probable also that small beds might be found by making a few trial pits along the foot of the Golaid hill, but Mr. Mackinnon's time being limited to four days, no such excavation could be made.

The fact, however, is established that there is an enormous supply of excellent kankar within a reasonable distance of the head-works.

Earth for Brick-making.

The following experiment was made for the purpose of determining the quality of the bricks made by the villagers at Pareechha:—Fourteen bricks were taken from the breast of a fresh-burnt "pazawa" and weighed when dry: the weight was 35¼lb. After being soaked in water for 13 hours the weight of the bricks had increased to 37lb., giving a rate of absorption of 5 per cent., which is by no means large. In fracture the bricks had a dark-red appearance; they had a metallic "ring" when struck, and were too hard for the finger-nail to make any impression upon them. Any earth of the kankar species is used by the burners. The supply of this earth is quite unlimited.

12. First-class brickwork will consist of first-class bricks laid in mortar as described. Every brick to be bedded and drawn up in mortar, to be laid in English bond, and no half or other portion of a brick to be used, except as a closer. No joint to be more than $\frac{3}{8}$ths of an inch in thickness. All bricks to be well saturated with water before being put into the work. All mortar must be used fresh in the work, and not more ground wet at a time than can be used within 24 hours. Kucha-pucka brickwork will be of pila bricks in mud, bonded the same as pucka brickwork, no joint being more than half an inch thick.

Rubble Masonry.

13. Rubble masonry to be in courses not more than one foot high, each course to be properly levelled before another is laid on it. No stone to be less than $\frac{1}{4}$th of a cubic foot, the interstices being filled in with smaller stones. Every stone must be laid on its natural bed and properly bedded in mortar. The plan of laying the stones dry and then grouting them will not be permitted.

14. The coursed rubble on the faces of walls to be in courses not less than 6 inches deep, and no stone to be less than 9 inches long and 8 inches broad on the bed, and to be properly squared with the hammer. Headers may be the height of two courses of stretchers, but not more. No header to be less than 2 feet long. One-fourth of the length of the course to be headers.

Ashlar Work.

15. Ashlar will consist of hard sandstone from Gwalior set in Portland cement; no stone to be less than 3 feet long, and no course to be less than 7 inches high. No hollow beds will be allowed, and no joint to be wider than $\frac{3}{8}$ths of an inch. All ashlar will be laid in mortar which has been passed in a dry state through a screen 40 meshes to the inch. The ashlar coping of weir to be 18 inches deep, and no stone to be less than 4 feet 6 inches long and 1 foot 3 inches wide.

16. The other works, such as mud plaster, pucka plaster, tiler's work, &c., will be as specified in the sanctioned Public Works Department specifications for Haidarabad.

Carriage of Materials to Pareecha.

The material to be carried is as follows:—

Rubble stone, 1,159,200 cubic feet, an average distance of one mile.
Stone (ashlar), 121,200 cubic feet, a distance of 43 miles.
Kankar for lime, 543,600 cubic feet, a mean distance of 12 miles.

Rubble Stone.

The rubble stone will be had so close to the weir that there will be no difficulty in carrying 400,000 cubic feet per annum. This work will be most economically carried out by a tramway to the range of hills above the weir, say 1½ mile.

Ashlar Stone.

The carts for the ashlar stone must be able to carry 17 maunds, and it may be necessary to get them from Agra or the other side of the Jumna. To be on the safe side, it is assumed that each cart will carry 12 maunds.

The total weight of ashlar to be conveyed is 121,200 cubic feet × 140lb = 212,100 maunds, or 70,700 maunds per annum. It is assumed that each cart will make the trip to the quarry and back in 8 days, or 37 trips in the working season of 300 days. 37 × 12 = 444 maunds = amount of work done by each cart in the year, and 70,700 ÷ 444 = 160, the number of carts required.

KANKAR FOR LIME.

Taking the weight of kankar at one maund per cubic foot, 543,600 maunds will have to be carried a distance of 12 miles in three years, or 181,200 maunds will have to be carried 12 miles in one year.

Assuming that the district carts will carry 10 maunds and do the journey to and fro in two days, the amount of work performed by each cart during the working season will be $\frac{300}{2} \times 10 = 1{,}500$ maunds, and $\frac{1{,}81{,}200}{1{,}500} = 121$, the number of carts required.

Altogether 160 x 121 or 281, say 300 carts will be required, and there will be no difficulty in obtaining this number, as Mr. Sturt, Assistant Commissioner, says he has had a heavier demand on the district before.

Memorandum by CLINTON ANDERSON, Esq., *Superintending Engineer, on the system to be adopted in delivering material during the construction of the Pareecha weir and head-works.*

1. THE quantities in the weir and subsidiary works are—

	Rubble.	Ashlar.	Brickwork.	Pitching.	Blasting.
Weir	524,747	78,436	...	...	94,434
Head-sluices	241,029	15,950	2,327	9,870	14,705
Under-sluices	46,260	26,842	...	...	3,510
Right flank	154,320	...	1,405	...	9,000
Bunds	...	...	...	138,600	...
	966,356	121,228	3,732	148,470	121,649

The total quantity of material to be carried to the weir and subsidiary works is therefore—

		Cubic feet.
Rubble stone	966,000 x 1·2 =	1,159,200
Ashlar		121,200
Brickwork		3,700
Pitching		148,500
Lime	(966,000 + 121,200)$\frac{1}{2}$ =	543,600
	TOTAL .	1,976,200

If the works are to be completed in three years the material to be carried in one year will be—

$$1{,}976{,}200 \div 3 = 658{,}700 \text{ cubic feet.}$$

The distance from the quarries, ashlar-yard, and lime-yard is about 1·5 miles. Allowing four trips daily for each truck, which is equal to a run of 12 miles, taking the working season at 200 days (15th October to 15th June), and the quantity carried by each truck at 30 cubic feet, the number of trucks required is—

$$658{,}700 \div (200 \times 30 \times 4) = 28.$$

Mr. Hair has estimated for 40 trucks, or nearly 50 per cent. in excess of the actual requirements. The extra wagons will be wanted to supply the place of those that may be undergoing repairs.

2. The quantity of material required is thus distributed :—

	Rubble.	Ashlar.	Brickwork.	Pitching.	Lime.
Head-sluices	289,235	15,9 50	2,327	9,870	123,490
Under-sluices	55,512	26,842	...	...	36,550
Left bank					
Right bank	185,184	...	562,776		
Bunds	...	...	1,405	...	77,860
			...	138,000	...
Right bank					
Weir	626,839	78,436	402,449	...	305,700
			...		
River-bed			1,010,975		

Left bank	562,800	
Right bank	402,400	
Bed of river	1,011,000	
		1,976,200

The cubical contents of the weir to 1,264 feet from the right bank is 125,590 cubic feet. Thus, then, the quantity that, for economical purposes, should be supplied from the two banks of the river is—

Left bank—		
1. Head-sluices and under-sluices		562,800
2. Half of weir between 1,264 feet and left bank		442,750
		1,005,550
Right bank—		
1. Right flank, &c.		402,400
2. Weir from right flank to 1,264 feet		125,500
3. Half of weir from 1,264 feet to left bank		442,750
		970,650
	TOTAL .	1,976,200

To save the expense of carrying any material from the left to the right bank, it is proposed to open quarries on both banks.

On the right bank the quarry will be at the hill near the end of the afflux bund. A single line of tramway will be laid on the afflux bund to within 2,000 feet of the right flank. From this point the tramway will curve to the left, and, running on a gradient of about 1 in 100, will reach the weir on a level with its crest. The tramway will be carried along the line of weir on masonry piers spanned with timber; the piers will be built of the same section as the weir, so that a portion may remain in the work.

On the left bank the quarries will be at the hills close to the line of canal. A single line of tramway will run from the quarries to the head-sluices, with sidings to the ashlar and lime yards and to the edge of river-bank.

The material brought down by the tram on the right bank will be delivered along the line up to 1,264, while that brought down by the tram on the left bank will delivered at the head-sluices and on the river-bank.

As a good portion of the material will be delivered in one spot, it will be necessary to construct front tilt wagons.

As but 14 trucks will be worked in the right and 14 in the left tramway, there will be no need of double lines. Again, the length of the lines are so short that the working of a single line should be an easy matter.

The estimate of the tramways must be increased to cover the cost of thei ncline in the right bank, the extra quantity of rails, sleepers, &c., required for the tramway on the weir.

The additional cost is R19,144, as given in the following abstract :—

ABSTRACT.

Items.	Rate.	Amount.	
	R	R	R,
19,700 cubic feet masonry	10·	1,970	
948 ,, beams	4·	3,792	
1,108 ,, sleepers	2·	2,216	
8,160 maunds rails	16·	5,056	
874,000 ,, excavation	5·	4,370	
			17,404
10 per cent. contingencies	...	...	1,740
TOTAL	...	...	19,144

The ashlar for the floor and piers of the head-sluices and under-sluices will be let down on earthen inclines; that for the coping of the weir will be delivered in the same manner at the left flank, and will thus be put upon trucks and delivered along the line of weir.

Comparison of the cost of steam and native mortar mills.

The mortar required daily is 900 cubic feet. A steam mortar mill will grind 150 cubic feet per diem; therefore the number required is 6.

A native mortar mill will grind 30 cubic feet per diem, sufficiently fine for rubble masonry: hence the number required is 30.

Comparison.

	R
Steam mortar mills—	
6 will cost at R4,000 each	24,000
Native mortar mills—	
30 will cost at R10 each	300
Saving	23,700

One engine will consume 35 maunds of wood in a day; therefore 6 will consume 210 maunds.

	R
210 maunds of fuel at R25 per 100 . . .	52·5
Labour, belting, oil, repairs, &c. . . .	17·5
Daily cost of six mills . . .	70
A native mill is worked by a pair of bullocks at 4 annas each, working six hours, or per diem	1·0
Labour in watering, driving, turning, &c. . .	·5
R . .	1·5

30 will therefore cost R45 per diem, or R25 less than the steam mills.

There will be 600 working days, so that the saving in native mills will be . . . . . 15,000 for working

and . . . . . 23,700 in first cost.

Total saving R . . 38,700

Memorandum on the time required to complete the Pareecha weir and head-works.

1. The quantity of ashlar to be dressed is 121,228 cubic feet, and 200 masons can be employed, each man being able to dress eight superficial feet of stone per diem.

The average size of the ashlar blocks may be taken at 3 feet long, 1½ foot wide, and 1¼ foot thick, the cubical contents being 3·75 cubic feet, and the superficial area 22·5 square feet.

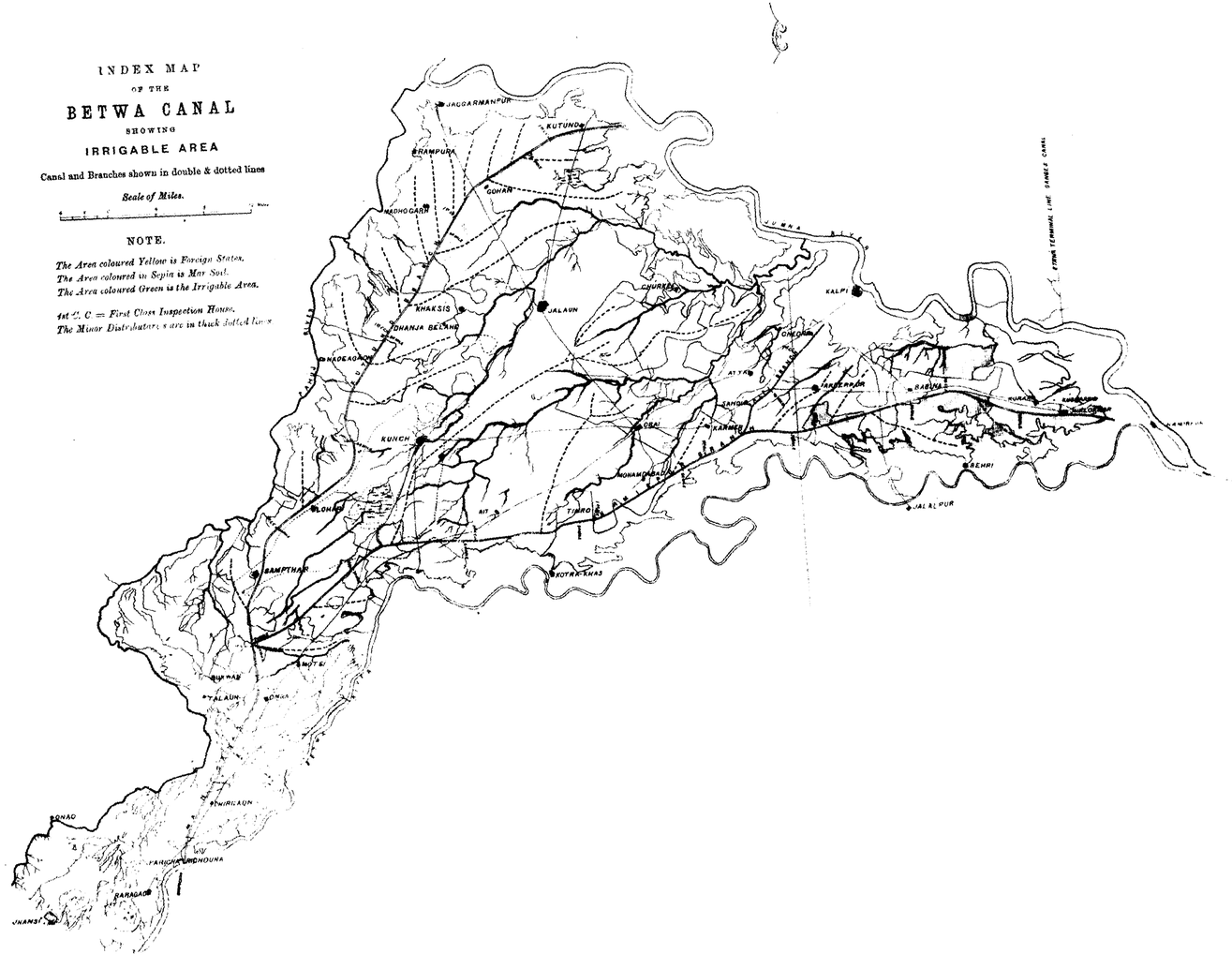
The number of blocks required is, therefore, $\frac{121,228}{3·75} = 32,324$, and the superficial area to be dressed 727,290 square feet.

One mason can dress eight square feet of stone per diem, and 100 men can therefore dress 1,600 square feet; the number of days in which the work can be done $= \frac{727290}{1,600} = 455$.

Allowing 300 working days in the year, the whole of the dressing can be done in *a year and a half*.

It will take some time before stone begins to be delivered at Pareecha; in organizing work, and in finishing up after all the ashlar is laid: these may be assumed to require a year; hence 2½ years will be taken; to allow for contingencies, however, three years have been allowed in the estimates.

2. The total quantity of rubble masonry and brickwork required is 970,088 cubic feet, and taking 20 cubic feet as the quantity which one man can lay in a day, and the time 2½ years at 200 working days a year (15th October to 15th June), the number of men required is found to be $\frac{970,088}{2½ \times 200 \times 20} = 97$, say 100 *masons*. There will probably be no difficulty in getting this number together.



No. C.1043W., dated 2nd November 1874.

Report by the Chief Engineer, Irrigation Works, North-Western Provinces.

SECTION I.

HISTORY OF THE PROJECT.

BEFORE entering upon a detailed examination of the project submitted by Mr. J. Hair, the Superintendent of the Bundelkhund Irrigation Works, it appears requisite to sketch its history.

2. The first proposal for the construction of a canal from the Betwa was made by Major-General (then Captain) Strachey in a memo.* dated November 1855, which was the result of a flying visit to Bundelkhund. An establishment provided to investigate the subject perished in the Mutiny. In 1859 the question was again considered, but nothing was done until the end of 1867, when Lieutenant Home, R.E., was directed to conduct the enquiry, and accordingly in 1867-68 the country was examined with a view to ascertain its capabilities for the projection of canals.

* Progs. $\frac{A}{W}$, August 1867, No. 75.

3. In August, 1868 Lieutenant Home submitted a preliminary report which established that it is practicable to utilise the waters of the Betwa river for irrigating the tract enclosed by the three rivers Jumna, Pahooj, and Betwa. Therefore further and more complete investigations were ordered, and in September, 1868 definite instructions for prosecuting the enquiry during the ensuing season were sent to Lieutenant Bagge, R.E., who had in the meanwhile relieved Lieutenant Home.

Progs. $\frac{A}{W}$, February 1869, Nos. 9 to 39.

4. Before leaving India Lieutenant Home sent in a more detailed project for a Betwa Canal. The cost was estimated at ₹19,29,246; the income at ₹1,52,500, or 7·9 per cent. This project was submitted to the Government of India with a note by Colonel Greathed, pointing out various alterations in design which were required.

5. Mr. Anderson, Superintending Engineer, was now deputed to examine the projected alignment of the Betwa Canal. The conclusions he came to were :—

Progs. $\frac{A}{W}$, May 1869, Nos. 5 to 9.

I. That Pareecha, the site fixed by Lieutenant Home, is the best position for a weir.

II. That for four or five months of the year 1,000 cubic feet of water could be depended on, even in years of deficient rainfall.

III. That further investigation was needed, however, before the alignments could be definitely fixed, and that until this was settled work should not be begun.

The Chief Engineer agreed to these conclusions and decided that the head of the new canal should be fixed at Pareecha.

6. In November 1869 Lieutenant Bagge, R.E., submitted a detailed project and estimate for the Betwa Canal, including provision of storage for water in the bed of the river with a view to perennial irrigation. But the amount of the estimate, 90 lakhs, was prohibitive; and as Lieutenant Bagge was obliged from ill-health to go to England, where he died, and as Mr. Anderson's services ceased to be available on account of his employment in supervising the construction of the Agra Canal, the question of the Betwa Canal was shelved until April, 1872, when, after the country had been visited by Sir W. Muir and the Chief Engineer, the approval of the Government of India was solicited to the preparation of detailed estimates of a scheme limited to affording irrigation for rubbee and *monsoon* khureef and excluding mar soil from present consideration.

Progs. $\frac{A}{W}$, June 1873, Nos. 325-56.

Progs. $\frac{A}{W}$, June 1873, No. 34.

7. In June, 1872 the Government of India sanctioned the preparation of detailed estimates, but desired that the eventual irrigation of mar soil should be contemplated in designing the works, and that a full discussion of the question of returns should at the same time be gone into.

No. 475I., dated 18th June.

Progs. $\frac{A}{W}$, June 1873, No. 42.

8. In March 1873 a fresh estimate for the canal was drawn up in accordance with wishes of the Government of India and the Chief Engineer's instructions.

Colonel Brownlow, basing his calculations on what were afterwards proved to be incomplete data, arrived at the conclusion that a greater return than from 2 to 3½ per cent. was not to be expected. In consequence of its defective financial prospects the project was again referred for local consideration by the Government of India, and in July again submitted to the Government of India with a note by Colonel Greathed, who had in the meantime returned to India. Lieutenant-Colonel Brownlow admitted that there is now hope of the ultimate returns being 50 per cent. more than he had put them at.

Progs. $\frac{A}{W}$, June 1873, Nos. 51 to 55.

9. The results of correspondence on the subjects of rates to be levied, the liability of Bundelkhund to periodical droughts, the volume of water in the Betwa, having likewise been duly submitted, the Government of India sanctioned, on the 4th November 1873, the preparation of detailed estimates for the Betwa Canal for submission to the Secretary of State. On the recommendation of the Inspector-General it was directed that the project should be restricted to a canal for monsoon and dry season irrigation without reservoirs and without any provision for navigation.

The estimate now under review is that called for by the Government of India.

SECTION II.

NECESSITY FOR IRRIGATION.

10. Colonel Greathed's report on the droughts which have occurred in Bundelkhund, submitted to the Government of India in September 1873, is divided into three parts :—

Progs. $\frac{A}{W}$, September 1873, No. 102.

I.—The Effects of Drought on the People.

The sufferings of the people in 1868-69 and in former famines are described in a narrative compiled from reports of various district officers, and the condition of the inhabitants of the Doab watered by the Ganges Canal in 1868-69 is contrasted with the terrible state of Bundelkhund in the same year. Mr. G. Ricketts, Officiating Commissioner, in a memo. dated 8th July 1873, showed that between 1865 and 1871 the population of—

Jhansie had decreased	...	...	45,669
	or 12·7 per cent.		
Banda ...	...	...	27,929
	or 3·8 per cent.		
Jaloun ...	...	...	4,800
A decrease of			78,398

in three districts only; whereas in Lalitpur, which will be indirectly benefited, the decrease in population during this period amounted to 33,555, or 13·5 per cent. Sir W. Muir, when Settlement Officer of Calpee, had reported that in 1834, 38,000 houses out of 75,000 were deserted.

II.—The Results on the Land Revenue Receipts.

In the first place the assessment has been made lighter than elsewhere in the North-Western Provinces to compensate cultivators for the frequent bad years, and, as seen from a table given at page 5 of Chief Engineer's report on droughts, there have been remissions in Bundelkhund amounting to ₹33,63,989 in ten years, or about 3½ lakhs per annum, the greater part of which is due absolutely to famine.

The rents fixed by the recent settlement of Jaloun average ₹1-7-1 per acre, while the former rents averaged ₹2-0-5 per acre. This shows that in the district of Jaloun there has been a positive diminution of production in recent years.

Board's Revenue Report for 1872-73, Appendix III of D Settlement Series.

III.—The Amount disbursed by Government in Relief of Distress.

In the famine of 1868-69, for which alone there is a detail of expenditure under this head, the amount given away by Government in Bundelkhund, exclusive of Lalitpur, which will be only indirectly benefited by the proposed canals, was ₹5,29,224. The total outlay on that one famine (including Lalitpur) was ₹16,24,136. The amount of uncollected land revenue is included in this sum.

Progs. $\frac{A}{W}$, September 1873, Nos. 91 to 102.

These figures, it will be observed, show only the loss to Government; the loss to private property and of life cannot be estimated.

11. The revenue officers of the districts of Bundelkhund, when asked for an expression of opinion as to the need for irrigation, have now unanimously declared that in every part of the country the people are eager to be supplied with water.

A species of grass termed "kans" spreads over fields left fallow and cannot be eradicated without extreme labour and expense which the people are incapable of affording; consequently the cultivable area is year by year diminished by the increase of this grass, whilst the power of removing it decreases annually. Vast tracts have been thrown out of cultivation, and the subject at present occupies the earnest attention of the district officers. Artificial irrigation will terminate the long periods during which land now lies fallow for want of moisture sufficient to make ploughing and seeding practicable, and will go far to prevent the spread of this noxious weed and to kill off that which has already grown up.

12. Sir W. Muir was deeply impressed with the absolute need of irrigation for Bundelkhund as the only safeguard against famine.

13. Wells cannot be relied upon for this purpose, as the following figures will show; it being premised that the water in wells which depends on surface drainage is soon exhausted and requires an ample fall of rain to renew it :—

District.	Depth at which water is first met with.			Depth at which permanent supply is attained.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
Jhansie	70	15	27	...	...	...
Jaloun	50	20	30	180	150	165
Humeerpoor . . .	90	45	67	105	...	90
Banda	...	12	77	157	...	...
Allahabad . . .	83	23	48	...	...	...

In the hilly tracts some small extent of irrigation is effected from minor channels leading from tanks, but in the plain countries no such stores of water are met with.

14. Thus the great depth of water below the surface of the ground, the scarcity of supply in wells and the cost of sinking them, renders resort to wells in all but the richest and most highly-manured lands impracticable. Tanks can only be made with advantage in the hilly tracts: for the plains, therefore, the large rivers must be depended on for a supply of water for irrigation purposes.

SECTION III.

COUNTRY TO BE IRRIGATED.

15. Endeavour has naturally been made to fix the head of the Betwa Canal as far up the course of the river as practicable, in order to extend the area of irrigation. But the rugged character of the country renders it impracticable to establish the head above latitude 25°-42′-30″. North-west of this line the country has an undulating surface frequently broken by quartz dykes and disintegrating masses of granite and its associate rocks; the nearness of these rocks to the surface, the irregularity of the elevations, and the rapid fall of the country eastwards towards the Jumna present insuperable obstacles to the construction of a canal.

16. But on the left bank the district of Jaloun and the native territories of Omrah and Samthar are well adapted for the distribution of water from canals.

This tract, forming a triangle included between the rivers Betwa, Pahooj, and Jumna, is accordingly the area with which we have to deal in the present project. It is represented in the index map facing this page.

The profile of this tract shows two watersheds, one bordering each of the rivers Pahooj and Betwa. The area is drained by two separate channels flowing towards the Jumna, uniting before they fall into that river, about six miles from the town of Calpee.

17. The central part of the Betwa-Pahooj Doab is found to be a depression composed of that mar or black cotton soil concerning whose capacity for irrigation much controversy has arisen. For the present, however, it is necessary to omit mar from our consideration and to confine the provision of irrigation to the lands bordering

See sections accompanying Captain Bagge's report.

the watersheds which consist of "kabar," a rich loam, "parwa," sandy soil, and "rakar," coarse sandy soil with nodules of quartz and kankar and gravel-beds. Excluding the large central mar area, the different soils are met with in the following proportions :—

Mar	29 per cent.
Kabar	53 „
Parwa	14 „
Rakar	4 „
	100 „

18. The three boundary rivers run in deep narrow valleys, the edges of which are greatly cut up by ravines, those of the Jumna extending from three to five miles from the stream.

The following table gives the areas of the country enclosed by the three rivers, exclusive of the low lands bordering the streams :—

British or Native Territory.	District.	Areas.	
		Square miles.	Acres.
British	Jhansie	49·0	31,360
Native	Samathr	155·5	99,520
British	Jaloun	1,115·0	713,600
Native	Bauni	72·5	46,400
Do.	Behri	10·0	6,400
Do.	Datia	36·5	23,360
British	Humeerpoor	53·5	34,240
	TOTAL	1,492·0	954,880

British	1217·5 square miles, or	81·6 per cent.
Native	274·5 „ or	18·4 „

Of the total area 518·42 square miles are barren and ravines, and of the balance 35 per cent. is mar; 1,492—518·42=973·58 square miles, the cultivated and culturable area; and $\frac{973·8 \times 65}{100}$ =63·83 square miles=405,011 acres, the area of arable land, less "mar," and the area requiring irrigation; 330,489 acres being in British territory and 74,522 acres in Native States.

SECTION IV.

SUPPLY OF WATER.

19. The next question to be considered is the supply of water available.

The table in Appendix, page 9A., gives all the discharges of the river Betwa measured since 1866, including the famine year of 1868, of which Mr. Anderson wrote in 1869 :—

"The Betwa no doubt was lower during last season than it has been known to be for years, some say since the famine of 1837-38."

See Progs., May 1869, page 7.

Mumtaz Ali Khan, an intelligent and well-informed native gentleman of Etawah, whose statements are reliable, was Deputy Collector of Humeerpoor in the year 1838 and had frequent occasion to go to Jhansie. He says that at no period of the monsoon was the depth of water at the Baruah Sagar Ghât, on the river Betwa, less than three feet. This corresponds to a discharge of 450 feet per second.

It is quite impossible to compare the volume of 1868 with that of either of the years 1834 or 1838, for before 1866 no discharge was ever taken. It is therefore necessary to have recourse to an inductive process of establishing the sufficiency of supply in the Betwa in the following manner :—

20. An examination of the table of rainfall during the monsoon months (Appendix, page 10A.) shows the fall in 1868 to have been much less than in any other of the fourteen years of which a record is available, and we have proved above that the volume of the river in 1868 was extraordinarily low. Now, turning to the diagram of discharges of that year (Appendix, page 26A.), we observe a rise of 1½ foot about the 15th July, which is shown in the table of discharges (Appendix, page 9A.) to have raised the volume to 914 cubic feet on the 18th, on which date the measurement was taken. Thus from the 15th July we had water enough to have filled our canal, and the diagram (Appendix, page 26A.) shows that the river even in the worst year ever known to any persons now alive remained always above this height until the 15th October.

21. *This minimum of water would have produced and matured the entire harvest of maize, millet, and Indian-corn, which completely failed in 1868, and would have saved the lives of the many thousands of people who perished miserably of starvation,* not from want of effort and liberality of the Government in dispensing food, but *from the absence of food in the country* and from the impossibility of transporting it to the country with sufficient rapidity.

We should also have saved a large proportion of the cattle that died in tens of thousands; and we should have saved a large proportion of the money-loss in the famine in Bundelkhund, which, as shown above, amounted to £170,000. Even in this year (1868) of least recorded supply there would have been water to afford the land the saturation requisite in September and October to allow of its being ploughed and sown for rubbee in the latter month.

22. The question now arises—Whence came this water in the Betwa sufficient in this year of drought to keep Bundelkhund alive?

As the volume of the Betwa was reduced in June 1868 to 70 cubic feet and the quantity of rain which fell in the whole monsoon at Jhansie was only 10 inches, the volume (sufficient for our needs) which the river acquired in July necessarily came from the country situated higher up its course.

The two great rivers of Bundelkhund, the Betwa and the Keyn, rise at no great distance from each other in the Vindhya mountains, and run nearly parallel courses, leaping down from the high lands of Central India to the level of the valley of the Jumna in channels which they have worn in the vast table of granite and trap rock which covers the country.

Near the head-waters of the Betwa stands the city of Indor, and near the sources of the Keyn the station of Sagar. The rainfall of those places in 1868 was 32 and 31 inches respectively (Appendix, page 10A.), which tallies so exactly with the rainfall for the Dakhan generally, returned in the Bombay records as 32½ inches in that year, that for other years the Dakhan average, which we have got, may be assumed to be the rainfall of Indor and Sagar, which we have not got.

Now the Sanitary Commissioner for Bombay reports that the average of the general Dakhan rainfall, taken over a space of 22 years from 1852 to 1873, was 28 inches. And this unfailing result of the breaking of the monsoon on the western cost furnishes *the unfailing minimum* on which we rely for the supply of the Betwa and Keyn in the driest years.

Register of Rainfall.

Station.	1868.						1869.					
	June.	July.	August.	September.	October.	Total.	June.	July.	August.	September.	October.	Total.
	Return obtained from Bombay Government.											
Mean for the Konkan	...	...	...	...	...	89·08	...	...	...	...	...	...
Mean for the Dakhan	...	...	...	...	...	32·67	...	...	...	...	...	...
	Near the source of the Betwa.											
Sagar	3·0	10·4	3·3	14·3	0·0	31·0	...	...	...	...	...	...
Indor	3·13	12·3	10·82	5·93	...	31·91	13·0	11·85	2·82	1·70	...	29·39
	In Bundelkhund.											
Humeerpoor	...	...	15·0	...	...	15·0	...	...	...	...	...	24·3
Jhansie	...	...	10·5	...	...	12·7	...	...	...	...	...	24·4
Average for Jhansie, 13 years	...		...	...	...	31·7	...	...	...	...	...	...

Had the Betwa been in Middlesex more complete and satisfactory returns could have been obtained; but traversing as it does some of the wildest regions of Hindustan, it is only after considerable research that the foregoing statements have been obtained.

23. In all but years of absolute scarcity the 600 cubic feet per second required for the purposes of this project in the beginning of the rubbee and 300 feet at the end can also be depended upon. A comparison between the agricultural calendar (Appendix, page 12A.) and the table of river discharges (Appendix, page 9A.) is the basis of this statement.

24. To provide for the possible extension of monsoon irrigation to mar lands, it is proposed by the Chief Engineer to make the canal for 19½ miles up to the point at which irrigation commences large enough to carry 1,000 cubic feet. When required, new distributaries will be opened for the purpose from this point. This provision is made in accordance with the instructions of the Government of India before referred to.

SECTION V.

WATER-RATES; AREA; IRRIGABLE. INCOME.

Extract from paras. 8 and 9 of LIEUTENANT-COLONEL BROWNLOW'S *Note on the Betwa Project, No. 674I.-C., dated January 1872, approved in* COLONEL GREATHED'S *Note, No. 233I.-C.* of 2nd February.*

"After studying the table of measured discharges in the river, extending more or less continuously over a period of four years, I think we may fairly rely on starting the rubbee crops during the end of September and October of ordinary years with 600 cubic feet per second, dropping to 350 cubic feet in January and 200 cubic feet in February. In dry years we shall be able to start the crops with very nearly the same volume (600 cubic feet) obtained in ordinary season, but this will only be available during end of September and early part of October. The supply of water in river falls rapidly to 160 cubic feet in end of October and to only 50 cubic feet in February. Allowing for the very great decrease in the volume of canal between the commencement and the end of rubbee, I think we should only calculate on full water-rates being realized on two-thirds of area irrigated at commencement of the season.

"Taking 200 acres per cubic foot per second as duty *ultimately obtainable* in irrigation of rubbee crops, we have :—

Cubic feet 600 × 200=120,000 acres irrigated in September and October, two-thirds of which=80,000 acres at ₹2	=₹	1,60,000
Add 12 annas per acre for enhancement of land revenue . .	,,	60,000
And 5 per cent. of water-rate, miscellaneous revenue . . .	,,	8,000
Total ultimate returns . .	,,	2,28,000
Deduct 25 per cent. for working expenses . .	,,	57,000
Balance net revenue .	,,	1,71,000

"These will be, of course, ultimate returns, but as they take no account whatever of khureef irrigation (which it is hard to believe will not be carried on more or less when the water is available), I think the estimate cannot be called excessive. ₹1,71,000 return 7 per cent. on 24½ lakhs of rupees, so that I think we have good grounds for recommending such a project for serious consideration."

25. The total estimated cost of the canal is shown by the abstract of expenditure (page 25) to be . . . . . =₹ 30,26,348

The amount of interest	,,	7,65,209
Capitalization of land revenue	,,	1,93,576
Total expenditure .	,,	39,85,133

on which the estimated net return, ₹1,71,000, will pay 4·31 per cent.

SECTION VI.

ALIGNMENT OF THE CANAL.

26. After a very careful consideration of the subject the head of the canal has been fixed at Pareecha, 13 miles east of Jhansie, near the Calpee road. This is the best site that could be found. A rocky barrier runs across the bed of the river, forming an excellent foundation for the weir; this barrier is said by the Executive Engineer, Mr. Dubus, to be free from cracks and

* See Nos. 34 and 38, Progs. June, 1878.

fissures visible to the eye. The river has a straight run between good stiff banks, and there is a plentiful supply of good building stone, suitable for coursed rubble, in the neighbourhood. The bed of the canal is so determined as to bring its water to the surface of the country at Mot, where the two rivers Pahooj and Betwa begin to diverge. Flow irrigation becomes possible at this "obligatory point."

27. Mr. Hair has designed the canal to carry 600 cubic feet per second only, which is the volume attainable in early rubbee, as shown above. The bed is 20 feet wide, the depth of water 7 feet, side slopes 1 to 1. Above the water-line the slope is expanded to 10 to 1 in deep cutting. To enable the canal to be easily modified, to carry 1,000 cubic feet per second in monsoon khureef at a future day, it is not necessary to alter the wetted part of the section shown on Sheet No. 1 of Atlas; but by throwing back the sides of cutting in the manner shown on the drawing by thick black lines and leaving berms 6 feet wide on either side, the width of the bed can at any time be increased to 30 feet in width by merely removing the berms and deepening the channel 1 foot. The bed thus enlarged will carry 1,000 cubic feet.

The effect of this alteration in the design of earthwork of the main canal will be to increase the quantity by 7,413,120 cubic feet at ₹3-8 per cent. = ₹25,945, which amount has been added to Mr. Hair's estimate.

28. The alignment of the canal, its branches, and distributaries are shown on the accompanying index map, page 4, and also on the large tracings of level charts.

From Pareecha to Reo the canal runs in a direct line and is in excavation varying from 30 feet at head to 5 feet, the slope of bed being 1 in 2,877. At mile 19½, or 3 miles beyond Reo, it bifurcates; the right or Humeerpoor Branch follows the watershed bordering the Betwa, and will irrigate the stretch of land lying between the high bank of the Betwa and the great mar basin in the centre of the Doab.

The Humeerpoor Branch is designed with a bottom width 15 feet for the first 30 miles; the depth of water at head is 6 feet, and slope 1 in 3,009. These dimensions give a mean velocity of 2·75 feet per second and a discharge of 342 cubic feet per second. The capacity of the branch may ultimately be increased to 500 cubic feet per second by increasing the depth of 1 foot and slope of bed, so as to raise the mean velocity to 3·25 feet per second.

From mile 30 to 48⅝ the bed is 14 feet wide and depth of water 4½ feet; and between mile 48⅝, the head of the Calpee Branch, and mile 58 the bed is reduced to 12 feet, the depth of water continuing the same.

From mile 58 to mile 68 the bed is 8 feet wide, and beyond mile 68 only 5 feet, which width the branch maintains to it tail at mile 78½, where it enters the ravines of the Jumna, about four miles west of Humeerpoor. The slope of bed varies between 1 in 2,785 and a foot per mile as below :—

Head	to	mile	10	...	1	in	3,009
Mile	10	,,	20	...	1	in	2,891
,,	20	,,	30	...	1	in	2,785
,,	30	,,	48	...	1	in	2,796
,,	48	,,	tail	...	1 foot per mile.		

A small branch, 11 miles long, will leave the Humeerpoor Branch at mile 48⅝ and will irrigate a small Doab south-west of the town of Calpee. This branch will be 5 feet wide at bed throughout, with a depth of water of 4 feet, slope of bed a foot per mile and capable of carrying 40 cubic feet per second.

29. The second or left of the two branches into which the main canal divides at mile 19½ will be called the Kutound Branch: it runs along the Pahooj watershed and will irrigate the country lying between the high bank of that river and the central mar basin. This line is designed to carry 257 cubic feet at its head, with a bottom width of 10 feet, depth of water 6 feet, and slope of bed 1 in 2,509. It will be necessary to design the masonry works on the Kutound Branch so as to admit of its carrying 500 cubic feet per second, which volume, added to that of the Humeerpoor Branch, will make up the 1,000 cubic feet per second which the canal will probably have to carry ultimately. In order to enable it to carry 500 cubic feet per second, the Kutound Branch will have to be 15 feet wide at bed, with 7 feet depth of water and a mean velocity of 3·25 feet per second, and the masonry works should be so constructed as to admit of the channel being ultimately enlarged to these dimensions.

The Kutound Branch will be 58½ miles long, the channel at the tail, where it meets the ravines of the Jumna, three miles east of Kutound, being 5 feet wide, and depth of water 4 feet.

The slope of bed varies as follows :—

Head to mile 10	1 in 2,509.
Mile 10 „ „ 20	1 in 2,847.
„ 20 „ „ 30	1 in 2,890.
„ 30 „ „ 40	1 in 3,515.
„ 40 „ „ 50	1 in 4,611.
„ 50 „ mile end	1 foot per mile.

30. The surface slope of the Betwa-Pahooj Doab is very great, necessitating numerous falls on the branches; the water-line has generally been kept above the surface, so that flush irrigation will everywhere be possible below the bifurcation.

31. The alignment of proposed distributaries, none of which will be of any great size, except that running down towards Churki, is shown on the index map; they have apparently been chosen with great care. The total length of distributaries is 220 miles, but this will be supplemented largely by direct irrigation from the branch canals.

32. It was at one time contemplated to have a navigable canal from Pahooj to Calpee, but owing to the rapid slope of the country the cost proved prohibitory, and the Government of India, in G. G. O. No. 818I., dated 4th November, 1873, finally decided that navigation should be left out of the project.

SECTION VII.

DISTRIBUTION OF SUPPLY.

33. The volume of water available at the beginning of the rubbee season is 600 cubic feet per second, and this is the volume the works are at present designed to carry. The area to be irrigated consists of two strips of nearly equal and uniform width. Mr. Hair has divided the supply available, 600 cubic feet, by the total length of the branches, *viz.*, 147 miles, and obtained a quotient 4·1, which represents the volume to be consumed per mile. The several channels have accordingly been designed on this regimen. This was the system pursued by Colonel Cautley on the Ganges Canal, and for the purposes of estimating may be accepted as sufficiently accurate; but in preparing the working designs it will be requisite to ascertain the volumes required by each distributary, varying with the areas to be irrigated, and to fix the dimensions of bed and masonry works accordingly. Mr. Hair's proposed distribution is given in Appendix, page 14A.

SECTION VIII.

DRAINAGE.

34. At only five points has drainage been crossed, *viz.*—

(1) At four furlongs from the head, where an inlet is provided to admit some small local drainage into the canal.

(2) At mile $1\frac{3}{4}$, where a second inlet will be built.

(3) At mile 7 the heads of drainage which flows at present to the Betwa are unavoidably crossed, but the map shows that it can easily be diverted into the Pahooj. The alignment of the canal is on the general line of watershed.

(4) At mile $16\frac{1}{4}$ a small drainage line is intercepted and will have to be provided for by syphon.

(5) At mile 20 of the Humeerpoor Branch, where the same thing occurs, a similar work will be required.

35. All the drainage of the country has been carefully surveyed, and is shown on the large contour maps prepared by Mr. Hair.

SECTION IX.

MASONRY WORKS.

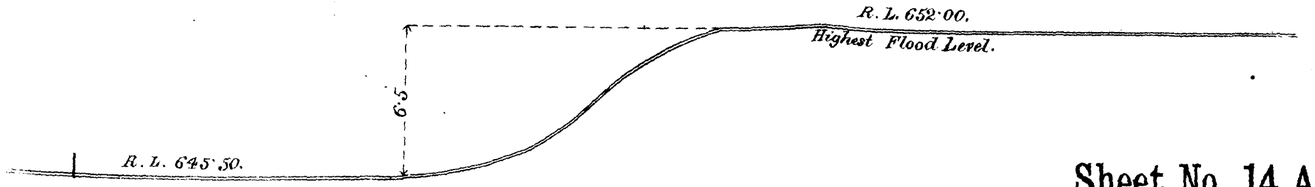
(For list see Appendix, page 23A).

I.—HEADWORKS.

36. The reasons for fixing the head of the canal at Pareecha have been already stated. The principal works obtaining and regulating the supply of the canal are—

(*a*) A weir across the bed of the river Betwa.

(*b*) Under-sluices on the left flank of the weir, to clear the river approach to

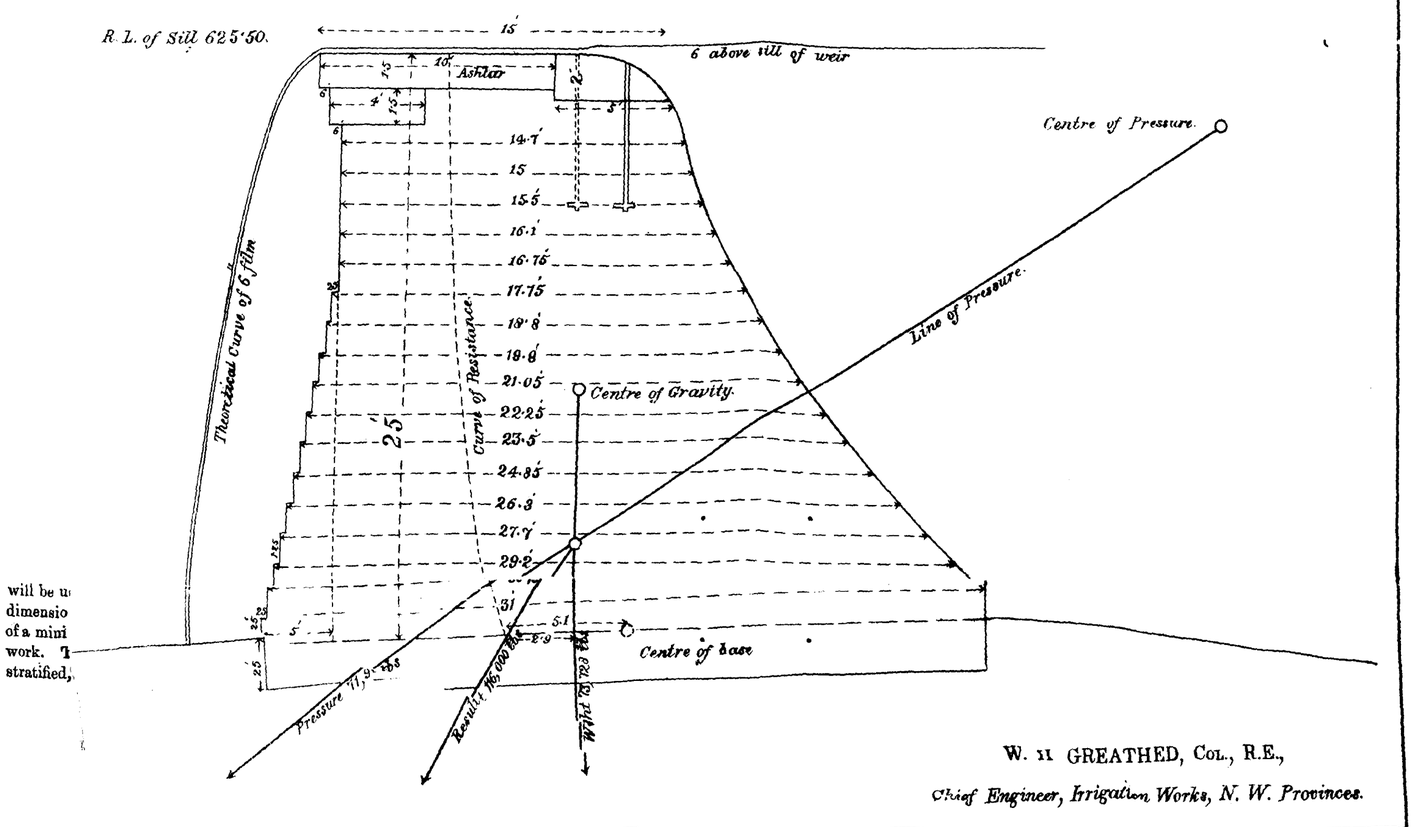


Sheet No. 14 A.

BETWA CANAL PROJECT.

SECTION OF WEIR AT PARICHHA, AS MODIFIED BY CHIEF ENGINEER.

SCALE—FIVE FEET TO AN INCH.



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W. H GREATHED, COL., R.E.,
Chief Engineer, Irrigation Works, N. W. Provinces.

PHOTOLITHOGRAPHED AT THE SURVEY OF INDIA OFFICE, CALCUTTA. NOVEMBER 1881.

(*c*) Head sluices at the head of the canal and left flank of the weir.
(*d*) Right and left flank protection works, and
(*e*) Afflux embankments.
It will be convenient to describe these different works in the order given above :—

(*a*) *The Weir.*

37. Mr. Hair has designed the weir alignment most skilfully, so as to make the most of the rock barrier already described: the weir is placed on the ridge of the reef, curved on the left flank, convex to the direction of the stream, so that the water will be thrown towards the middle. The sill of the weir has been fixed in reference to the level of the "obligatory point" at R. L. 625·50. The height of the weir above the river-bed varies between 25·5 feet and ·4 of the foot, except on the left flank, where the rock is higher than the sill and will have to be cut down. The total length of the weir between the steps at either end is 2,395 feet, or nearly half a mile, and is calculated to produce an afflux of 6·5 feet. (*Vide* Appendix, page 14A.)

38. The maximum flood volume of the Betwa has been calculated by various observers to be about 750,000 cubic feet per second, and it is this volume which gives an afflux of 6·5 feet. This flood discharge has been verified by a computation based on the area of the catchment basin, which is roughly 185 miles long and 48 miles wide, or 8,892 square miles. Allowing 80 per cent. of the rainfall to pass off, which is a reasonable allowance on rocky land of rapid slope, these results give a calculated flood discharge of 799,440 cubic feet.

Vide Progs $\frac{A}{W}$, June 1873, No. 38.

39. The cross section proposed by Mr. Hair is a trapezoid, with sides of equal slope, *viz.*, 10 horizontal to 25½ vertical, the top width being 10½ feet, increased by a ledge to 15 feet. The section proposed is stable, but the Chief Engineer does not approve of the slope on the down-stream side: a 6-inch film passing over the weir would fall, theoretically, at a point 6 feet measured horizontally from a line drawn plumb to the lip of the weir. Practically this distance would not perhaps be more than 4 feet, in which case the falling water would strike the down-stream slope of the weir at about half its height, and would ultimately affect the stability of the structure by wear and vibration. The down-stream face of the weir should therefore be nearly plumb; but to increase the stability of the work, and thereby to decrease its cost, the base of the weir has been extended up-stream as far as is consistent with the necessary conditions defined above. The up-stream edge will be rounded, as in certain works in Madras, in order that drift wood may pass over without obstruction and injury to the masonry. Instead of a batter for the up-stream face the Chief Engineer prefers a curve, which facilitates the passage of water and drift; the curve is so designed as to reduce the thickness of the weir in proportion to the pressure exerted. The section shown is for the highest part, and so much of the section, measured from the top downwards, as is requisite for the completion of the weir to a uniform still level will be built throughout the length of the structure. Fifteen feet has been adopted as a convenient uniform dimension for the width of the weirs at top.

A section of the weir as approved by the Chief Engineer is given on a separate sheet (No. 14A); the calculations of pressure and resistance have been made in a manner laid down by Rankine; the impact due to the velocity of approach, of which very little is known, has been neglected, but to allow for it, the weir is designed to support the whole weight of the water *above* in time of flood, on the supposition that the channel *below* is dry.

To avoid the expense of dressing the face stones to a curve which varies in each course, it will suffice to dress the face of each course to a plain surface, corresponding to the chord of the portion of the arc that falls upon it. The up-stream face will therefore be trapezoidal in detail.

40. The weir will be coped with ashlar 18 inches thick, finely cut; the principal blocks will be of the dimensions shown on the drawing, not less than 15 inches wide and 1·1 ton each in weight. The stone will be procured from Tapkin Mohal, in the Gwalior territory, about 43 miles from Pareecha, where the quarries afford a very hard and durable red sandstone of fine grain, capable of nice and accurate workmanship. The stones on the up-stream edge of the sill will be tied down to the body of the weir by iron bolts 1¼ inch in diameter and 6 feet long.

41. The body of the weir will be built of rubble masonry coursed on both faces: the stone will come from the Pareecha hill, and from the hill on the right bank of the river; no stone will be used in any part of the work under ¼th of a cubic foot, and for face work the minimum dimensions are 9 inches long, 8 inches wide, and 6 inches high; a due proportion of bond stones, of a minimum size, 2½ feet long, 1½ foot wide, and two courses in height, will be built into the work. The stone procurable from the Pareecha hill is a gneissoid, very hard; and being stratified, it is expected that it will be easily worked into blocks of convenient size.

42. Ashlar will be set in Portland cement and rubble in kankar lime mortar: the kankar will come from Upara, 12 miles from Pareecha, along the canal line, where there is an extensive bed, estimated to yield 40 millions of cubic feet of good hydraulic lime. The faces of the weir will be pointed with Portland cement to a depth of 2 inches.

43. In paragraphs 4 and 5 of the General Specification (Appendix, page 15A.) Mr. Hair describes the system he proposes to adopt in building the weir, which appears simple and practicable.

(*b*) *Under-sluices.*

44. The under-sluices are designed by Mr. Hair in a line with the weir, and making an angle of 75° with the face of the head-sluices; but this arrangement is not approved. In order to create a sufficient scour along the face of the canal head and so to prevent a deposit of shingle and silt, the two works will be placed at right angles to each other. Sheet No. 11A shows the alignment which the Chief Engineer proposes for these two works.

45. The height of the face wall of the under-sluices is taken by Mr. Hair at 3 feet above the calculated afflux level. The Chief Engineer has increased this margin to 6 feet. The highest flood level is shown on the drawings at R. L. 645·50, and has been determined by local observation at different times and by different officers: Captain Home in 1867-68 gives R. L. 645·67 as the flood level; Captain Bagge in 1868-69 gives R. L. 645·54, and more recent enquiries show that R. L. 645-50 as the highest point to which floods have been known to rise. The floods of 1869 only rose to 641·99, and these are generally acknowledged to have been unusually high. The height of afflux is calculated at 6·5 feet, so that the reduced level of flood water above the weir will be 652·00. The R. L. of the top of the under-sluices' wall, of the canal head-sluices' roadway, and of the affiux embankments are therefore fixed at 658·00, 3 feet higher than Mr. Hair proposed.

46. The under-sluices will consist of six vents of 10 feet each, in all a waterway of 60 feet, which the Chief Engineer considers sufficient; the head-sluices have eight vents of 6 feet. To give a greater length to the under-sluices would contract the weir unduly.

47. The piers of the under-sluices were originally designed 3 feet thick, but in order to support the great superincumbent weight with safety they have been increased to 5 feet.

The hearting of concrete proposed for the spandril wall will give trouble in building and may settle unequally and shrink away from the face walls: it will be but a trifle more expensive to build the wall entirely of rubble masonry, and this the Chief Engineer proposed to do.

The tread of the steps leading down to the weir should be twice the rise instead of only equal to the rise, as at first designed.

48. The abutments, piers, arches, groove pilasters, cut-waters, flooring and the treads of steps leading down to the weir will be of ashlar; the rest of the work of rubble masonry, the up-stream face being pointed with Portland cement.

(*c*) *Head-sluices.*

49. The head-sluices were first designed to admit 600 cubic feet per second into the canal by six vents of 6 feet each; but in order to admit of an expansion of the capacity of the canal to 1,000 cubic feet per second the number of openings has been increased. With a mean velocity of 3 feet per second, a waterway of 47·6 feet will be required, or eight bays of 6 feet, say.

50. The alignment of the head-sluices in connection with the under-sluices, has already been discussed; the Chief Engineer proposes to place them in the manner shown on Sheet 11A.

51. Here also, as in the case of the under-sluices, the piers are too thin, and a thickness of 3 feet has been provided in the estimate.

Instead of the long flight of steps in prolongation of the piers, which are needlessly expensive, the Chief Engineer proposes buttresses, 10 feet long at base, tapering to 2 feet at top.

The top of the face wall should be at the R. L. 658·000, for reasons already assigned, and the wall itself should be built of solid rubble masonry throughout.

52. The abutments, piers, arches, groove pilasters and cut-waters, and flooring will be built of ashlar, the parapet of brickwork or rubble stone, and the rest of the head-sluices of rubble masonry. The river face of the work will be pointed with Portland cement 2 inches deep.

The head-sluices will be founded on solid rock.

(*d*) *Flank Protection Works.*

53. The left flank is protected by an up-stream and down-stream wing wall; the former runs 140 feet in from the river edge and the latter 75 feet. In order to hold up the bank immediately below the under sluices, the down-stream wing wall will run at right angles to them for a length of 50 feet. The whole of the left flank wing walls will be founded on rock.

54. On Sheet No. 14 of Atlas a plan of the right flank works is given. Two diverging walls will run into the bank; that on the up-stream side will be 100 feet, and that on the down-stream 50 feet in length. These walls will not rest on rock, but the soil is stiff and well able to support the weight that will be put on it, as shown by the geological sections.

The tops of the flank walls will be 6 feet above the afflux level, *i. e.*, at the R. L. 658·00, exclusive of parapets.

55. Except the parapets, which will be of brickwork, if the rubble stone is not found to be suitable, the whole of the flank walls will be of rubble masonry.

(*e*) *Afflux Embankments.*

56. In order to avoid inundation by the afflux caused by the weir and to prevent water passing round the ends of the weir, embankments will be required on both sides of the river; they will be thrown up on the alignment shown at Sheet 12 of the Atlas. The formation width has been fixed at 20 feet, and the level at 658·00, or 3 feet higher than allowed by Mr. Hair, The portions near the weir which are liable to scour will be pitched with any stone, and the bank itself will be hearted with a puddle wall 3 feet thick.

(*f*) *Construction.*

57. A memorandum by Mr. C. Anderson, Superintending Engineer (Appendix, page 19A.), describes the manner in which it is proposed to deliver material into the weir; quarries for rubble stone will be opened in the Pareecha hill on the left bank and in another hill at the upper end of the right afflux embankment. Tramways, to be worked by manual labour, as being cheapest, will be run from both these sites to the weir, and the loaded wagons will pass down to the bed of the river by means of inclines of 1 in 100. A timber staging, carrying rails, will be run along the line of weir resting on piers, which will be built of the section and of the same materials as the weir, of which they will finally form portions. The tramway on the line of weir will be removed annually before the flood season, during the period of construction. A tramway will also be run to the lime-kilns and another to the ashlar-yard.

58. Mortar for rubble will be ground by bullock power in native mills, as being cheaper for the quantity of work to be executed, both in first cost and in working expenses, than steam mortar mills. (*Vide* Appendix, page 21A.) The number of mills required being only 30, they will not occupy undue space. For finer work, however, it will be necessary to have a couple of mortar mills worked by steam, which will serve to supplement the native mills in times of high pressure; two have accordingly been included in the estimate.

59. It is calculated that it will require 2½ years (*vide* Appendix, page 21A.) to complete the head-works. In the first year work on the head and under-sluices and flank protections will be pushed on, nothing being done to the weir, except cutting the bed, preparing ashlar and quarrying stone; in the second year the head and under-sluices and flank protections will be completed and the weir built up to R. L. 615·00, and in the third year the whole work will be completed. It is anticipated that by the end of the third year, counting from the date of sanction, water will be admitted into the canal.

Appendix, page 18A., is a calculation of the number of carts required for the carriage of materials to Pareecha.

Extensive workshops will not be required. The work required for the weir being of a simple nature, hand blast forges and carpenters' benches are probably all that will be required. A portable engine has, however, been added to the estimate for tools and plant to meet contingencies.

(*g*) *Estimate.*

60. The alterations above described have rendered necessary the preparation of an entirely fresh estimate of the weir and head-works in the Chief Engineer's Office. The cost, including 20 per cent. for contingencies, is now found to be **R6,63,207.**

II.—Bridges.

(*a*) *Main Canal.*

61. On the main canal 13 bridges have been estimated for, including the head-works and the bifurcation. This number affords one in every mile and a half, which is excessive. There need be only a bridge for every two miles, or nine in all.

The designs submitted by Mr. Hair only provide for a discharge of 600 cubic feet per second, but the bridges should be built to allow of the increased capacities of 1,000 cubic feet, *i. e.*, they should be 38 feet between abutments, and the flooring should be depressed one foot below the canal bed, to meet the ultimate deepening provided under earthwork. As at the site of two of the bridges the canal is in heavy digging, the bridge abutments should be sufficiently high to allow of the roadway being in a level with the country: the style of depressed bridge proposed by Mr. Hair is not approved in the deep digging which is encountered on the main canal, on account of the difficulty of affording proper drainage to the approaches. The estimates have been modified to provide for these alterations.

All masonry works on the main canal will be built of rubble.

(*b*) *Branches.*

62. On the Humeerpoor Branch 54 bridges are given, at intervals of 1½ mile; on the Calpee Branch nine bridges, at 1·3 miles apart, and on the Kutound Branch 43 bridges, 1·35 miles apart: in all there are 119 bridges at an average distance apart of 1·4 miles.

According to the provision for regulating the distances at which bridges shall be placed over channels of diverse dimensions, adopted with the approval of the Government of India in Circular A. of 1874, there should be a bridge at every mile of these branches, since the bed is everywhere under 20 feet. In Bundelkhund, however, roads are few, and in all probability the number of bridges allowed by Mr. Hair will prove ample; it is nevertheless deemed advisable to enter the full number, and the cost of 42 occupation bridges has accordingly been added to the estimate.

63. The bridges are provided with grooves, for use as stop-dams and in other respects the designs are good and call for no further remarks.

64. Except on the first ten miles or so of the branches, good building stone is not procurable; the works have therefore been estimated at brickwork rates. Good clay for brickmaking is reported as not difficult to find, and good kankar lime is everywhere procurable within a reasonable distance of the works. (*Vide* Appendix, page 16A.)

III.—Inlets.

65. There will be two inlets, one in the 1st mile and the other in the 2nd mile of the main canal, to admit local drainage unavoidably intercepted. Mr. Hair has designed the inlets on inclines of 1 in 2, with retaining walls at intervals: with this construction there is great danger of settlement, and consequent cracks, which would admit water under the masonry; a safer and cheaper construction will be to have a vertical drop down a rectangular well, from the bottom of which a culvert will lead to the canal.

IV.—Drainage Syphons.

66. Two drainage syphons are required, one in the 17th mile of the main canal, and one in the 20th mile of the Hamirpur Branch. They are both of the same design which has been adopted on the Agra Canal for the Buriah Nala.

The syphons on the main canal will have to be built 10 feet longer and a foot lower than designed, to allow for an ultimate increase in the size of the canal; this alteration will cost ₹1,500, which amount has been added to the estimate.

Mr. Hair calculates (Appendix, page 25A.) that this syphon will have to pass off 1,290 cubic feet per second, and has provided five vents of 30 square feet in section, with a heading up of 1·25 feet; this waterway would discharge the whole volume with a mean velocity of 8·5 feet per second. The calculations on which these figures are based are, however, faulty; it is assumed that all the rain that falls will flow off, whereas not more than 50 per cent. is likely to do so: the volume to be provided for is, therefore, only 645 cubic feet per second, and this will give a mean velocity through the five events of 4·3 feet per second, which is perfectly safe.

67. The syphon on the Humeerpoor Branch is provided with three vents of 20 square feet each. For calculations see Appendix, page 25A.

V.—Falls.

68. The falls are all designed of the usual pattern, and have been placed in connection with bridges, which should be built below the falls, and not above them, so as to avoid unnecessary ramps. The crest of the falls may be placed just so far above the face of the bridge that the water may fall clear of it. A sloping apron of dry pitching should be provided along the up-stream fall of the weirs.

VI.—Mills.

69. In connection with the falls native flour-mills will prove very profitable; they need only be of the very simplest construction, and ₹25,000 will amply suffice for all requirements under this head. This amount has accordingly been included in the general abstract.

VII.—Regulators.

70. Complete designs for these works are given in the Atlas: one will be required at the head of the two principal branches and another at the head of the Calpee Branch.

The designs admit of improvement in the following respects:—

(1) The masonry apex should be omitted, as it ensures a deposit of silt immediately in front of the regulator when shut; and

(2) The wall connecting the two bridges should be on a much flatter curve. These modifications will not affect the cost of the works.

VIII.—Tail Works.

71. Tail works have been entirely omitted from the project, because the ravines into which the channels fall extend so far from the Jumna, and are so high above it, as to render any retrogression of levels too distant a contingency to require present provision.

IX.—Escapes.

72. Mr. Hair proposes to meet the cost of escapes from the allotment for distributaries; but this is quite inadmissible. Allowing an escape for every 40 miles of canal, four will be required in all, which with their masonry heads may be taken at ₹10,000 each. ₹40,000 has been added to the estimate on this account. The distance from the canals to the adjoining rivers is always inconsiderable.

X.—Inspection Houses.

73. Mr. Hair allows 15 first class inspection-houses; but as the branch canals are mere distributaries, it will be sufficient to allow these large buildings for important situations only. These are—1, the Head-works. 2, the bifurcation. 3 and 4, the head-quarters of the sub-divisional officers in charge of the branch canals.

Owing to the nature of the soil in Bundelkhund travelling is a work of some difficulty; hence inspection-houses should not be built too far apart. Ten miles are considered a very fair day's march in Bundelkhund, and the inspection-houses are arranged accordingly.

74. On the main and branch canals 16 inspection-houses will be required in all, including one on the Calpee Branch; four of these will be first class and 12 second class.

As all the distributaries are within easy reach of the branch canals, no accommodation will be required on them beyond patrols' huts, which are provided for every 5 miles or $(\frac{220}{5})$ 44 in all.

75. The first class inspection-houses will be on the standard plan recently sanctioned. The accommodation provided will allow of shelter being afforded to a European officer, an upper subordinate, and native office and establishment.

The second class inspection-houses will be of the standard design recently adopted. The accommodation afforded comprises a centre room 18′ × 16′, with a dressing-room and bath-room, an open verandah and small room for the native office, a porch over the west door, and a long open verandah to shade the east wall.

Drinking wells will in all probability be required at many of the inspection-houses' sites; 10 have been allowed for in the estimate.

The cost of patrols' huts has been fixed at ₹100 each, which provides for permanent buildings.

XI.—Temporary Accommodation.

76. During the progress of the head-works a temporary settlement will be required at Pareecha, and temporary buildings will be required in the branch canals for sub-divisional officers and native establishment.

A plan of the proposed settlement at Pareecha (Sheet No. 13, revised) has been drawn out by Mr. Hair, but it appears to be compressed within too narrow limits; a survey of the ground on a large scale will be called for and Mr. Hair's proposals modified according to circumstances. To allow for possible extra requirements 500 acres have been taken as the area within station boundaries.

77. The extent of temporary accommodation has been limited by the establishment which it is proposed to employ. A detailed list of the buildings provided is given in the General Abstract, pages 20 to 23. The designs for the buildings will be similar to those erected at Narora, the head of the Lower Ganges Canal. Five drinking wells are included in the estimate, as is also the cost of station roads and drains.

XII.—Distributaries.

78. The approximate alignment of distributaries is shown on the large maps and on the index map; there will be 220 miles in all estimated by Mr. Hair to cost ₹350 per mile. Exclusive of land, this appears to be too low, and it is doubtful whether the works could be constructed for this amount. ₹500 would be a safer rate per mile and has been allowed in the abstract.

Including the branch canals, from which direct irrigation will be practised largely, five outlets have been allowed per mile of irrigating channel, and this provision should prove ample.

SECTION X.

LAND; TOOLS AND PLANT; RATES, &c.

I.—Land.

79. The estimate for land provides for the following widths being taken up on the several channels :—

	Average width,
Main canal	400 feet.
Humeerpoor Branch—	
Head to mile 48	110 „
Mile 48 to mile 68	80 „
Mile 68 to tail	75 „
Kutound Branch—	
Head to mile 50	95 „
Mile 50 to tail	75 „
Calpee Branch	75 „
Distributaries	40 „

In addition to the land required for channels, the whole area included between the afflux embankments, 1,228 acres in all, will be taken up; 500 acres for Pareecha station and 60 acres for inspection-houses, bringing up the total area of land required to 5,477 acres. A rate of ₹25 per acre is allowed by Mr. Hair.

Land in Jaloun is worth eight years' purchase of revenue (*vide* Revenue Administration Report of Board of Revenue for 1872-73, para. 27), and the average land revenue is ₹1-8 an acre; the price of land is, therefore, ₹12 an acre, so that the rate taken in the estimates allows an ample margin for other forms of compensation. With 10 per cent. for contingencies, the total cost of land will be ₹1,50,618.

80. The land enclosed by the afflux embankments will either be planted out or leased for cultivation, as may be found most expedient.

No increased width of land is provided for plantations, but on the main canal the spoil bank may ultimately be planted out.

II.—Tools and Plant.

81. Mr. Hair estimates that ₹65,844 only will be required for tools and plant, but he has omitted so many essential articles from his list that a revised estimate has been drawn up. The total amounts to ₹1,49,886, or a little over 5 per cent. of the cost of works.

III.—Canal Roadway.

82. A width of 25 feet is allowed on the main canal, left bank, between the spoil bank and edge of canal to serve as a road; on the branch canals the roadway will be on the surface of the country just outside the bank.

For facility of inspection during construction a strip of land, 15 feet wide, immediately outside the spoil will be roughly levelled off to serve as a road.

IV.—Rates.

83. A list of the rates on which the estimates have been based is given in Appendix, page 22A. Mr. Hair's rates for rubble masonry and brickwork have been raised from ₹18 and 20 to ₹20 and 25 respectively.

84. On a project such as this, and in so inaccessible and backward a country, the provision for contingencies should not be less than 10 per cent. on the estimated cost of the works, which has been allowed on all the estimates, except for the head-works, where 20 per cent. has been taken to cover the contingencies to which the weir works will be subject.

V.—Establishment.

85. It is proposed to organize two divisions; the first division will consist of the head-works and main canal, the second will comprise the two branches. A list of the establishment proposed for each is given in Appendix, page 22A. The estimated expenditure in the first division is ₹14,00,000, and in the second division ₹10,00,000, exclusive of the cost of establishment. The first division works will be confined within comparatively narrow limits, while those of the second division will be spread over a large area of country and supervision will be more difficult.

86. The cost of executive establishment for three years is estimated at ₹2,85,156, but to allow for direction and contingencies 20 per cent. on the cost of works and tools and plant has been entered in the abstract.

SECTION XI.

GENERAL.

I.—Preliminary Works.

87. The total expenditure debited to the Betwa Canal up to date together with a sum sufficient to complete the necessary works of setting out, surveying, and preparing detailed designs for distributaries has been included in the classified abstract under the head "A., Preliminary."

II.—Interest.

88. A detailed calculation of the interest to be charged to the capital of to Betwa Canal, according to the recent orders of the Government of India, is given in Appendix, page 25A. It is assumed that the canal will take three years to construct, and a further period of six years before it will begin to pay the full interest calculated in para. 25 of this report, *viz.*, 4·31 per cent. The total amount of interest debitable to capital is on these assumptions ₹7,65,209, which includes the working expenses for the first six years.

III.—Capitization of Land Revenue.

89. The total area of land required is 5,277 acres, *viz.*, 2,682 acres in the Jhansie district and 2,795 in the Jaloun and Humeerpoor districts.

From the Board of Revenue's Report on the Revenue Administration for the year 1872-73 it appears that the Government land revenue is assessed by the last settlement at ₹1-7-1 per acre in Jaloun, and ₹1-3-11 per acre in Jhansie, on the area actually under cultivation.*

* *Vide* D. Settlement Series, Appendix III.

In another part of the same report† the land revenue of 569 acres of cultivated land in Jaloun is put down at ₹767, or ₹1-5-7 per acre. We may therefore safely assume ₹1-4-0 as the land revenue per acre in Jhansie and ₹1-8-0 in Jaloun and Humeerpoor. The land revenue to be annually remitted is therefore—

† A. Revenue Series, Appendix VI., "Lapses."

2,682 × 1·25 = ₹3,352 in Jhansie.
2,795 × 1·5 = „ 4,193 in Jaloun and Humeerpoor.

Total ₹ 7,545

90. The Government of India in Resolution Circular No. 43, dated 24th April 1873, ruled that the capital which represents the annual abatement of land revenue is that sum which, if invested in 4 per cent. Government securities at the market value of the day, would produce interest equal to the abatement.

The latest quotations of Government 4 per cent. securities are from ₹102 to ₹103-4-0, mean ₹102-10-0: hence the amount debitable to the Betwa Canal on account of capitalization of land revenue is ₹1,93,576.*

$$* \frac{102\frac{1}{2} \times 7.545}{4}$$

IV.—General Abstract.

91. The general abstract has been drawn out in the budget form lately approved by the Government of India and is given in pages 20 to 24. A summary of the general abstract, to which is added the interest to be charged to capital and the amount due to capitalization of land revenue, will be found at page 25.

The cost of works, tools and plant, and establishment is	₹30,26,348
Interest	,, 7,65,209
Land revenue	,, 1,93,576
Grand Total	,, 39,85,133

(Thirty-nine lakhs eighty-five thousand one hundred and thirty-three rupees.)

Mr. J. Hair, Superintendent of Works, prepared his project with great care and his designs with skill, but the failure of his health rendered it necessary for him to take medical leave before the review could be effected.

W. H. GREATHED, *Colonel, R.E.,*
Chief Engineer, Irrigation Works, N.-W. Provinces.

THE PROJECT

OF

THE BETWA CANAL, BUNDELKHAND.

From Colonel W. H. Greathed, R.E., Joint Secretary to Government, N. W. P., P. W. D., Irrigation Branch, to the Secretary to the Government of India, P. W. Dept.,—No. 1311W., dated 12th December 1874.

I am directed by His Honor the Lieutenant-Governor of the North-Western Provinces to submit for the approval and orders of His Excellency the Governor General in Council a detailed estimate for the construction of the Betwa Canal, with detailed drawings of certain of the proposed works, and a comprehensive note by the Chief Engineer which relates the history of the project up to the present time and investigates the questions especially raised by the Government of India and by the Right Honourable the Secretary of State in your despatches No. 8181 of 4th November last and No. 336 of 21st May.

2. The submission of these papers has been delayed by the Superintendent of Works, Mr. Hair, who prepared the estimates, being obliged to take leave to England for the recovery of his health in the month of August last, which has laid the burthen of completing the investigations on the Chief Engineer.

3. His Honor the Lieutenant-Governor has carefully considered the statements and conclusions of the Chief Engineer in respect of the dependence to be placed on a supply of water in the Betwa sufficient for the wants of the canal, and is confirmed in the opinion expressed in the 3rd paragraph of my letter No. C.538W. of the 20th June, which is quoted marginally for easy reference.

"From these sources the Government of the North-Western Provinces so far back as 1868 had certain knowledge that in a year of extremely scanty rainfall a sufficient volume of water in the river Betwa for the supply of the proposed canal can be depended upon during the three months in which a failure of the regular rains is most disastrous. This supply is a guarantee against famine at all times, for it will bring ordinary monsoon grain crops to maturity and will ensure the sowing and germination of the spring crops. In every year but the very worst irrigation will also be afforded throughout the rubbee season."

4. It will be seen that Sir John Strachey and the Chief Engineer, Colonel Greathed, demur to the statement in paragraph 2 of the Secretary of State's despatch, that in ordinary years water would not be required to any great extent for khureef crops, nor be available in sufficient quantity for rubbee crops.

5. Information regarding rainfall has been sought from the Government of Bombay, the Agent to the Governor General in Central India, Political Agent, Bundelkhund, the Deputy Commissioner of Sagar, the Meteorological Reporter, and the Board of Revenue, North-Western Provinces, but from none of these authorities, copies of whose letters will be found in the Appendices, page 11A., can any statistical information regarding the rainfall of 1830 to 1834 or 1838 be obtained.

The note made by Mr. Anderson, Superintending Engineer, in 1869, which is quoted in the Chief Engineer's report—"The Betwa no doubt was lower during last season than it has been known to be for years; some say since the famine of 1837 and 1838—" is the sole result of the very particular local enquiry promised in paragraph 4 of my letter of June above quoted and carried out in accordance with that engagement.

6. Attention is invited to the decided advocacy of the canal contained in the report of the Settlement Officer of Jaloun, paragraph 7 of Appendix, page 7A.

7. The estimate has mounted up to 40 lakhs of rupees* in consequence of the imposition of 7¾ lakhs for interest and nearly 2 lakhs for capitalization of land revenue; of the provision and estimate in minute detail of all subsidiary requirements for the execution of the

* The exact amount as given at page 25 is ₹39,85,133.

works, which did not come into the previous estimates, and to a scrupulous fulfilment of the requirements of paragraph 3 of your letter No. 8181 of 4th November 1873.

8. The Chief Engineer is unwilling, notwithstanding the Settlement Officer's more sanguine expectation, to alter the returns of net revenue anticipated in his note on Colonel Brownlow's first report on the Betwa project, found at page 122 of the Proceedings of this Government for June 1873.

9. The estimated capital expenditure being ₹40 lakhs, the estimated revenue ₹1,71,000, the estimated return amounts to 4·3 per cent., which will very nearly pay the interest of the capital. The revenue thus estimated includes enhancement of land revenue, due to the canal, and in consequence no further direct return can be claimed. The other pecuniary advantages which the canal will afford are stability of revenue where all was insecure, and affluence where abject poverty was the universal rule. The value of these results cannot be estimated in money, but they will doubtless be allowed due weight by the Government of India and the Right Honourable the Secretary of State in Council.

10. As His Excellency the Governor General in Council is satisfied of the propriety of the proposed undertaking, it is unnecessary for the Lieutenant-Governor to say more than that he entirely concurs in the cordial recommendation of the project which has always been afforded by Sir W. Muir, and recommends the detailed estimates for early sanction. Sir John Strachey wishes, however, to guard against the possibility of his views being misunderstood. It seems to him that no more obvious duty ever fell upon the Government than that of constructing irrigation works in Bundelkhund, and this Betwa Canal in particular. At the same time he does not anticipate that these works will financially prove directly remunerative within any time which can now be foreseen. Almost every canal that has been made up to the present time in this part of India has been, under the existing system, a burden on the finances of the Empire, and the Betwa Canal is not likely to be an exception.

The 3rd and 4th paragraphs of the Secretary of State's despatch have been answered in paragraphs 6 and 7 of my letter to your address of the 20th June, which has been frequently quoted in this despatch.

From Colonel C. H. Dickens, R.A., Secretary to the Government of India, to the Joint Secretary to the Government of the N. W. P., in the P. W. Dept., Irrigation Branch,—No. 318-I., dated Simla, 8th September 1875.

I am directed to acknowledge the receipt of your letter No. 1311W., dated the 12th December last, submitting plans and a detailed estimate, amounting to ₹30,26,348 (including cost of establishment), for the Betwa Canal project in Bundelkhund, together with a comprehensive note by the Chief Engineer on the subject; and in reply to communicate the following remarks for the consideration of His Honor the Lieutenant-Governor.

2. The quantity of masonry and earthwork provided for the head-works appears to be unnecessarily large, and may apparently be considerably reduced.

3. The number of bridges, about one to each mile, is considered to be in excess of the immediate requirements of a tract of country the traffic and resources of which is confessedly undeveloped. Probably half the number would suffice for many years to come.

4. Mills are not a necessary adjunct of the project, though they are always a profitable investment if judiciously located. In the present case, when the demand for them arises they can be readily built.

5. The cost of the inspection-houses and temporary shelter appears to be very large, and is considered to be capable of material reduction.

6. The extent of the land to be taken up may apparently be reduced considerably.

7. It appears that every possible expense required to complete the project in the best style has been provided for in the estimate; but it is considered by His Excellency the Governor General in Council that in a scheme of this character, where the estimated returns are so meagre, it will probably suffice to construct such works only as are absolutely necessary for the present. If the supply of water is found to be greater than can now be calculated upon for a certainty, or a demand arises, as is not improbable, for khureef irrigation, the necessary additions can then be made to the works, though the cost would possibly be greater than if all the works were carried out simultaneously now.

8. In proposing that the amount of the estimate to be sanctioned at first should be reduced, the Governor General in Council wishes that in so doing there should be a record

served of what, according to the present aspect of the case, the eventual additional outlay is likely to be if the project proves to be a financial success. This will prevent its being supposed hereafter that the probability of such outlay was unforeseen.

9. I am also to remark that the estimated cost of the Betwa project, as reported by the Local Government in April 1872, was stated approximately at 17¼ lakhs of rupees. Subsequently, in April 1873, it was roughly estimated at ₹18 lakhs. The amount of the detailed estimates now received come up, however, to 30¼ lakhs. The former estimates have been returned to the Local Government, and cannot consequently be referred to. I am, therefore, to enquire to what cause the great difference between the approximate estimates above mentioned and the present detailed estimates is chiefly due.

10. As regards the remissions of revenue in the five districts of Bundlekhund during the 12 years from 1860-61 to 1871-72, which are stated to have amounted to ₹33,63,989 and which are attributed to famines and drought, I am to request that the opinion of the Revenue officers may be obtained as to the amount due to the tracts affected by the proposed Betwa Canal. If the exact figures are not obtainable, an approximation should be given, and the probable saving which may be effected in the remission of land revenue in those tracts in future years should also be estimated by the Revenue authorities.

11. I am further to suggest that it may be considered whether it is not possible to reduce the cost of the establishments. Except at the head-works, and possibly for the first 20 miles of the main channel, the works are similar in character to what would be provided on distributaries elsewhere, and it seems possible, therefore, to reduce the cost of this item for such comparatively petty works.

12. The abatement of land revenue is calculated on the whole of the land to be occupied, including that in the Native States which should apparently be omitted.

13. The proposed arrangements with the Native States for occupation of land and payments for water to be supplied to them should be stated.

14. The estimate for land compensation should be attested by the Revenue authorities.

15. The estimate submitted contains no provision for leave and pension allowances, nor for charge for exchange on payments in England, if any, for the work. The necessary additions should be made to the estimate on this account.

16. I am directed to forward for consideration by the Chief Engineer copy of a note* by the Inspector General of Irrigation Works on the engineering details of the project.

* No. 5 A.-I. G., dated 21st June 1875.

Note by Colonel J. Crofton, R. E., Inspector-General of Irrigation Works, on Betwa Canal Project.—No. 5 A., dated 21st June 1875.

1. *Dam and Head-works.*—The maximum discharges of the Betwa in flood is calculated at 750,000 cubic feet per second. The calculation is based on a measured discharge of the river on the 10th September 1869, which amounted to 45,150 cubic feet per second, through a sectional area of 14,492 square feet, giving a mean velocity of 3·11 feet per second. The sectional area of the maximum flood is stated to have been 88,018 square feet. The mean velocity would, therefore, be $\frac{741,200}{88,018} = 8·42$ feet per second. These results agree very fairly with those deduced from an estimate of the proportion of rainfall running off the catchment, (see annexure by Captain Marshall to Colonel Brownlow's note, No. 674½, dated 1st April 1872.)

Now, in the calculation of the afflux at the proposed weir, the velocity of approach is left out, because, Mr. Hair states in a footnote to his calculation, it made no appreciable difference in the result. What velocity he assumed in his calculation, is not shown in the papers, but taking it at 8 feet per second, I calculate that a discharge of 751,908 cubic feet per second would cause an afflux of only 4 feet instead of 6½ feet, so that the works on the flanks of the weir and the afflux embankments would seem to be 2½ feet higher than is necessary. Again, the walls and top of embankment are designed 6 feet above the surface of highest flood. This is, I think, an excess of precaution. Three feet, or at the most 4 feet, would be ample.

If the maximum discharge of the river does not exceed that assumed—and there seems every reason, I think, to suppose that it is rather over than under the mark—the height of the head-works and river embankments might, according to the above calculation, be safely reduced 5¼ feet. It is, besides, to be borne in mind that the co-efficient (0·628) used in the formula for calculating the afflux is only applicable when there is a deep pool above the weir:

and when this pool silts up, as it will ultimately to a great extent, if not entirely, the velocity of the current immediately above the weir will increase to a certain extent, and consequently the height of flood will be something less than calculated by the formula.

This decrease in height would effect a considerable diminution in the cost of the work.

2. The alteration in the alignment of the regulating bridge and escape sluices in the weir made by the Chief Engineer is a decided improvement on the original design. The water-way through the under-sluices is, I think, too small for a river like the Betwa, where the deposit brought down in floods must be coarse sand, and probably shingle, which will need a strong current to scour away.

Colonel Rundall was of opinion that the aggregate width of water-way should be double that of the canal regulating head. It is designed in the proportion of 60 to 48; and the bays of the under-sluices are each 10 feet in width, but only 8 feet in height up to the crown of the arches. I would increase the height to 16 feet, leaving the width as designed.

3. The body of the weir is thicker than is perhaps absolutely necessary; but in a river with so steep a slope, and subject to floods of such magnitude, it is well to be on the safe side.

The top width might, however, with safety be reduced to 12 feet along nearly one-half of the length where its height above the rocky bed is inconsiderable. It should all be built of *uncoursed* rubble, which the experience in similar works in France and lately in Bombay has shown to be much superior to coursed masonry for this description of work. The Doomagoodiem weir, on the Godavery, also goes to prove that good rubble in cement is at least equal to, if not superior to, ashlar for the coping. That work has now been standing for about six years and has suffered little or no damage, though exposed to exceptionally violent action. The cement with which the work was built was manufactured on the spot from material obtained in the vicinity.

The top of the weir should be countersloped up-stream to facilitate the passages of trees or other floating substances over it. The edge is rounded off in the design, but this would not answer the purpose.

No provision is made in the estimate for protecting the bed below the weir from the scour and the impact of the falling water. It is stated that the reef of rock on which the work is to be constructed is free from cracks or fissures visible to the eye; if any should hereafter be discovered, they must be carefully filled with masonry in good cement.

Portland cement is estimated for; but if a good cement can be manufactured on the spot, it will answer equally well and be much cheaper.

4. A core of puddle is designed along the centre of the affiux embankments. This is quite unnecessary. From the levels shown on the plan, it appears that the greatest depth of water in the highest flood (in which the afflux is calculated to be 6½ feet) standing against the embankment would be about 1½ feet only, except in one or two places which are evidently isolated depressions of small extent, the deepest of which is not more than 7 feet below the surface of flood. The width, too, at top of the bank (20 feet) is excessive: 15 feet should be ample on the high portions, 10 feet over the greater portion of the length.

5. *Bridges.*—The number of these seems enormous. Including those at overfalls and regulators, the distribution is as follows:—

Channels.	Length, miles.	Bridges.			Remarks.
		At falls and regulators.	Ordinary occupation.	Total.	
Main Line	91½	2	7	9	1 in 2·16 miles.
Humeerpoor Branch . .	78¼	11	67	78	1 in 1 mile.
Kutound . .	58½	8	52	60	1 in 0·98 mile.
Calpee	11	1	9	10	1·1 mile.

In a populous well-cultivated tract, such as the Doab between the Ganges and Jumna, experience has shown that it is necessary to provide crossing places to this extent; but in an undeveloped country, with a comparatively sparse population, such as Bundelkhund at present is, it can hardly be necessary to make so large a provision. Probably less than one-half the number of bridges estimated for would answer for present wants and for many years to come. With channels so small as these, the construction of additional bridges, if found necessary hereafter, will not be a difficult matter.

The minimum full supply depth being 4 feet, fords cannot be substituted for bridges, but ferry-boats or rafts of inexpensive construction would probably answer all requirements in many places.

6. *Falls.*—The width between abutments or length of crest, including bridge piers, need not exceed the bottom width of channel up-stream. Down-stream it will be better to splay the side retaining walls (instead of carrying them parallel to centre line of channel), so as to form a large pool, in which the violent action of the falling water may be deadened. The vertical wall at the tail of the cistern should be dispensed with, and the floor sloped up from about the middle of its length to meet the level of the bed down-stream.

7. *Drainage syphons.*—The length of these works might be reduced by omitting the road or pathway (it is 8 feet wide) on one bank.

8. The drop walls and side retaining walls in the falls, as well as the arches of the drainage syphons, if built of brickwork, should be backed with a layer of puddle to prevent absorption of water.

9. *Inspection-houses.*—For small channels such as these are, no larger than distributaries elsewhere, the number of buildings of this class seems excessive. The Chief Engineer states that they have been designed at 10-mile intervals, owing to the difficulties of marching in Bundelkhund. With a good road along the canal channels, however, there should be no great difficulty in getting over 12 to 15 miles a day, and if so, the number of inspection-houses might be reduced by about one-third.

Besides, as the anticipated extent of khureef cultivation is very small, the necessity for good shelter in the hot weather and rains is not so great as on the other canal systems in Northern India. In the rubbee season tents would answer the purpose.

The temporary accommodation seems very costly for a work expected to be completed in 2½ years.

10. *Earthwork.*—There are some long reaches shown on the longitudinal sections where it would be advisable, if possible, to carry the bed at a greater depth below surface. On the Humeerpoor Branch, from the 50th to the 72nd mile, there is little or no digging; also from the 88½ mile to the 92½ mile there is heavy embankment, and of this about 3 miles is altogether above soil; on the Calpee Branch, from the 73rd to 79th mile the bed is close to the surface. The section of the Kutound Branch is fair.

11. *Land occupied.*—The area of land seems to be capable of considerable reduction. Four hundred feet in width is estimated for the whole length (19½ miles) of the main channel. So great a width seems to be only required on the first 4 miles; on the remaining length, when the depth does not exceed 15 feet or thereabouts, 200 feet would be ample. On the branches the width estimated for appears to be generally about 30 feet more than is required for the banks and channel where the bed is on the surface of the ground. This can hardly be necessary unless to give room for plantations, which should be separately estimated for.

12. *Distributaries.*—The cost of these comes to ($\frac{1,61,316}{220}$ =) Rs. 733 per mile, a very high rate for channels so small as these must be.

13. *Tools and plant.*—The estimate is very large. Dredgers and centrifugal pumps are entered, but there is no provision in the estimates for well foundations or unwatering foundations, and Mr. Hair states that no well foundations will in all probability be required anywhere; the sections, too, confirm this. Except on a portion of the head-works, the springs appear to be everywhere below the level of foundations.

14. *Canal road.*—This is projected, Mr. Hair states, on the left bank of the channels, but no reason for this departure from the usual position is assigned. The roads elsewhere are formed on the side where the shade from a line of trees would be available during the heat of the day.

From the Secretary to the Government, N. W. P., P. W. Dept., Irrigation Branch, to the Secretary to the Government of India, P. W. Dept.—, No. C.345W., dated 28th June 1876.

I AM directed to acknowledge the receipt of your letter No. 318I., dated 8th September 1875, conveying the orders of the Government of India upon the estimate of the Betwa Canal project, and to communicate replies to the various points raised in that letter, as well as to the criticisms of the Inspector General of Irrigation Works forwarded with it.

2. The criticisms of paragraphs 2, 3, 5, 6, 7, and those of the Inspector General are replied to in a Chief Engineer's note* by Colonel Greathed, whose conclusions appear to His Honor the Lieutenant-Governor to be well founded.

*No. C145½, dated 6th November 1875.

3. Pending further instructions, therefore, the Chief Engineer has not been required to carry out the orders of paragraph 8. The Lieutenant-Governor would prefer to avoid the necessity of reducing the scale of the works, which will involve a great deal of re-estimating and preparation of new plans; while at the same time it will be a difficult matter to predict with any certainty the cost of extending the scale if requisite at a future period, when a similar increase in rates may have occurred in the districts irrigated by the Betwa Canal to that which has taken place in the Ganges Canal districts, and which is well exemplified in the correspondence* regarding the cost of restoring the Salawa lock to its original condition.

* Progs. $\frac{A}{W}$, February 1876, Nos. 20-7.

4. With regard to paragraph 9, I am desired to point out that the project of 1872 was roughly estimated at 17¼ lakhs, without any items being specified. The second estimate of 1873 amounted to ₹14,29,290 for works, and was brought up by Colonel Brownlow to 18 lakhs by adding ₹3,57,322 for tools and plant and establishment. The following statement compares the items given in† Colonel Brownlow's abstract of the cost of the weir, 9½ miles of main canal, and Kutound branch, with the corresponding items of the project as now submitted :—

† Progs $\frac{A}{W}$, June 1873, No. 57.

Items.	Estimate of 1873.	Present estimate.
	₹	₹
Weir and head works	5,17 000	7,79,123
Inspection houses	8 500	37,236
Assistant Engineer's bungalow	1,500	
Workshop	3,000	81,155
Workmen's huts	1,500	
Bridges—main canal	35,000	70,564
Ditto—Kutound	67,000	96.845
Excavation	2,87,500	3,71,006
Land	43,000	92,235
Drainage works	25,000	17,901
Sleepers, &c.	9,000	...
Establishment	2,12,500	3,47,276
Tools and plant	53,125	84,685
Preliminary works	...	43,000
Falls, weirs, and rapids	...	27,132
Escapes	...	20,000
Mills	...	12,500
Outlets	...	5,000
TOTAL	12,88,125	20,83,658

It will be seen that an excess occurs on every item, but especially on head-works, temporary accommodation, excavation, and establishment, and that in the first estimate many items were omitted. The explanation of the differences is that the first estimate was avowedly drawn up roughly, while the present one has been drawn up with great care and with great attention to the rates.

5. In compliance with the orders of paragraph 10, I am directed to forward the correspondence marginally noted, respecting the remissions of revenue due to drought in the tracts to be irrigated by the proposed canal. It is stated by the district officers that the remissions of revenue in the tracts affected by the canal amounted to ₹3,460 only. It will be seen that in this statement the actual revenue remitted on account of *drought only* has been taken into account, whereas in the statement from which the figures of the Chief Engineer were taken, and which is printed in Proceedings of this Government ($\frac{A}{W}$, September 1873, No. 101), the remissions quoted include revenue remitted on every account, as remarked in the paragraph at the foot of the statement; and the Commissioner of Jhansie, commenting on the figures now given, observes that although the actual sum remitted for drought amounted to so small a sum, yet the amount of revenue suspended on account of drought and afterwards realised represents a load of ever-increasing debt for the people which might have been warded off by the canal.

Secretary to Board's Nos. 263-IV.-17 and 328-IV.-17, dated 16th and 28th March 1876, and enclosure.

6. The estimate for compensation for land is also attested by the district authorities in the above correspondence as required in paragraph 14 of your letter. The Lieutenant-Governor approves of a retention of ₹5 per acre margin as proposed by the Chief Engineer. The total cost of land is reduced in the estimates by ₹60,248.

7. *Paragraph 11.*—The Government of India suggests that the cost of establishment should be reduced; but the Chief Engineer clearly shows, in the enclosed note, that such a reduction is impracticable.

8. *Paragraph 12.*—The total area of land in Native States is—

For channels	937·72
Head-works and Pareecha station	1,728·00
TOTAL	2665·72

Omitting this from the calculation, the capitalised value before calculated for the whole area will be reduced to ₹1,03,728, which should now be substituted in the estimate.

9. *Paragraph 13.*—It appears to this Government premature to suggest arrangements for the supply of water to the Native States until the project is further advanced. The subject will be considered in due course as soon as the position of channels is definitely fixed.

The charge to be entered for leave and pension allowances will, under the orders of Public Works Circular 2 of 1876, be 25 per cent. upon establishment, or $\frac{5,04,391}{4}$ =₹1,26,098. No charge for loss on exchange need be entered, as it is not at present intended to obtain any stores from England.

The adjustments and reductions effected in the estimates reduce the amount to ₹39,43,304, for which the sanction of the Government of India is solicited. A copy of the project is submitted in which the figures have been corrected in the abstracts, pages 20-25.

Finally, the Lieutenant-Governor desires to remark that the country in which these works are to be carried out is one of the least accessible parts of the North-Western Provinces, only to be got at by a metalled road from Cawnpore, which is distant 150 miles. No large public works have ever been constructed in Jhansie and Jaloun. All skilled labour, much of the unskilled labour, all timber, manufactured iron, and machinery, has to be imported. The cost of these works will necessarily be higher rather than lower than those which are constructed in the civilised tracts of the Doab; and Sir John Strachey considers that Colonel Greathed has exercised a wise discretion in framing his estimates with a liberal margin. The Lieutenant-Governor is of opinion that the sum entered should stand, so that all contingent expenses may be covered.

Note by COLONEL W. H. GREATHED, C.B., R.E., Chief Engineer of Irrigation, N. W.P., on the Betwa Canal,—No. C.1450½W., dated 6th November 1875.

Remarks on the Inspector General's Note on Designs.

1. COLONEL CROFTON considers that the height of the head-works and of the river embankments against afflux may be lowered 5½ feet in height. This recommendation is based upon three assumptions :—

I.—That R. L. 751·908 is the highest possible flood.

II.—That the rainfall adopted as a basis of calculation in Colonel Brownlow's note of 1st April 1872 is a maximum, and that the proportion there supposed to run off cannot be exceeded.

III.—That the bed of the river in front of the dam will silt up.

Concerning flood volumes and rainfall, our observations are so limited in extent as to be, in my opinion, unreliable as maxima. We know from experience how invariably "unprecedented" floods occur in large rivers of which the phenomena have been closely studied and watched for a series of years, upsetting all calculations. Something of the kind has even now occurred, I believe, on the Beas; and in the present state of our experience of the Betwa, I am unwilling to base designs on any close estimate of probable highest flood.

The subject was very carefully considered when the designs were determined, and I am not prepared to relinquish any of the margin of safety given to the head-works.

Regarding the possible silting up of the Betwa in front of the dam we have no experience, I believe, to guide us. Nowhere, as far as I am aware, has the stream of such a river, filling during the flood season, a rectangular rock channel forty feet in depth and moving with terrific violence, been barred by any artificial work: and no experiments ever yet made can certify what the velocity of such floods will be at the bottom of such a channel.

On this point turns the question whether, and, if at all, to what depth the shingle brought down from the Vindhyas can rest on the bottom of the river and raise the bed in front of the

weir. Colonel Crofton would have the works designed on that assumption. I cannot rely on a conjecture that the afflux will never be more than is calculated by the Inspector General, and prefer to maintain the provision of the estimates.

2. Colonel Crofton's proposal to double the height of the uuder-sluice openings.

The under-sluices for scouring the river-bed in front of the canal or head-sluices are six openings of 10 by 8=480 square feet. With a low velocity of 5 feet per second they will dicharge 2,400 cubic feet per second, which is the whole volume of the river in September (nearly), except when there is a freshet. The velocity when the sluices are 10′×8′ is calculated at 11·32 feet per second, and when they are 10′×18′ it would be 11·50 feet per second, or practically the same. It will not be desirable to open the weir sluices, excepting in falling floods, and their capacity as designed is four times that of the canal supply. The object of an enlargement is not apparent.

3. The strength of the body of the weir is purposely in excess of the minimum of safety. The top width was studiously designed of width sufficient to afford a roadway during the eight months of the year in which it will be dry, for which purpose 12 feet would be insufficient. It is therefore unadvisable to diminish the proposed surface width of 16 feet.

It was intended to construct the weir after the manner of that at Furens, the masonry courses being broken in all directions. The term coursed-rubble indicates that the work will be constructed with the largest self-bedded stone procurable, and not with small irregular stones, which cannot be dressed, as is usual in uncoursed or random rubble. Portland cement is necessarily estimated for because it is not known at present that sufficiently good cement can be obtained on the spot.

4. The embankment on the right bank follows the road from Bhetre and taps a range of hills from which rubble stone could be obtained. It was therefore designed with a top width of 20 feet, in order that it might be used for traffic. A similar reason fixed the width of the bank on the left from the weir to Pareecha and on to the metalled road. As the Customs hedge divides the bank from the road above this point, it would be a boon to the cultivating community to make the bank of sufficient width for carts to pass along, and the possible saving to be effected is quite unimportant.

5. The number of bridges is determined by the probable wants of the country when irrigation is developed. The experience of the Ganges Doab has led to the establishment of a scale according to which the intervals between bridges diminishes as the bed width of the channels, and consequent cost of structures becomes less. The same scale is applied to the Betwa project, for the same requirements will arise as the population bordering that canal increases. The bridges are occupation-bridges, required for communication between the severed lands of an estate; it is provided in the report of the estimates that they would only be built as required: the accuracy of the estimates as financial indicators will be vitiated if due provision is not made for bridges. Rafts and ferries are impossible in these small channels, which would be choked by them and would in this situation be more costly than bridges: for a ferry requires a man in charge, besides constant repairs, if there is anything temporary in its character. If it is a pontoon raft plying between metalled approaches, it only pays where the channel is wide and bridges costly. It was contemplated that foot-bridges may be substituted in most cases, but our knowledge of the country is not sufficient to determine whether this is the case, or to what extent. The Chief Engineer is unwilling to alter this part of the estimate.

6. The falls are designed in the manner habitual in the North-Western Provinces, with a length of crest equal to the mean width of the channel. If the proposed alterations were carried out, there would be a saving (ex. the fall in first reach of Humeerpoor Branch) of Rs. 367 on an estimate of ₹6,335, against which there should be a set-off for additional cost of repairs caused by increased velocity at the fall tail. Splayed wing walls have been given up on the Ganges Canal and straight ones adopted. The Inspector General's recomendation that the walls in these falls should be splayed is opposed to our experience and practice.

7. The proposed reduction of syphons by 8 feet in length would save ₹665 at mile 16½ of the main canal and ₹204 at mile 39 of the Humeerpoor Branch, which would not compensate for the inconvenience of narrowing the normal width of the canal bank. If the canal banks were very high and the cost of maintenance of full width considerable, the case would be different.

8. The distance fixed between inspection-houses was the result of mature consideration of the character of the country and of the distribution of the irrigation which will have to be managed and examined from them. There will be no good road along the canal bank beyond

the first 19 miles, but in the rains very bad roads on the level of the country, at the foot of the banks, which are too narrow for the purpose. There are only two first class inspection-houses. The remainder are rest-houses, and if they are built further apart than they are designed, others will have to be interpolated to allow of a proper management of the irrigation, which is at right angles to the canals, covering a great number of distinct minor Doabs. The inspecting officer will have to ride up a distributary and back before he finds shelter, and if he has a long ride on the canal bank besides, the labour will prejudice the work. Further consideration will show that the number of inspection-houses is really very small, for none have been allowed on distributaries, but all have been brought up to the canal banks, to serve also as staging-houses.

9. The temporary accommodation does not appear susceptible of reduction. (See project, page 16, paragraphs 76 and 77.) It is almost entirely at the weir. Everybody employed on the weir must be housed; the neighbourhood affords no sort of help, and reasonable shelter is indispensable for men who have to endure the force and glare of a Bundelkhund sun on the white rocks of the bed of the Betwa. The extreme moderation of the workshop arrangements has not been noticed by the Inspector General. It is the point of the estimates on whose sufficiency I have the greatest doubt.

10. The canal canot be a cheap one. A vast weir to raise a very small volume of water must make it a barely remunerative undertaking.

11. The only practicable savings in earthwork appear to be from mile 59½ to 72 of Humeerpoor Branch road, and from mile 88½ to 92½ of Calpee Branch, on which lengths the depth of digging may be diminished 2 feet.

	R
Humeerpoor Branch	13,475
Calpee ditto	4,356

The saving will amount to ₹17,831.

12. In estimating land no more has been taken than is requisite to allow a margin for borrow-pits and for repairs. For instance, on the Humeerpoor Branch from the head to the beginning of Calpee Branch a width of 110 feet is provided, *viz.*:—

	Feet.
Width between outside foot of banks	58
Add for road	25
Leaving a margin of 30 feet	83
And on Calpee Branch: Width of bed and banks	52
Add for road during construction	25
Leaving a margin of 18 feet	77

The estimates cannot bear any reduction of quantity, but the price per acre has been lowered from ₹25 to ₹15, which leaves a margin for establishment, rise in rates, &c., on the Commissioner's estimate of ₹10. The estimate is reduced from ₹1,50,618 to ₹90,370. The reduction is not a real one, for the compensation payable for land is governed by special rules and is quite independent of the estimates.

13. *Tools and plant.*—The longitudinal section shows that a portion of the head-works, the three first bridges, and an inlet will have their foundations below spring-level, and unwatering, therefore, will be necessary. It is possible, too, that the two syphons will have to be founded below spring-level. As it cannot be said what the force of the springs is likely to prove, it is only an ordinary precaution to provide for the purchase of two pumps; of course they would not be bought if not actually required. Again, the fact of some foundations being in saturated soil indicates the probability of more or less dredging being required. Fifteen drinking wells have to be sunk, and it is likely that more will be needed at some of the larger works. These considerations and the area over which the works are scattered show that a provision of 10 dredgers is not excessive.

14. *Establishment.*—The provision made in the Chief Engineer's estimate is the now established rate of 20 per cent. on the cost of works and tools and plant, ₹5,04,391.*

The cost cannot possibly be reduced below that proposed by the Superintending Engineer, which is for *executive* establishment alone taken for three years, ₹2,85,156†

To which must be added Direction and Accounts 5 per cent. on works	„ 1,10,538
Total	„ 3,95,694

* See page 24A. of Appendix to Betwa Project. | † See p. 22A. of Appendix to Betwa Project.

Suppose (which is highly probable) that the work occupy four years in execution, then the cost of establishment would be increased by ₹95,052, making a total of ₹4,90,646.

Or the failure of health of two or three Engineers (which must be looked for in works in one of the hottest regions of Northern India) would double the charges for their salaries, and so exceed the minimum amount above specified. It is not practicable to reduce the amount provided in the estimates.

15. It is but just now that the Government of India has succeeded in introducing a system of complete and accurate estimate which includes all probable charges; and there cannot but be risk of retrogression in this important matter if a Chief Engineer is required to make a complete estimate for one scheme and a less complete estimate for another.

There is no safety save in the hard-and-fast line of completeness; and I submit, with every respect for the professional advisers of the Government of India, that the proper course is that estimates for all works without exception should include all probable charges.

OPINION OF REVENUE OFFICERS ON CERTAIN POINTS CONNECTED WITH THE BETWA CANAL PROJECT.

(APPENDIX TO CHIEF ENGINEER'S NOTE No. C.-1480-W., DATED 6TH NOVEMBER 1875.)

From C. H. T. CROSTHWAITE, Esq., Officiating Secretary, Board of Revenue, N. W. P., to COLONEL W. H. GREATHED, C.B., R.E., Secretary to Government N.-W. P., Irrigation Branch,—No. 263-IV.-17, dated Allahabad, the 16th March 1876.

IN reply to Government Order No. C.1391W. of 20th October last, regarding the Betwa Canal project in Bundelkhund, I am desired by the Board to forward the papers noted on the margin, received from the Commissioners of Allahabad and Jhansie, and to state that the remissions on account of famine and unfavourable seasons in the tracts affected by the proposed Betwa Canal in the Humeerpoor, Jhansie, and Jaloun districts amounted in the course of 12 years to ₹3,460-2-2 only, the whole of which amount was remitted in the Jhansie district.

Allahabad Commissioner's No. 1560, dated 31st December, 1875, and enclosure.
Jhansie Commissioner's No. 86, dated 16th February, 1876, and enclosure.
Copy of Deputy Commissioner, Jaloun's No. 64, dated 4th March 1876.

The Board consider that the estimate of compensation at ₹25 per acre is well over the mark, the rates per acre, as estimated by the local officers, being in Humeerpoor (1) cultivated, ₹21; (2) culturable, ₹8; (3) barren, ₹1-8-0; and in Jhansie ₹15, or ₹10 all round.

From G. H. M. RICKETTS, Esq., Commissioner, Allahabad Division, to C. H. T. CROSTHWAITE, Esq., Officiating Secretary to the Board of Revenue, N. W. P.,—No. 1560, dated Allahabad, the 31st December 1875.

IN reply to your endorsement No. 700-IV-81 of November 12th, I have the honour to submit the information called for from the Collector of Humeerpoor. It will be observed that the proposed canal will affect only that very small portion of the Humeerpoor district adjoining Jaloun and situated on the left bank of the Betwa.

From W. KAYE, Esq., Officiating Collector, Humeerpoor, to THE HON'BLE R. DRUMMOND, Commissioner, Allahabad Division,—No. 585, dated Hamirpur, the 11th December 1875.

IN reply to your letter No. 340, dated 18th November 1875, I have the honour to state that from 1860-61 to 1871-72 there were no remissions of revenue on account of drought in the tract affected by the proposed canal in this district.

The average revenue-rate for cultivated land per acre in the tract above mentioned is ₹1-12-0. Taking the profit at an equal amount and allowing 12 years' purchase, the compensation would amount to ₹21 per acre for cultivated land. The compensation for culturable land would amount to, perhaps, ₹8 an acre, and that for barren lands ₹1 to ₹2 an acre.

From A. R. S. POLLOCK, Esq., Commissioner, Jhansie Division, to C. H. T. CROSTHWAITE, Esq., Officiating Secretary to the Board of Revenue, N.-W. P.,—Docket No. 86, dated Camp Hudruklo, the 16th February 1876.

WITH reference to his No. 701-IV.-81, dated 12th November last, forwards copy of Deputy Commissioner of Jhansie's letter No. 319, dated 1st instant, with annexure, and intimates that the report of Jaloun district will be submitted when received.

From COLONEL J. DAVIDSON, Deputy Commissioner, Jhansie, to A. R. S. POLLOCK, Esq., Commissioner, Jhansi Division,—No. 319, dated Jhansie, the 1st February 1875.

I HAVE the honour to acknowledge the receipt of your letter No. 881, dated 2nd December, forwarding copy of Board's No. 701, dated 12th November, with printed papers* relating to the Betwa Canal project, and calling upon me to furnish the information required by paras. 10 and 14 of Government of India's letter No. 318-I. of 8th September last.

* Sent to Deputy Commissioner, Jaloun.

2. Para. 10 refers to the amount of remission of revenue in the five districts of Bundelkhund during the 12 years ending with 1871-72, attributable to famine and drought, amounting in all to ₹33,63,989, and my opinion is called for as to the amount due out of this sum to the tracts affected by the proposed canal, and also as to the probable amount of saving in future years on the remission of land-revenue in those tracts.

3. I have been in communication with the Executive Engineer, Mr. Dubus, on the subject, and I beg to enclose a list of the villages, 24 in number, which he thinks may be fairly included in the estimate as capable of irrigation from the canal. Mr. Dubus originally included only 16 villages of pargana Moth, but the eight now added can, in his opinion, be watered by a special distributary at no great additional cost, all these 24 villages being on the level lands away from the ravines of the Betwa.

4. I also append a statement showing the amount remitted in this tract during the period in question on account of drought or famine. The amount is very small:—

	₹	a.	p.
In 1864-65	2,616	2	2
and in 1781-72	844	0	0
Total	3,460	2	2

This amount, spread over a period of 12 years, gives an average of only ₹288 per annum.

5. In these 24 villages the area, cultivated and culturable, which is at present not irrigated in any way amounts to 21,227 acres. Of this Mr. Dubus assumes that two-thirds will ultimately be benefited by the canal. But I do not think he has made sufficient allowance for khureef lands, which in ordinary years would take little or no water. If, therefore, one-third be assumed as the area which would take water for rubbee crops, it would amount to 7,076 acres. This is a matter beyond the scope of the inquiry I am called on to make, but I mention it as showing that the average of a few hundreds of rupees per annum for remissions of revenue would, as a matter of course, be saved to Government, besides the direct returns from water-rates.

6. Para. 14 calls for an attestation of the estimates for land compensation. The rate allowed by Mr. Hair is ₹25 per acre, and without knowing the details of the land to be taken up under the headings of cultivated, culturable, and barren, it is not easy to fix the amount with any precision. It will, perhaps, be sufficiently near the mark to take the jama rate per acre all round on the malguzari area, which averages in the 24 villages about ₹1 per acre. This multiplied by 10 for 10 years' purchase gives ₹10 per acre, and if to this be added ₹5 per acre for cultivators' rights, &c., the total comes to only ₹15, or ₹10 less than Mr. Hair's estimate.

List of Villages capable of Irrigation from the Betwa Canal.

	Villages.	Culturable.	Cultivated.	Total unirrigated.	Remissions granted from 1860-61 to 1871-72. In 1864-65.	Remissions granted from 1860-61 to 1871-72. In 1871-72.	Remarks.
					R a. p.	R a. p.	
1	Moth	195	1,281	1,476	...	...	
2	Nari	234	1,224	1,458	...	...	
3	Bhipta	62	504	566	Drought 251 0 0	...	
4	Kamtari	137	508	645	Drought 356 3 11	...	
5	Pahargaon	384	2,001	2,385	...	...	
6	Kunch	97	1,464	1,561	Drought 747 4 0	Famine 511 0 0	
7	Khilli Kallan	121	452	573	Drought 550 0 0	Famine 333 0 0	
8	Tori	149	566	715	...	...	
9	Gulpura	24	163	187	...	...	
10	Ahrauli	87	279	366	...	...	
11	Silari	142	333	475	...	...	
12	Ahrora	77	174	251	...	...	
13	Saina	190	607	797	...	...	
14	Tanda	170	435	605	...	...	
15	Amkhera	284	304	588	...	...	
16	Barthari	266	304	570	...	...	
17	Nimonia	21	491	512	...	...	
18	Patharra	166	915	1,081	...	...	
19	Kumrar	512	1,052	1,564	...	...	
20	Bamroli	246	794	1,040	...	...	
21	Burauli	127	895	1,022	...	...	
22	Pulgahna	82	809	891	...	...	
23	Belma	277	1,174	1,451	Drought 711 10 3	...	
24	Basona	43	405	448	...	...	
	TOTAL	...	...	21,227	2,616 2 2	844 0 0	

From COLONEL A. G. DAVIDSON, Deputy Commissioner, Jaloun, to A. R. S. POLLOCK, Esq., Commissioner, Jhansie Division,—No. 64, dated Jhansie, the 4th March 1876.

I HAVE the honour to acknowledge the receipt of your docket No. 85, dated 12th *ultimo*, with which you enclosed Revenue Board's endorsement No. 701-IV.-81, dated 12th November, with annexures and printed correspondence, and reply as follows.

I have had examined before myself the accounts of remissions granted to the Jaloun district from 1862-63 till 1869-70, which amount to R1,07,333-10-9, but I find that no remissions of revenue have been made in this district for years of famine or for unfavourable seasons. All the remissions were made for reduction of jama consequent upon revision of settlement and for lands taken up for public purposes during the famine year of 1868-69. A portion of the year's demand, amounting to R2,38,815, was suspended *pro tem.*, but the whole of this was collected in subsequent years by instalments, and from 1869-70 till the present time no remissions of the nature enquired about have been required or made: hence the remissions made in the districts of Bundelkhund during the 12 years and amounting to R33,63,989. None of this amount is debitable against the Jaloun district.

In this view of the case, supposing 12 years in the immediate future with similar seasons to the past 12 years under report, the revenue of the district would be realized in full; hence there would be no probable saving to be effected by the cessation of remissions, none having hitherto been made. The rate of R25 per acre allowed in the estimates for land compensation would be ample to cover all demands of this kind.

I append the translation of the Revenue Accountant's report as to no remissions for unfavourable seasons having been made in Jaloun.

From C. H. T. CROSTHWAITE, Esq., Officiating Secretary, Board of Revenue, N. W. P., to A. COLVIN, Esq., Officiating Secretary to Government, N. W. P.,—No. 328-IV.-17, dated Allahabad, the 28th March 1876.

In continuation of my No. 263, dated 16th instant, I am desired to submit, for the information of Government, a copy of the letter noted in the margin. The report of the Deputy Commissioner of Jaloun was forwarded to Government with the Board's former letter.

Jhansie Commissioner's No. 198, dated 13th March 1876.

From A. R. S. POLLOCK, Esq., Commissioner, Jhansie Division, to C. H. T. CROSTHWAITE, Esq., Officiating Secretary, Board of Revenue, N. W. P.,—No. 198, dated Jhansie, the 13th March 1876.

WITH reference to your endorsement No. 701-IV.-81, dated 12th November last, with which you forwarded printed papers connected with the Betwa Canal project, and called for opinion as to the portion of the R33,63,989 of remissions of revenue made in the five districts of Bundelkhund during the 12 years from 1860-61 to 1871-72, which is due to the tracts which will be affected by the proposed Betwa Canal, I have the honour to forward, for the information of the Board, copy of the report of the Deputy Commissioner of Jaloun. A copy of the report of the Deputy Commissioner of Jhansie was forwarded with my docket No. 86 on the 16th February 1876.

2. The Board will observe that the proposed canal will only irrigate land in 24 villages in the Jhansie district; that during the 12 years referred to remissions on account of drought were made on account of these 24 villages to the extent of R3,460 only, or at the rate of R288 per annum.

3. It is hardly worth while to delay the submission of this report by ordering inquiries to be made as to the exact amount of savings which would have been effected in this small tract if the canal water had been available during those 12 years, but we may fairly presume that upwards of half of the loss would thereby have been avoided.

4. In the Jaloun district the Deputy Commissioner reports that no remissions whatever were made during the period under report on account of drought. But on account of the drought of 1868 temporary suspension of the revenue demand for 1868-69 was made to the extent of R2,38,815, the whole of which was, however, subsequently recovered by instalments.

5. The Deputy Commissioner does not attempt to show to what extent this large suspension might have been reduced if canal water could have taken the place of absent rainfalls, nor do I think it possible that any approximate estimate could, without a very elaborate enquiry, be formed of the result of such a condition.

6. But there can be no doubt that the canal water would have saved at least one-half of the tract affected, and the result would have been a large increase to the food-supply of the district and division at a time when scarcity and the greatest distress existed in these parts.

7. Besides, although the Government revenue for 1868-69 was all collected eventually, there is nothing to show to what extent the arrears were liquidated with money borrowed from bankers and banyas, which will burden the zemindars for years with an ever-increasing debt. Such was certainly the case in the Jhansie district, and if remissions had been made more liberally, instead of the demand being enforced to the last farthing, much of the indebtedness of the present time would certainly have been avoided.

8. But the question asked by Government is, what portion of the R33,63,989 remitted by Government in Bundelkhund during 12 years would have been saved if the Betwa Canal had during that period been in existence? And the reply to that question is, that the direct saving to Government, if the canal water had been available, as regards actual revenue, would have been next to nothing, for out of that large sum remitted apparently only R3,460 was on account of land which will come within the influence of the canal-irrigation.

From the Government of India, P. W. Dept., to the Secretary to the Government of the N. W. P., P. W. Dept., Irrigation Branch,—No. 457 I., dated the 23rd October 1876.

I AM directed to acknowledge the receipt of your letter No. C.345W. of the 28th June last, replying to the orders of the Government of India on the Betwa Canal project and soliciting sanction to an estimate of R39,43,304 for carrying out the work.

2. In reply I am directed to state that the Government of India considers the present project to be much too costly an undertaking to admit of its being constructed from the "Ordinary" grant; and as the anticipated earnings are too small to allow of the work being classed as "Extraordinary," the Government of India regrets its inability to accord sanction to the project in its present form, and would suggest that a less expensive scheme be prepared and submitted for the consideration of His Excellency the Governor General in Council.

From C. ANDERSON, Esq., Officiating Secretary to the Government of the N. W. P., P. W. Dept., Irrigation Branch, to the Secretary to the Government of India, P. W. Dept.,—No. C. 1250W., dated the 11th December 1877.

WITH reference to your No. 457I., dated 23rd October 1876, returning the Betwa Canal estimate, I am desired to forward a note* by the Officiating Chief Engineer, and an estimate which, in the opinion of His Honor the Lieutenant-Governor, gives the lowest possible figure at which the Betwa Canal can be constructed.

* No. C. 1249W., dated 11th December 1877.

2. I am desired to call particular attention to paragraph 8 of the Officiating Chief Engineer's note, and to state that, as the scheme is represented to be less promising than other projects in the North-West Provinces, and as, in the event of a famine, work for the people will be provided by the system of light Railways which is now in contemplation, the Lieutenant-Governor would deprecate, in the present state of his finances, being called on to undertake a work which, when all is said and done, "may possibly just pay its expenses." It is certain that it would remain unremunerative for many years, during which period this Government would have to pay the interest on the capital embarked in the scheme, and this is a liability which His Honor is unprepared to meet, at all events for the present.

Note by C. ANDERSON, Esq., Officiating Chief Engineer, N. W. P., P. W. Dept., Irrigation Branch, on the Betwa Canal, No. C. 1249W., dated the 11th December 1877.

THE detailed estimate of the Betwa Canal was first submitted to the Government of India with letter No. 1311, dated 12th December 1874. This estimate amounted to R39,85,133.

2. The estimate was returned by the Government of India under cover of letter No. 318I., dated 8th September 1875, with a note by the Inspector General of Irrigation, in which the project was criticised and certain possible reductions indicated.

3. With North-Western Provinces letter No. 345W., dated 28th June 1876, was submitted a second estimate amounting to R39,43,304, and a note by Colonel Greathed, in which that officer replied to the several criticisms of the Inspector General. Sanction to this second estimate was solicited.

4. The Government of India, in returning the second estimate with Secretary's No. 457I., dated 23rd October 1867, stated that the project was much too costly to admit of its being constructed from Ordinary funds, and its anticipated income too small to allow of the work being classed under Extraordinary, and suggested the preparation of a less expensive scheme.

5. The estimates and designs have been examined by the present Officiating Chief Engineer, who is prepared to accept the recommendation of the Inspector General to the extent noted in the accompanying statement marked B. An estimate embodying the several modifications accepted by the Officiating Chief Engineer has been prepared and accompanies this note.

6. As compared with the estimate submitted in 1875, the present estimate shows a saving of R5,21,428, of which R3,76,096 is due to works.

7. The net income was estimated in 1874 at R1,71,000; this is equal to a return of 4·31 per cent. on the estimate of 1876. The Officiating Chief Engineer is certain that the net income has not been under-estimated. Accepting the figures of 1874, the net income gives a return of 4·93 per cent. on the present estimate.

8. The Betwa Canal scheme, though not so remunerative as other projects in the North-West Provinces, may possibly just pay its expenses and thus escape being a burden on the finances of the province. It certainly will provide work for a large number of people whom the peculiarities of the season may have deprived of their usual means of subsistence. Under these circumstances, it seems advisable to postpone the project until such time that the State is compelled to provide work for the poorer classes of the Bundelkhund population and thereby protect them from starvation.

From the Government of India, P. W. Dept., to the Secretary to the Government of the N. W. P., P. W. Dept., Irrigation Branch,—No. 91I., dated the 23rd April 1878.

REFERRING to your No. C.1250W., dated 11th December last, and previous correspondence regarding the Betwa Canal, I am directed to request that the Government of India may be furnished with statements showing the volumes discharged by the Betwa and Keyn rivers during each month of 1877. It should be stated how the figures submitted have been arrived at, volumes actually measured being distinguished from those interpolated by calculation from gauge readings.

2. In connection with this subject, I am to draw your attention to paragraphs 2 and 3 of despatch No. 37 P.W., dated 23rd April 1874, from Her Majesty's Secretary of State, forwarded to you with Resolution, Government of India, No. 3361., dated 21st May 1874, to point out the necessity of accurate measurement of minimum discharges in the Betwa and Keyn rivers, and to ask whether the tributaries of the Betwa have been examined for sites of storage reservoirs. In paragraph 6 of his reply to the Resolution of Government of India above quoted the Chief Engineer of Irrigation, North-Western Provinces, pointed out that the question of storing water in the bed of the Betwa itself had been very carefully considered, but no mention is made of examination of the tributaries.

From the Government of India to Her Majesty's Secretary of State for India,—No. 27P.W., dated Simla, the 1st July 1881.

WITH reference to Your Lordship's predecessor's despatch* on the subject of the Betwa Canal project, and also to our Financial Despatch No. 97F., dated 30th April 1881, regarding "Protective Works," in which the Betwa project is mentioned, we have the honour to forward the papers enumerated in the margin for the consideration of Her Majesty's Government.

* No. 37P.W., dated 23rd April 1874.

Note by the Inspector-General of Irrigation, dated 19th June 1875, describing the project.
Proceedings, Government of India, September 1875, Nos. 7-9A.
Letter from the Government, North-Western Provinces, to the Government of India, No. C.716W., dated 22nd August 1878, and enclosure.
Resolution by the Government, North-Western Provinces, No. 831, dated 30th October 1878.
Letter from the Government of India to the Government, North-Western Provinces, No. 581., dated 5th April 1879.
Extracts from Notes by the Inspector-General of Irrigation, dated 5th February 1879 and 7th February 1879.
Letter from the Government, North-Western Provinces, to the Government of India, No. C.122W., dated 25th April 1881, and enclosure.

2. In the despatch No. 37P.W. referred to above, the attention of our Government was invited to three points which required investigation before considering the project—(1) the rainfall to be anticipated during years of drought and famine; (2) the formation of reservoirs at some distance to supplement the drainage from the immediate neighbourhood of the river; and (3) the substitution of numerous small reservoirs in suitable situations in place of a single river-fed canal.

3. The papers now forwarded show that although the rainfall is precarious in the tract of country to be commanded by the canal, yet the supply in the river never altogether fails, owing to its sources being in the Vindhyan range of hills, where the south-west monsoon never fails; and thus a good supply can confidently be looked for even in dry years for the ordinary khureef crops between the 15th July and the 15th October. On the other hand, a series of small tanks would be dependent on the local rainfall and liable to total failure in years of drought.

4. No record can be traced of the rainfall in the famine years in the earlier part of the century, but the observations recorded in the papers now submitted extend over a period embracing two years of great drought, 1860 and 1868, and during this period the rainfall at the sources of the river never fell below 30 inches in any year. It is clear, therefore, that the river is a far more reliable source of supply for dry years than any system of small reservoirs could be.

5. A full description of the project as now elaborated will be found in the note by the Inspector-General of Irrigation, dated 19th June 1875; the subsequent papers relate chiefly to the financial aspect of the scheme. The estimate was stated in our Financial Despatch No. 97 of 30th April last at R27,50,000; but as now completed it provides for a direct outlay of R30,13,485, entailing indirect charges amounting to R2,03,527, and loss of interest during construction of R7,65,209, or a total of R39,82,221 under all heads. A full explanation of the increase, which is caused chiefly by a modification of the design for the weir, will be found in letter No. C.122W., dated 25th April last, from the North-Western Provinces Government, copy of which is sent herewith. The net income from the project is estimated at R67,000,* which would only yield a return of 2·22 per cent. on the direct outlay, and 1,69 per cent. on the total outlay under all heads, including loss of interest during construction.

	R
* Gross revenue, direct	1,20,333
" indirect	46,667
TOTAL	1,67,000
Maintenance charges	1,00,000
Net revenue	67,000

6. The prospect of direct financial success is thus not encouraging, but the condition of the tract of country which would be affected by the canal is such that the Government could not neglect the duty of taking measures for securing the food-supply. There is a general unanimity among all officers acquainted with the tract that the construction of this canal would give stability to the land revenue and protect against drought some of the least accessible districts in the North-Western Provinces. We therefore request the sanction of Her Majesty's Government to the carrying out of the canal as a protective work from the ordinary revenues as funds become available.

7. The question of construction of storage resorvoirs above the weir has not yet been thoroughly investigated owing to paucity of establishment available, but in any case the works must prove of great benefit. It will also probably be found possible to extend the area of irrigation by filling during seasons of ample supply the tanks and hollows which will be commanded by the canal below the weir.

Enclosure to P. W. D. Despatch No. 27, dated 1st July 1881.

Note by the Inspector General of Irrigation on the Betwa Canal Project.

THE detailed estimates for this project now submitted are those called for by the Government of India in November 1873. The history of the project from the commencement is detailed in the Chief Engineer's Report.

A brief summary of the main features and the reasons which have led to its elaboration in its present shape may be useful.

That irrigation is absolutely necessary in Bundelkhund as the only safeguard against famine, the very general consensus of opinion of the Revenue officers and all who have been acquainted with the district for many years past sufficiently proves. The reports also show that the people everywhere are anxiously looking out for the proposed supply of water.

As to the sources whence a supply of water is obtainable and the modes of making it available for irrigation. These are—

1st.—From the subsoil springs by wells.

2nd.—By storing the rainfall in tanks constructed in the tract to be irrigated.

3rd.—By storage reservoirs formed in the valleys of the rivers.

4th.—By drawing off water from the rivers by inundation canals.

5th.—By perennial canals from the rivers in which there is a continuous supply.

That the first mode is out of the question except for a very limited area of irrigation is shown by the excessive depth generally of the spring level below the ground surface, and that in places where that level is in ordinary years sufficiently near the surface, the supply being dependent on surface drainage, is not to be relied on in years of drought, just when it is most required.

As regards the second mode, reservoirs have been long in existence, some from a very ancient date, in portions of the Jhansie and Humeerpoor districts, but the country is not everywhere suited for the formation of capacious works of this description. Small tanks, such as were formed in Mhairwarra by Colonels Dixon and Hall, would cost in these days nearly three times the amount then stated to have been expended, and I have shown elsewhere that this is the most expensive of all the modes of irrigating a given area, small tanks, besides, being almost certain to run dry just in the very seasons when water is most wanted.

The third method of impounding water in the valleys of the rivers is practicable, but at a large outlay, and further investigations are needed before detailed projects can be submitted.

The fourth method, that of inundation canals, or channels to draw off the supply without raising the level of the stream in the rivers by weirs, is economically impracticable on account of the great depth of the river-bed below the tracts to be irrigated and the variations of the surface level of the stream even in the monsoon months. To ensure a supply sufficiently continuous to mature khureef crops, the beds of the channels must be projected at so low a level that the excavation at their heads and for a considerable distance below would involve an expenditure quite disproportionate to the results to be obtained. The reports besides show that rubbee irrigation* is more required than khureef,† and this inundation canals could not supply.

* Spring crops (wheat and barley).

† Autumn crops (rice, &c.)

The fifth mode is that adopted in the scheme now submitted for the Betwa.

As to the supply of water available from the Betwa no records exist previous to 1866; but the gauge registers kept from that year up to date show that, except in years of absolute drought, 600 cubic feet per second at the beginning of the rubbee season and about 300 cubic feet at the end can be depended on. For the ordinary khureef crops the supply will usually be ample without storage. The early khureef crops, such as sugarcane and indigo, cannot be supplied, as water fails from March to June. In the driest year on record (1868) there was an ample supply in the rivers from about the 15th July to 15th October, with one temporary fall from about the 23rd August to 17th September. Towards the end of October in that year the volume fell to 160 cubic feet, and in the following February to 50 cubic feet.

The reason of the supply never altogether failing in this river is due to the fact of its sources being in the Vindhyan range, near Saugor and Bhopal, where the rain of the south west monsoon never fails.

No records are discoverable of the rainfall in those localities during the droughts of 1830, 1834, and 1838. The earliest date of the Saugor register is July 1843; that of Sehore (Bhopal) from the year 1867.

The following table shows the fall during the months of June, July, August, and September from the year 1860, one of the famine years :—

	Jhansie.	Saugor.	Sehore.
1860	25·1	30.73	...
1861	43·1	44·69	...
1862	25·3	37·77	...
1863	46·9	77·80	...
1864	20·6	37·41	...
1865	37·0	51·40	...
1866	28·8	30·20	...
1867	41·6	58·10	69·20
1868	12·3	30·90	27·60
1869	47·3	47·00	38·20
1870	29·9	44·14	60·70
1871	41·0	64·20	82.60
1872	32·5	43·97	36·40
1873	42·9	40 07	44·24

During these 14 years it will be seen that the fall at Saugor was never less than 30 inches.

The Betwa runs a course of about 360 miles from its source in Bhopal to the Jumna at Humeerpoor, half of which is beyond the British border. The tract affected by this project is a triangle bounded by the rivers Betwa, Pahooj, and Jumna. The area commanded by the proposed channels is thus distributed—

		Sq. miles.	Sq. miles.
British	Jhansie	49·	
	Jaloun	1,115·	
	Humeerpoor	53·5	
			1217·5
Native States.	Sumpther	1,55·5	
	Baunee	72·5	
	Behree	10·0	
	Datia	36·5	
			274·5
	Total	...	1492·
Deduct			
	Barren and ravines	518·42	
	Mar soil	340·75	
			859·17
			632·83
	Total irrigable	...	405,011 acres
	or	...	

Of which—

330,489 acres are British.

74,522 „ Native States.

Assuming that not more than one-third of the culturable area should be irrigated, the area for which water is required is 135,000 acres, but for this the average supply of water will not, according to the calculations made in this estimate, be sufficient.

The projected works consist of a permanent weir across the Betwa, 25½ feet above the deepest point of the bed, with a regulating head for the canal on the right flank and escape sluices to keep the bed clear of deposit in front of the regulator. Thence a main channel it led off 19½ miles in length and three branches, the Humeerpoor, Calpee, and Kutound, carried along water-sheds, so as to command the whole of the tract above described.

The dimensions are as follow :—

	Length.	Bottom width.	Depth of water full supply.
	Miles.	Feet.	Feet.
Main Line	19½	20	7
Humeerpoor Branch	78¼	15 to 5	6 to 4
Calpee Branch	11	5	4
Kutound Branch	58½	10 to 5	6 to 4
TOTAL	167¼		

Distributaries aggregating 220 miles in length are provided in the estimate.

The full supply which the channels are designed to carry and distribute is 600 cubic feet per second, but the estimate provides for widening the main channel to carry 1,000 cubic feet per second, in anticipation of a larger demand for khureef irrigation hereafter. Distributaries for the extra 400 cubic feet are left for future consideration when the necessity for them arises.

The following abstract shows the estimated expenditure under each main heading :—

	Main Canal.	Humeerpoor Branch.	Calpee Branch.	Kutound Branch.	Distributaries.	Total.
	R	R	R	R	R	R
Preliminary	13,000	48,000	4,000	30,000	...	95,000
Land compensation	73,755	26,180	2,888	18,480	29,316	1,50,619
Head-works	7,79,123	...	...	...	...	7,79,123
Regulators	8,598	2,932	...	...	...	11,530
Falls, &c.	...	46,288	2,313	27,132	...	75,733
Torrent works, &c.	17,901	6,532	...	...	...	24,433
Bridges, &c.	70,564	1,60,689	14,535	96,845	...	3,42,633
Escapes	...	20,000	...	20,000	...	40,000
Mills	...	12,500	...	12,500	...	25,000
Buildings, permanent	14,092	27,946	3,000	20,546	...	65,584
„ temporary	61,927	8,643	...	8,643	...	79,213
Miscellaneous masonry works	...	...	...	...	44,000	44,000
Earthwork	2,77,951	1,25,001	18,447	87,535	66,000	5,74,934
Miscellaneous	...	7,200	1,000	5,000	22,000	35,200
Maintenance during construction	12,296	9,591	775	6,407	...	29,069
Total	13,29,207	5,01,502	46,958	3,33,088	1,61,316	23,72,071
Tools and Plant						1,49,886
Establishment						5,04,391
						30,26,348
Interest						7,65,209
Capitalization of abatement of land revenue						1,93,576
						39,85,133

It is anticipated that the work may be completed in three years, and the accumulation of interest at the end of this time is calculated to amount to R2,03,093; but in the estimate of total outlay the interest debt is taken as the balance of the accumulation at the end of the sixth year after completion of the works, when, it is supposed, the returns may cover all current expenses, including interest. The difference, or (7,65,200—2,03,093) R5,62,116, should obviously not form a portion of the cost of the project. Deducting this, the probable outlay is R34,23,017.

The probable returns are estimated by the Chief Engineer according to the calculation made in 1872. The water-rate is taken at R2 per acre, whilst the Board of Revenue are of opinion that the full average rate of the Ganges Canal, *viz.*, R2-6, would be obtainable.

Khureef irrigation is altogether omitted, and for the rubbee the full supply, 600 cubic feet per second, will always be available to begin with; but as that supply diminishes more or less during the season, the full return is only calculated on from two-thirds, the area irrigable at the beginning : 200 acres per cubic foot per second is taken as the duty ultimately obtainable. The figures, then, are :—

⅔ × 600 × 200=80,000 acres at R2	R	1,60,000
Enhancement of land revenue at 12 annas per acre	„	60,000
Miscellaneous revenue, 5 per cent. of water-rate	„	8,000
Total	„	2,28,000
Deduct 25 per cent. Maintenance	„	57,000
Balance	„	1,71,000

This on the total outlay of R39,85,133 gives net profit of 4·31 per cent.

This estimate of outlay is, I think, a maximum, and the return a minimum. In a separate note I have made some remarks on the engineering details and the items for which the provision in the estimate seems to be excessive.

The quantity of masonry in the head-works seems to me to be unnecessarily large, and may, I think, be considerably reduced.

The number of bridges, about one to each mile, may be required many years to come, but I cannot think the same provision for cross traffic is requisite in a confessedly undeveloped tract as in the most highly cultivated and populous parts of the country. Probably half the number would suffice for many years to come.

Mills are not a necessary adjunct of the project. If the demand for them arises hereafter, they can be built. They are always a profitable investment if judiciously located.

The cost of inspection-houses and temporary shelter seems very large, and is, I think, susceptible of reduction.

The extent of land occupied may apparently be reduced considerably.

Every possible expense required to complete the project in the best style seems to be provided for in the estimate; but in a case of this kind, where the estimated returns are so very meagre, I think it would suffice to construct only the works absolutely necessary *for the present.*

If the supply of water is found to go farther than can now be calculated on for a certainty, and a demand arises, as is probable, for khureef irrigation, the necessary additions can then be made to the works, though the cost would possibly be greater than if all were carried out simultaneously.

The estimate of the probable returns I have stated above is that made in 1872, when the project was first submitted; and although the duty assumed for the water is probably an absolute maximum, the gross income is, I believe, much below what will ultimately be obtained. It is hard to believe that, in so dry a country, water even in ordinary years would not be eagerly sought for the khureef crops.

The indirect benefits, however, were the main grounds on which the North-Western Provinces Government recommended the project from the very first

These are enumerated in the Commissioner's (Mr. Ricketts) memorandum dated 8th July 1873. The chief items are—

1st.—Protection against famine.

2nd.—*Ensuring* the permanence of the land revenue.

3rd.—The possibility of obtaining a higher land revenue, as there would be no longer a necessity for allowing a large margin in revenue settlements as a set-off against unfavorable seasons.

The remissions of revenue in the five districts of Bundlekhund during the 12 years from 1860-61 to 1871-72 are stated to have amounted to R33,63,989; and though a portion of this was directly due to revisions and reductions of assessments and to causes connected with the Mutiny of 1857, it is probable that no revisions would have been required if famine had not reduced the resources of the district in men and cattle.

I omitted to mention above that the sum calculated as capitalization of abatement of land revenue includes that on land in the Native States, which should, of course, be omitted.

It is not stated what arrangements have been made with the Native States for occupation of land or payment for water supplied.

The compensation for land is estimated at R25 per acre, but this is not attested by the Revenue authorities.

Before submitting the project for the sanction of the Secretary of State, it may, perhaps, be thought advisable to obtain the views of North-Western Provinces on the suggested reductions of cost. The project as submitted is presented in a more unfavourable light financially than the facts seem to warrant.

J. CROFTON.

19th June 1875.

From the Secretary of State for India to the Government of India,—No. 51, dated the 8th September 1881.

I HAVE received and considered in Council your Excellency's Public Works letter No. 27, dated the 1st July last, submitting for my sanction a project for the construction of the Betwa Canal in the Bundelkhund district of the North-West Provinces.

2. The question of the construction of this work has already formed the subject of communications between the Government of India and my predecessors, but before any definite action was sanctioned, more precise information as to the prospects of the work, both in its engineering and financial aspects, was called for by the despatches from this office marginally noted.

Public Works Despatch to Government of India, No. 12, dated 20th February 1873.

Ditto ditto No. 37, dated 23rd April 1874.

3. This information is now supplied by your Government, and I am glad to learn from your letter that you are now satisfied from careful inquiries instituted by you that the supply of water in the Betwa river may be relied on to feed a canal even in years of drought, and that the financial prospects of the work are such as to afford, in your opinion, a reasonable hope of some small return to Government on the capital which it is proposed to expend on the undertaking.

4. Irrespectively, however, of the financial aspect of the project, regarding which I do not hold very sanguine expectations, your Excellency dwells strongly on the duty of the State to undertake the construction of the work in order to secure the food-supply of this tract of country—a tract which has so often suffered from the severest scarcity in the past, and may at any time be visited again with famine in the future.

5. The Famine Commission of 1878 also urgently recommended, as your Excellency is aware, in paras. 31 and 32 of their Report, the early construction of this work, among others, as an absolutely necessary work for the mitigation of famine in the North-West Provinces.

6. I fully appreciate the force of these expressions of opinion, and I trust that the expectations of a supply of water sufficient in years of drought to afford the means of irrigation may be realized, and that the views of your Government may thus be borne out, and a probable future outlay on the relief of the population may be avoided. In this hope I will not withhold my sanction to the construction, from ordinary funds, of the Betwa Canal as a protective work, at a total estimated cost of R39,82,221, of which R30,13,485 is estimated as direct outlay and the balance as indirect and interest charges.

7. I gather from the enclosures* to your letter that the work will probably be completed in three years, and that the expenditure on it will probably be distributed in the following manner:—five akhs during the current official year, eight lakhs during each of the succeeding official years, and the balance of estimate for works before the rainy season of 1884.

*Letter from Secretary to Government, North-West Provinces, to Secretary to Government of India, Public Works Department, No. C.122W., dated 25th April 1881.

From the Joint Secretary to the Government of the N. W. P. and Oudh, P. W. Dept., Irrigation Branch, to the Secretary to the Government of India, P. W. Dept.,—No. F. C. 87I., dated 21st March 1882.

WITH reference to correspondence ending with your letter No. 396, dated the 18th October 1881, I am directed to forward, for the information of the Governor General in Council, copies of the papers noted in the margin, on the subject of construction of the weir for the Betwa Canal in Bundelkhund.

Superintendent of Works' No. 126, dated 20th January 1882.

Note by Chief Engineer, No. F. C. 87½ I., dated 21st March 1882.

Note by COLONEL J. G. FORBES, R.E., Chief Engineer of Irrigation, N. W. P. and Oudh, on construction of the Betwa Weir,—No. F. C. 87½ I., dated the 21st March 1882.

A SUM of R30,13,485 was sanctioned in Government of India's Public Works Department letter No. 396, dated 18th October 1881, as the direct charges for the Betwa Canal project. Of this amount R9,88,186 was * on account of the weir and head-works at Pareecha, *viz.*:—

* (Exclusive of gates, R64,000.)

	R
Weir	7,83,519
Canal regulating head	1,62,810
Afflux embankments	41,857
TOTAL	9,88,186

2. The reason for choosing Pareecha as the site of the weir is given in para. 26 of the Chief Engineer's (Colonel Greathed) Report, dated 2nd November 1874, as below:—

After a very careful consideration of the subject, the head of the canal has been fixed a Pareecha, 13 miles east of Jhansi, near the Calpee road. This is the best site that could be found. A rocky barrier runs across the bed of the river, forming an excellent foundation for the weir; this barrier is said by the Executive Engineer, Mr. Dubus, to be free from cracks and fissures visible to the eye. The river has a straight run between good stiff banks, and there is a plentiful supply of good building-stone, suitable for cour sed rubble, in the neighbourhood.

3. Now, however, that preparations have been made for an actual commencement of the work, and a minute inspection and detailed surveys of the site have been made, it is found that the description given above regarding the rock being free from cracks and fissures, and thus forming an "excellent foundation" for the weir, does not correspond with existing facts.

4. Early in December 1881 I received a communication from Major Western, R.E., Superintendent of Works, reporting the above and stating that he had suspended work at the Pareecha site pending further orders. On the 20th December I arrived at Pareecha and carefully examined the locality.

5. For a distance of 800 feet on the left flank of the Pareecha site the barrier is not composed of a "homogenous rock without fissures." On the contrary, it consists of weathered and greatly decomposed quartz blocks and moorum, and is, in fact, an outcrop of the quartz ridge which is met with on the Calpee road at Gulara, about two miles from Pareecha. The position of this quartz ridge and its conjunction with the gneiss is clearly shown on Map A—plan of river near head-works.

6. Map B—Plan of Pareecha weir site—shows on a larger scale the position of the gneiss and quartz. The trial pits in the latter, which were down to a depth of 8 to 10 feet below W. S. L. on the date of my visit, showed unmistakeably the utterly rotten state of the rock, which apparently got worse the lower it was dug into. When pieces were broken off, they could be crumbled between the fingers; and it was seen that the rock was, besides, full of fissures at all angles and many nearly vertical.

7. The weir sluices having to be built on this flank, it was evident that the sanctioned design would have to be materially altered if this site was to be retained. The cost, therefore, would be greatly increased, as, in addition to the greater depth of foundations than originally estimated for, a much longer pavement or talus would have to be put in. A rough estimate showed that a weir at this site would cost nearly 10 lakhs of rupees instead of R7,83,519 as allowed in the sanctioned estimate. Besides this, it was clear that if the weir was built here, there would undoubtedly be very heavy leakage below through the fissures in the rock.

8. Under these circumstances it became incumbent to reconsider the question of the Khoord site, which is situated about a mile below Pareecha. Khoord was originally chosen as the site for the weir by the late Lieutenant Bagge, R.E. It was finally abandoned on account of the Pareecha weir being supposed to cost about 2 lakhs of rupees less than the one at Khoord, but on this point Mr. Anderson, Superintending Engineer, 2nd Circle, Irrigation Works, who was deputed by the Chief Engineer (Colonel Greathed) to report on the two sites, stated as follows in his letter No. 796, dated 26th March 1870:—

PARA. 4.—Thinking that a considerable reduction in cost would be the result of adopting Pareecha, which is above Khoord, as the site for the dam, I prepared the accompanying estimates My anticipations were not realized.

5. The following is a comparison of the two works :—

	Length.	Content. C. ft.	Cost. R
Khoord dam	5,500	2,055,860	13,36,720
Pareecha „	2,650	1,465,253	11,01,886
Saving .			2,34,834

6. Against this saving of R2,35,000 must be placed loss of revenue due to the 37 cubic feet per second of supply which is contained between the Pareecha site and Khoord dam. The revenue from this 37 cubic feet calculated at R500 per cubic foot represents, at 7·5 per cubic cent., a capital of R2,60,000.

7. The advantages of the two sites are pretty fairly balanced; but if the afflux due to each dam is considered, the Khoord site has the preference, for at Pareecha the afflux is 11·23 feet, while at Khoord it is only 6·00 feet.

9. On carefully going over the gound (*vide* Map C), I came to the conclusion that in every way was the Khoord site more satisfactory than the one sanctioned at Pareecha. By going a little above the site fixed upon by Lieutenant Bagge and utilising an island in mid-stream, we find that instead of a weir 5,500 feet in length being required, two weirs, one 800 feet in length across the west channel of the river, and the other 2,650 feet long across the east channel, are necessary; thus giving a total weir length of 3,450 feet only. Good homogenous rock (gneiss) extends across the whole width and for about half a mile or more down the river. This rock goes well into the right bank, whereas at the Pareecha site a heavy revetment wall is required to guard the right flank. The greater part of the site now chosen across the east channel is itself a natural weir, and little will actually have to be built up in many places, whilst in others the rock will have to be cut down. On the west channel, however, in the deepest part the height of the weir would have to be 41 feet against a maximum at Pareecha of 34 feet. Notwithstanding this, a rough estimate showed that a weir at Khoord could be built for a little more than 7 lakhs of rupees, or within the sanctioned sum.

10. It should also be noted that at Khoord the ground on the right bank of the river and the island in the centre are in British territory, whereas the Pareecha site is entirely in the Rajah of Urcha's domains. In addition to this, good building stone is found *in situ* at Khoord, whilst at Pareecha a tramway one mile in length is required to bring material.

11. The advantages of the Khoord over the Pareecha site may be briefly summed up as follows:

1.—Good rock extending across the whole width of the river.
2.—Loss expense in building.
3.—Less leakage below weir.
4.—Less height of afflux.
5.—Greater impounding of water, giving an increased discharge in canal of 37 cubic feet per second.
6.—Building material actually on site.
7.—Site almost entirely in British territory.

12. Taking the above facts into consideration, I had no hesitation in ordering Major Western to abandon the sanctioned site at Pareecha and to consider Khoord as the proper position for the weir for the Betwa Canal. As the rough estimates above alluded to, although reliable enough to form an opinion on, were necessarily too vague to be submitted as an authoritative basis on which to apply for formal sanction to the change of site for the weir, I further ordered Major Western to submit more detailed estimates when the surveys were completed at Khoord.

13. Estimates have now been received with Superintendent of Works' letter No. 126, dated 20th January 1882 (accompanying this Note), and show the comparative cost of the weir at the two sites, *viz.*:—

	R
Pareecha weir	9,44,659
Sanctioned cost	7,83,519
Excess .	1,61,140
Khoord weir	7,05,030
Sanctioned cost	7,83,519
Saving .	78,489

From the Superintendent of Works, Betwa Canal, to the Joint Secretary to the Government, N. W. P. and Oudh, P. W. Dept., Irrigation Branch,—No. 126, dated the 20th January 1882.

THE site fixed for the weir at the head of the Betwa Canal is described in paragraph 26 of No. C.1043W., dated 2nd November 1874, page 32, and was accepted as fixed by Chief Engineer in paragraph 5, section I, page 25 (Proceedings Nos. 16—42 of April 1875).

2. This rocky barrier is made up of two kinds of rock. That on right of cold-weather stream consists of a fairly level platform of gneissoid granite running square to the stream and some 400 feet wide: that to the left is a quartz ridge with moorum in a more or less decomposed state on the up and down-stream, and this quartz ridge is of no great thickness, varying from 6 feet upwards, and does not run in a direct line.

3. To erect a weir at this site, therefore, the quartz and moorum must be cut down until a sufficient width of base is obtained, and the line of weir either run to conform with the ridge or partially based on the quartz and partially on the moorum. As the quartz is broken and fissured in every direction, it is doubtful if the weir so built would be safe for a day without extra protection or a flooring on the down-stream side.

4. As I further found on reading the Betwa Canal papers that Lieutenant Bagge had preferred a site a mile below Pareecha, called Khoord, and as Mr. Anderson had reported that Khoord was not a bad site, I stopped the work of alignment, &c., for Pareecha and commenced survey for alternative sites (see Proceedings Nos. 32—56, June 1873, Part V., page 51, paragraph 45, page 94 and pages 66—67).

5. The large scale tracing herewith shows that there are three sites on rocky barriers in this reach of the river or above the Khoord rapids. The uppermost is the Pareecha site and has been spoken of above. The intermediate site was apparently covered with silt at the time of previous surveys. It consists of good gneissoid granite, but its contour is bad. The lower site is that of Khoord, or at the head of the rapids.

6. At Khoord the river has, in a length of about 2 miles, a fall in cold weather of 25·0 feet from surface to surface, and in flood of 15·28 feet (page 48, Proceedings, June 1873). The width of channel here is some 5,000 feet, divided up by islands against an undivided width above Pareecha of 1,350. Naturally on such a site nothing but rock is found from bank to bank, and as far as trial quarrying has gone, it has proved a good quality of gneissoid granite, somewhat cracked and fissured in places, but perfectly good with ordinary precautions. On either hand the rock rises to above flood level, but is of inferior quality. Probably the inferior quality merely overlies rock equally sound with that in bed, but as both of these are actually on flank slopes, there will be comparatively but slight action, and measures can easily be taken to render them safe.

7. This Khoord site, therefore, appearing far superior to the Pareecha selected site, detailed surveys were made, and I now beg to submit rough alternative estimates.

The data used have been Colonel Brownlow's revised section of weir, Mr. Hair's alignment of Pareecha weir; but with 3-feet foundations for portion on right of cold-weather stream and R. L. 601·50 for portion on left, 601·50 has been assumed. As we have no facts as to actual depth it would be necessary to cut the reef down to, and 601·50 is 1 to 2 below lowest level of river or a level at which work could be executed without pumping, a width of 100 feet paving below this portion of weir, or for 600 feet in length by 1·5 feet in thickness, is allowed for. For the Khoord site the calculations have been made on the alignment shown in tracing from levels and contours as available; 4·0 depth of foundations allowed to cover possible inaccuracy of levels, &c., due to boulders and loose rocks hereafter requiring removal. Rates the same throughout as allowed by Mr. Hair. Portland cement rubble is estimated for as coping in place of ashlar, though it is not quite evident from the papers which system has been finally decided on.

Proceedings Nos. 12—17, August 1886, para. 3, page 3.
„ „ 12—17 „ „ „ 2 „ 5.
„ „ 3—5, March 1878, item 4 „ 3.

Three feet in thickness at an extra rate of R50 per 100 cubic feet has been entered to allow for possible further alterations.

PAREECHA SITE.

Blasting or excavation for foundations.

	C. ft.	R
On right of river . . .	139,290	
On left, to level 601·50 . .	93,258	
For pavement, ½ of quantity, at R5 / „ 10	94,200	
Flank wall	9,000	
	335,748 at R 10	= 33,575

Rubble masonry weir.

	C. ft.			₹
Excluding foundations, R. B.	524,307			
Foundation, R. B.	439,290			
L. B.	305,208			
Flank wall	154,320			
	1,123,125	at ₹20		= 2,24,625
Ashlar floor.—L. B. 600 × 100 × 1·5 =	90,000	„ 2		= 1,80,000
Brickwork.—As in Mr. Hair's estimate.				
Portland cement.—Pointing	20,244	„ 4		= 80,976
Ditto. —Coping 2,400 at 3′ deep = 96,000 extra rate ₹50				= 48,000

KHOORD SITE.

Blasting or foundations.—Right channel	169,320			
Flank walls	4,320			
Left channel	89,000			
Flank walls	4,240			
	266,880	at ₹10		= 26,688
Rubble masonry.—Right west channel	482,480			
Ditto foundations	169,320			
Flank walls	62,480			
Left east channel	352,690			
Ditto foundations	89,000			
Flank walls	56,310			
	1,212,280	at ₹20		= 2,42,456
Brickwork.—Double Mr. Hair's estimate—				
East part	12,600			
West „	8,400			
Portland cement pointing	21,000	at ₹4		= 84,000
Ditto coping 2,800 r. feet 3′ deep = 112,000 c. feet, extra rate ₹50				= 56,000

Comparative Abstract.

Sub-heads.	Rates.	Mr. Hair's Estimate increased by 35 per cent. (Colonel Brownlow's Estimate of 1886).	Major Western's Estimate.	
		Pareecha Site.	Pareecha Site.	Khoord Site.
	₹	₹	₹	₹
Foundation or blasting	10	13,963	33,575	26,688
Rubble masonry	20	1,83,347	2,24,625	2,42,456
Ashlar coping	2	2,13,777	.....	.....
Portland cement coping	50	.....	48,000	56,000
Ashlar flooring	2	.....	1,80,000	.....
Brickwork	27·8	521	521	1,042
Portland cement pointing	4	55,139	80,976	84,000
Contingencies	20 per cent.	93,349	1,13,539	82,039
Total	...	5,60,096	6,81,236	4,92,225
Add weir sluices	...	1,22,807	1,22,807	1,22,807
„ retaining weir	...	.....	40,000	40,000
Total allowed in present estimate for weir without gates	...	6,82,903	8,44,043	6,55,032
To this may be added tramway	...	1,00,616	1,00,616	50,000
		7,83,519	9,44,659	7,05,030

9. The figures given, as Mr. Hair's estimate increased by 35 per cent., are taken from his original estimate, and this accompanies for reference. The total will probably not agree exactly

with Colonel Brownlow's figures on which revised sanctioned scheme has been based. ₹1,00,616 have been allowed in original estimate for tramway, as the quartz hills from which the building stone was to be obtained were situated a good average mile from the site (see page 11, paragraph 41, and pages 18A and 19A, Proceedings, 1875). As the Khoord site is so large, it is evident the whole of the rubble will be obtained on the spot, and at the most tramways only being required in short lengths for leading the stone to heavier sections of weir and for delivery of lime, I have entered ₹50,000, considering ₹30,000 will be nearer the maximum possible expenditure.

10. The weir sluices have been assumed to cost the same in all cases, as we have not sufficient data to re-calculate. It may be, however, taken as a fact that at Pareecha the foundations will require to be deeper than at Khoord, where we know good rock is to be found at R. L. 604·00.

11. A subsidiary retaining weir is to be built—see note by Colonel Brownlow on section of weir; but as the details of this are not known, the cost may be assumed as the same in either case or ₹40,000.

12. For capability of passing the assumed maximum flood volume of 750,000 cubic feet with the formula—

$$D = 3{\cdot}5\, Z h_1 \sqrt{h_1 + {\cdot}035v^2} + 5\, Z\, h_2 \sqrt{h_1 + {\cdot}02v^2}$$

	C. ft.
At Pareecha—Natural flood level being	645·50
Weir sill	631·50

Length of sill, 2,396 feet.

with an assumed velocity of approach = 6 feet, or that taken by Colonel Brownlow, afflux becomes 8·8 on flood surface above weir 645·30.

At Khoord—assuming 641·0 as the natural flood level—weir sill as before 631·50, and length in two portions of 2,650 and 800 with velocity of approach of 4 feet and 6 feet, we find afflux will be 8 feet, and discharge of the two channels 76 per cent. and 24 per cent. of 750,000. But with this assured present flood level at site of weir of 641·00, the lowest channel of 800 is calculated to discharge 60 per cent. of the 750,000 cubic feet. It is evident, therefore, that with weir built and forcing more down the smaller eastern channels, the level below weir will vary, becoming higher possibly towards right (east) bank and lower in west channel.

The maximum 800 feet weir across west channel can pass (assuming R. S. above at 648·00 or with 7·0 theoretical) afflux will be when surface below is at or below 631·50, and this may be taken to be something over 200,000 cubic feet.

We have then to pass 550,000 over the 2,650 feet length, and with surface above as before at 648·0, we find surface below will be about 639·00.

The sectional areas of approach and exit are for west weir evidently ample, for the east, or 2,650 feet, part we have 65,000 square approach up to level 648·0 on present bed. As this bed is rock and coarse sand, the sand will evidently scour until sufficient area for the 550,000 cubic feet is obtained. Downstream there are three channels—two small ones leading to main stream below village of Khoord and one large direct channel running towards the village of Moratta.

The portions of lengths of weir discharging with these channels may be assumed as 1,050 and 1,600, and with volumes of 220,000 and 330,000. The slope of surface down the channels may be taken as 1 in 300; and if we take a low co-efficient of 90 and a H. M. D. of 15 mean velocity comes to 20 feet, and sectional areas required 11,000 and 15,500. The minimum sections obtained are 12,000 and 27,000, and this on earth in places overlying rock and only taking centre or deep portions.

It would appear, therefore, that there will be a free exit from weir, and that W. S. below will be below R. L. 639·0 and that surface above, therefore, will never rise as high as R. L. 648. As our data of water surface over these rocks is very incomplete, it will be as well to assume in all calculations for R. L. 648 as maximum level upstream.

13. The maximum gauge of 641·0 given by Captain Bagge appears to be, from his cross sections, at a point about 1,600 feet above the present proposed site of weir. Taking the same slope of surface as given from Khoord to Pareecha, or 4·48 feet per mile, existing flood water surface at weir site will be about 639·50, and possible afflux on weir 648·0—639·50=8·5 feet.

14. It would seem, therefore, that weirs can be built on either site, but that the cost of the Pareecha one would exceed that of one at Khoord by the cost of the extra pavement or protection necessary downstream, and that even then the Pareecha weir would probably be more expensive to maintain.

15. I am therefore, with your permission, having all detailed estimates and plans made with reference to this Khoord site, and I would request your formal orders regarding them.

16. I may mention that maximum height of weir at Khoord will be 41·0 feet against 34·0 feet at Parceeha.

17. I enclose herewith for reference the original plan of the Pareecha reef, with notes on it by General Rundall; also a detailed survey of this reef as at present existing.

18. The copy of weir section accompanies for record in your office.

From the Government of India, Public Works Department, to Secretary to the Government of the N. W. P. and Oudh, P. W. Dept., Irrigation Branch,—No. 118I., dated the 20th April 1882.

IN reply to your letter No. F.C.87I. of the 21st March last (the plans accompanying which are returned), forwarding, for information, copies of certain papers on the subject of construction of the weir for the Betwa Canal in Bundelkhund, I am directed to communicate the sanction of the Government of India to the proposal made in the Chief Engineer's Note,* which forms an enclosure to the letter quoted above, of changing the site of the Betwa weir from Pareecha to Khoord.

*No. F.C.87½I., dated 21st March 1882.

Note by LIEUTENANT COLONEL J. G. FORBES, R.E., Chief Engineer, Irrigation Works, North-Western Provinces, on the Revised Estimate, Betwa Canal,—dated the 13th March 1885.

Now that the Betwa Canal is approaching completion, it is seen that some items were under-estimated, whilst others were omitted; and although it is possible that all the amounts entered in the enclosed abstract may not be considered absolutely necessary, or at all events may be postponed for a time, yet it is undoubtedly necessary to show them in an open and clear light.

2. The grand total of the revised abstract as now submitted is ₹47,50,681 against ₹39,82,221 as sanctioned by Government of India letter No. 3961, dated 18th October 1881; thus showing an excess of ₹7,68,460 as compared in the following table :—

Head.	Estimate of 1881.	Revised Estimate.	Excess.	Saving.
	₹	₹	₹	₹
Works	25,14,491	32,29,749	7,15,258	...
Establishment	3,99,195	7,42,830	3,43,635	...
Tools and plant	99,799	99,799	...	...
Direct charges	30,13,485	40,72,378	10,58,893	...
Indirect charges	9,68,736	6,78,303	...	2,90,433
GRAND TOTAL	39,82,221	47,50,681	7,68,460	...

The different items of excess will now be explained.

3. In September 1883 it was seen that the excess on land was likely to be heavy; the value as entered in original estimate according to Board of Revenue's valuation being only ₹12 per acre, whereas the rate actually paid is about ₹35 in British territory and ₹80 in Native States and "muáfi" lands. The total excess, which is due entirely to the above cause, is ₹1,04,173.

4. Under "torrent works" a sum of ₹24,433 only had been provided, whereas it is necessary to expend ₹67,018, or an excess of ₹42,585. In the first six miles of canal, which crosses a large amount of drainage, only two petty inlets costing ₹1,248 each had been provided.

This amount was totally inadequate, for although it was said in Mr. Hair's estimate of 1874 that it was "easy to divert the drainage of the upper part into the Pahooj," yet inadvertently the cost of this diversion was not entered. This has caused an increase of ₹16,265 on the main canal. The experience of last rains has shown that a further expenditure of 5,000 will have to be incurred on the diversion of minor drainages. On the Hamirpur branch two

more syphons costing in the aggregate ₹7,000 are required, and minor drainage lines costing ₹5,000. On the Kutound branch no provision had been made, whereas three syphons costing ₹4,320 are necessary, and cuts for minor drainage costing ₹5,000 will be required.

The line actually taken for the Betwa Canal is much more on the watershed than that originally projected, which, if adhered to in all points, would have landed us in greater difficulties regarding drainage, besides losing command of the country, which is now everywhere attained.

5. Escapes were very much under-estimated. Mr. Hair simply proposed to provide the cost from distributaries, as the "escapes would be very simple and short, as the canal passes close to a number of nullahs."

The Chief Engineer, Colonel Greathed, however, said this proposition was inadmissible, and allowed a lump sum of ₹40,000 on this account, or "allowing four escapes at ₹10,000, the idea being that it was quite sufficient to turn the escape water into a nullah; and it being taken for granted that all nullahs in Bundelkhund were rock, it was apparently not deemed necessary to take any precautions for the cutting back of these nullahs. These nullahs, however, are not rock, and it is necessary to protect them.

In addition to this, no provision whatever was made for an escape from the main canal to meet the possible (and probable) case of a flood suddenly entering the canal, owing to the difficulty and delay in closing the head-gates with the enormous pressure under which they will have to work during the rains. To make a proper escape, with full controlling power, would add nearly two lakhs of rupees to present estimate. It would, in my opinion, have been very desirable to make this escape; but taking into consideration the expense, and the fact that in the original estimate approved of by the Local Government and the Government of India it was evidently thought that this escape was not required, the cost of it has not been entered in present estimate. About 18 miles below canal regulating head (which has three sets of gates) the banks have been lowered to within two feet of high water level, so that in case of a flood down the canal, the extra water may flow off towards the Pahooj river. A few miles lower down the canal escapes capable of carrying off 2,000 cubic feet per second have been made.

The increase under this head, for the above reasons, is ₹82,357, or a total expenditure of ₹1,22,357 on account of escapes for the Betwa Canal, which has an estimated discharge of 1,000 cubic feet per second. On the Fatehgarh Branch of the Lower Ganges Canal, which has a discharge of 600 cubic feet per second only, the amount sanctioned in 1877 for escapes was ₹1,43,267. The sum stated above for the Betwa Canal is therefore a most moderate allowance, especially bearing in mind the abnormal conditons under which the regulation of supply will have to be effected.

6. The excess of ₹17,115 under the head of buildings is due to the omission in the original estimate of any provision for inspection-houses on distributaries. The total length of distributaries it is proposed to construct is 377 miles, and as many of the lines extend long distances away from the main channels, it is absolutely necessary to admit of efficient supervision during the hot weather and rains to build not less than six 2nd class inspection-houses.

7. Under "earthwork," main canal, the excess is under three heads :—

	₹
A. Increase of rate	57,290
B. Deepening of canal at head	87,718
C. Proposed pitching at head and berm-cutting in first 10 miles	2,00,000
TOTAL	3,44,948

As regards A., the rate originally put down in Mr. Hair's estimate was that prevailing in 1874. Eight years afterwards not only had the value of labour increased, but within a few months after the Betwa Canal had been commenced the Jhansie-Manikpur Railway was begun, and labour was at one attracted to it. Work practically came to a standstill, and rates perforce were obliged to be raised. In addition to this, a larger amount of rock than was anticipated was met with, and this again led to a further increase of rate.

With reference to B., the increased deepening gave an increased supply over that originally estimated for of 100 cubic feet per second for 75 days during the early "khureef," or the season when water will be most urgently required. The cost was ₹87,718, and taking into consideration the great advantage to be gained, and the fact that there was an anticipated saving of upwards of a lakh of rupees on the head-works, the order to carry out this deepening to an extent of 5 feet at canal head was given in February 1882, and to an additional 3 feet in January last.

Item C. for ₹2,00,000 is a proposal for forming 10-feet berms in the first ten miles of the canal and pitching sides and bed in the first three miles. From the facts originally brought forward, it was assumed that the sides would stand at a slope of 1 to 1 and as noted when the present excavation was commenced (see Superintendent's letter No. 69, dated 12th January 1882), "In the very hard soil we have to deal with, to judge by the river-banks and kutcha wells, dry slopes of 1 to 1 will stand perfectly, and with the same excavation section we shall, with a bed width of 20 feet, be able to allow a small water berm of 3 feet between the two slopes."

On these facts, which still hold good and which agree with the data given by Mr. Hair, who assumed the wet slopes (on which the others depend) to be 1 to 1, the canal was excavated. Now, however, that we have nearly reached the bottom of the digging, it is seen that the lower strata are a much more friable description than was originally anticipated.

I feet extremely doubtful whether the slopes as now dug will eventually stand. In any case I am of opinion that berms are necessary in the first five miles, where the digging ranges from 40 to 25 feet and where the bed in places is 14 feet below spring level. Orders have accordingly been given to form berms in this reach. It is almost certain that strong pitching will be required when the bed is below spring level; constant slips will occur when the water is admitted, and the only moot point is whether we should accept facts as they are and let the banks slip, clearing out the dèbris when the canal has been opened and charging the cost to "Revenue," or openly face the difficulty and say that we will provide against the contingency before the opening of the canal.

My own opinion is decidedly in favour of the latter. *It is, I admit, a very serious thing* to be considered that the capital of the canal may possibly be increased by 2 lakhs of rupees; but, on the other hand, we must face the fact that the sides will slip. This slipping will probably take place when the water is being lowered, *i. e.*, when irrigation is most urgently required, and to clear out the dèbris we shall have to close the canal at a time when water is in most demand. In addition to this untoward closure, it must be borne in mind that repairs with a running canal will cost more than protective works carefully executed at the present time. On a rough estimate I calculate that it will cost nearly 50 per cent. more to protect the banks when the canal is open than to do it now, but the expenditure will be spread over three or four or five years and will be charged against "Revenue" and not against "Capital." As I have said above, my opinion is decidedly in favour of incurring the expenditure at once, and in this view the total cost has been entered in the present abstract.

8. The excess under "plantations" amounts to ₹34,503, and is due to no provision having been made under this head in the original estimate. The above sum includes ₹6,370 for fencing the canal in Native States, and the balance is for planting shade lines of trees along canal-banks. In no part of India are such lines more required than in Bundelkhund, where the heat is proverbially great in the hot months.

9. Under "miscellaneous" the excess is ₹21,700; of this ₹11,100 is the estimated cost of discharge sites in the main canal and branches, for which no provision was made in the original estimate; the balance ₹10,600 is the sum that is estimated for outlets in the main branches of canal, from which there will be a considerable area of direct irrigation.

10. The above accounts for an excess of ₹6,26,975 on main canal and branches. Against this, however, there are savings on the same, which, added to savings on head-works, amount to ₹2,32,411, leaving the net excess at ₹3,94,564; or excluding the excess of ₹1,04,173 on land, an item over which the Irrigation Department had no control, the net excess on engineering works proper, on head-works, main canal and branches, is reduced to ₹2,90,391. Considering the important and necessary additions that have been made to the project in the shape of torrent works, escapes, and plantations, and last, but certainly not least, the increased storage capacity of the reservoir equivalent to an addition of nearly 50 per cent. to the supply of the canal during a period of 75 days at a time in the year when the river is at its lowest ebb and water much in demand for valuable early khureef crops, this additional sum cannot be considered too great.

11. The remaining portion of the total excess on works, *viz.*, ₹(7,15,258—3,94,564) 3,20,694 is under the head of "distributaries." The provision under this head in Mr. Hair's estimate of 1874 and in estimate of October 1881 was ₹1,49,590, or for 220 miles at ₹680 per mile.

The country to be irrigated by the Betwa Canal has now been thoroughly examined, and it is estimated that at least 377 miles of distributaries will be required.

In all canals the mileage of distributaries is a function of the maximum volume of water to be distributed at any time, and in the Betwa Canal the conditions are such as to require large and immediate distributing power, so that in years of scanty rainfall the irrigation for the rubbee may be quickly effected and the water got on to the land before the supply in river falls below 1,000 cubic feet per second, the maximum volume which the canal is capable of passing.

This is a very important point to bear in mind, for it is agreed on all sides that water will be taken for every kind of soil to soften the ground for ploughing in years when the September rain fails; and we can always count on the river supplying a volume of 1,000 cubic feet per second to the end of October. It is, therefore, absolutely necessary to provide a sufficient length of distributary channels to meet sudden demands.

The combined maximum discharges of the Upper and Lower Ganges Canals may be taken at 10,000 cubic feet. The total length of distributaries on these canals completed to the end of 1883-84 was 4,303 miles, or at the rate of one mile of distributary to 2·32 cubic feet of maximum discharge; and the system is not yet complete. Similarly on the Eastern Jumna Canal, the maximum discharge of which is 1,400 cubic feet, there are 618 miles of distributaries, or one mile to 2·25 cubic feet of maximum discharge.

It is, therefore, clear that an allowance of one mile of distributary to 2·5 cubic feet of maximum discharge is not an excessive estimate; and in the case of the Betwa Canal this factor would give a length of $\frac{1,000}{2·5} = 400$ miles against 377 miles estimated for.

The total amount allowed for distributaries in the revised abstract is ₹4,70,284, or at the average rate of $\frac{4,70,284}{377} = ₹1,249$ per mile, which is a moderate rate, considering that the distributaries are to be of average size, and one line, the Jaloun distributary, is to carry a khureef discharge of 200 cubic feet.

After spending nearly ₹28 lakhs on head-works, main canal and branches, it would obviously be bad economy to starve the project in the way of distributaries.

This has been proved in the case of the Agra Canal, where it has been found necessary to double the length of distributaries originally sanctioned.

When the Betwa Canal project was originally drawn up, it was thought that a very cheap type of distributary would suffice, that land would cost little, and that masonry works would be few. But, with the exception of a few miles, the distributaries are all situated in the Jaloun district, which is highly cultivated. Land is as dear as elsewhere and bridges are as much required as in other districts. Again, the slope of the country necessitates numerous masonry falls, and the fluctuation between the early and late khureef and the rubbee supplies requires ample means of regulating the surface level of the water. Every bridge is thus either a fall or a regulator. But great care is being taken that the works are so placed as to meet the various conditions in the most economical manner, and cheap standard designs have been prepared in order to keep down rates to the lowest possible limit compatible with efficiency.

12. The excess on establishment is heavy, namely, ₹7,42,830—3,99,195=3,43,635. The original provision of ₹3,99,195 was based on a special estimate and amounted to 15·87 per cent. only on the estimate for works. The normal allowance for establishment charges in such cases as laid down in Public Works Code, Chapter XV, paragraph 131, is 23 per cent. on works. This allowance has been based on wide experience and, on the average, has proved not to be excessive. In the present case is has, therefore, been adopted.

The greatest difficulty has been experienced in obtaining sufficient labour. The nature of the soil in Bundelkhund is such as to render excavation in the dry season almost impracticable; while in the rains people will not work at all in black soil, if they can possibly help it, and carriage of material is quite stopped for five months in the year.

13. The provision under Tools and Plant is the same as in the estimate of 1881.

14. The provision for Indirect charges has been estimated as follows. The amount in the estimate of 1881 for capitalization of land-revenue has been allowed to stand; for, although the awards for compensation for land have exceeded the provision under that head in the former estimate, a large proportion of the area taken up is in Native States, and has therefore had to be purchased out-and-out, and there will be no future liabilities of any kind. The area of revenue-paying land in British territory will not exceed 2,000 acres, and allowing that the average assessment is ₹1-8 an acre, the capitalized value of this revenue at 25 years' purchase is $3,000 \times 25 = ₹75,000$ only against ₹1,03,728 provided. But the larger sum has been allowed to stand.

The leave and pension allowance calculated in accordance with Standing Order No. 56, dated 30th November 1883, Public Works Code, Volume II, Chapter XV, paragraph 177, is 14 per

cent. of charges for establishment. In the present case the actual charges up to end of 1883-84 amounted to R49,818, and adding to this R52,532—14 per cent. on the establishment-charges to be incurred after 1883-84—the total comes to R1,02,350, which amount has accordingly been entered in the revised abstract instead of the previous sum of R99,799.

Interest charges during construction amount to R4,74,820, and have been calculated as laid down in para. 176, Chapter XV, of Public Works Code, on the following scale of annual expenditure :—

		R
Expenditure in	1881-82	1,66,147
,, ,,	1882-83	8,77,514
,, ,,	1883-84	11,17,007
Six-monthly estimate	1884-85	8,00,000
Budget-estimate	1885-86	6,00,000
Probable in	1886-87	3,00,000
	TOTAL	38,60,668

The above figures for the three years 1881-82 to 1883-84 are taken from the Annual Finance and Administrative Accounts of the Provinces, and the figures for 1884-85 and 1885-86 from the Budget-estimates for these years, while the amount entered for 1886-87 is the probable sum that will be spent in that year in practically completing the works. The difference between the total shown here and the amount of the revised estimate (40,72,378—38,60,668)= R2,11,710 is the estimated cost of permanent irrigation outlets and some minor works that will gradually be constructed as irrigation developes, the capital account being finally closed in 1892-93.

The canal will however, it is hoped, be opened in May 1885 and begin working from that time; but the irrigating channels will not all be ready before the close of 1885-86. The completion of works not absolutely required at once will be deferred until 1886-87.

The indirect charges calculated as above amount to R6,78,303 against R9,68,736 in the estimate of 1881, showing a saving of R2,90,433.

15. The following is a comparison of the present revised estimate and that of 1881 for the the final direct and indirect charges :—

Estimate.	Direct charges.	Indirect charges.	TOTAL.
	R	R	R
Present estimate	40,72,378	6,78,303	47,50,681
Estimate of 1881	30,13,485	9,68,736	39,82,221

showing an excess of R7,68,460.

16. The return expected from the Betwa Canal barely exceeded 2 per cent. on the original estimated cost (*vide* para. 4 of Government of India letter No. 671., dated 23rd February 1882); but the forecast now prepared shows that, notwithstanding the increased cost of the revised estimate, the net direct income, ten years after the works are completed, will probably be R1,50,000, or a return of 3½ per cent. on the total capital outlay of R42,51,412, which includes a sum of R1,79,034, the expenditure on the project prior to 1881-82, which was not taken into consideration in the original estimate.

The improved revenue now anticipated is due to the increased storage capacity provided and to the greater length of the distributaries proposed.

BETWA CANAL.

Revised classified abstract of the Betwa Canal Project.

1	2	3	4	5	6
Main and sub-head.	Estimate of 1881.	Revised estimate.	Excess.	Saving.	Remarks.
I.—WORKS.					
(1)—HEAD WORKS.	R	R	R	R	
A.—Preliminary expenses	...	4,760	4,760	....	
B.—Land	28,512	33,547	5,035	...	
C.—Works	10,52,764	10,01,488	...	51,276	
Total, (1) Head Works	10,52,764	10,39,795	...	41,481	

Revised classified abstract of the Betwa Canal Project—(concld.)

1	2	3	4	5	6
Main and sub-head.	Estimate of 1881.	Revised estimate.	Excess.	Saving.	Remarks.
I.—WORKS—(contd.)					
(2)—MAIN CANAL AND BRANCHES.	R	R	R	R	
(i)—*Main Canal.*					
A.—Preliminary expenses	13,000	946	...	12,054	
B.—Land	5,429	32,507	27,078	...	
D.—Regulators	8,598	8,560	...	38	
E.—Falls and weirs	...	7,283	7,283	...	
F.—Torrent works	17,901	39,166	21,265	...	
G.—Bridges	70,564	61,653	...	8,911	
H.—Escapes	...	5,500	5,500	...	
K.—Buildings	76,019	72,712	...	3,307	
L.—Earthwork	2,77,951	6,22,899	3,44,948	...	
M.—Plantations	...	8,612	8,612	...	
O.—Miscellaneous	...	6,302	6,302	...	
P.—Maintenance	12,296	10,000	...	2,296	
Total, Main Canal	4,81,758	8,76,140	3,94,382	...	
(ii)—*Humeerpoor Branch.*					
A.—Preliminary expenses	48,000	3,255	...	44,745	
B.—Land	15,708	48,278	32,570	...	
D.—Regulators	2,932	2,045	...	887	
E.—Falls and weirs	46,288	44,025	...	2,263	
F.—Torrent works	6,532	18,532	12,000	...	
G.—Bridges	1,60,689	1,07,409	...	53,280	
H.—Escapes	20,000	76,384	56,384	...	
K.—Buildings	36,589	48,030	11,441	...	
L.—Earthwork	98,051	99,346	1,295	...	
M.—Plantations	...	12,199	12,199	...	
O.—Miscellaneous	7,200	14,600	7,400	...	
P.—Maintenance	9,591	9,591	...	...	
Total, Humeerpoor Branch	4,51,580	4,83,694	32,114	...	
(iii)—*Kutound Branch.*					
A.—Preliminary expenses	30,000	2,748	...	27,252	
B.—Land	11,088	47,685	36,597	...	
E.—Falls and weirs	27,132	21,029	...	6,103	
F.—Torrent works	...	9,320	9,320	...	
G.—Bridges	96,845	76,319	...	20,526	
H.—Escapes	20,000	40,473	20,473	...	
K.—Buildings	29,189	37,627	8,438	...	
L.—Earthwork	87,535	67,727	...	19,808	
M.—Plantations	...	13,692	13,692	...	
O.—Miscellaneous	5,000	11,400	6,400	...	
P.—Maintenance	6,407	6,407	...	...	
Total, Kutound Branch	3,13,196	3,34,427	21,231	...	
(iv)—*Calpee Branch.*					
A.—Preliminary expenses	4,000	525	...	3,475	
B.—Land	1,733	4,626	2,893	...	
E.—Falls and weirs	2,313	500	...	1,813	
G.—Bridges	14,535	5,000	...	9,535	
K.—Buildings	3,000	3,583	583	...	
L.—Earthwork	9,735	7,800	...	1,935	
O.—Miscellaneous	1,000	2,600	1,600	...	
P.—Maintenance	775	775	...	...	
Total, Calpee Branch	37,091	25,409	...	11,682	
(3)—DISTRIBUTARIES.					
A.—Preliminary expenses	...				
B.—Land	17,590				
C.—Works	44,000	4,70,284	...	...	
L.—Earthwork	66,000				
O.—Miscellaneous	22,000				
Total, (3) Distributaries	1,49,590	4,70,284	3,20,694	...	

Abstract by Sub-heads.

Main and sub-head.	Estimate of 1881.	Revised estimate.	Excess.	Saving.	Remarks.
	₹	₹	₹	₹	
A.—Preliminary expenses	95,000	12,234	...	82,766	
B.—Land	62,470	1,66,643	1,04,173	...	
C.—Works (head-works)	10,52,764	10,01,488	...	51,276	
D.—Regulators	11,530	10,605	...	925	
E.—Falls and weirs	75,733	72,837	...	2,896	
F.—Torrent works	24,433	67,018	42,585	...	
G.—Bridges	3,42,633	2,50,381	...	92,252	
H.—Escapes	40,000	1,22,357	82,357	...	
K.—Buildings	1,44,797	1,61,952	17,155	...	
L.—Earthwork	4,73,272	7,97,772	3,24,500	...	
M.—Plantations		34,503	34,503	...	
O.—Miscellaneous	13,200	34,902	21,702	...	
P.—Maintenance	29,059	26,773	...	2,296	
(3).—Distributaries	1,49,590	4,70,284	3,20,694	...	
Total	25,14,491	32,29,749	7,15,258	...	

GENERAL ABSTRACT.

1	2	3	4	5	6
Main and sub-head.	Estimate of 1881.	Revised estimate.	Excess.	Saving.	Remarks.
	₹	₹	₹	₹	
(1) Head-works	10,81,276	10,39,795	...	41,481	
(2) I. Main Canal	4,81,758	8,76,140	3,94,382	...	
II. Humeerpoor Branch	4,51,580	4,83,694	32,114	...	
III. Kutound	3,13,196	3,34,427	21,231	...	
IV. Calpee	37,091	25,409	...	11,682	
(3) Distributaries	1,49,590	4,70,284	3,20,694	...	
Total I. Works	25,14.491	32,29,749	7,15,258	...	
Total II. Establishment	3,99,195	7,42,830	3,43,635	...	
Total III. Tools and plant	99,799	99,799	...	...	
Total, Direct charges	30,13,485	40,72,378	10,58,893	...	
Indirect charges.					
VI. Capitalization of abatement of land-revenue	1,03,728	1,03,723	...	...	
Leave and pension allowances	99,799	1,02,350	2,551	...	
VII. Interest during construction	7,65,209	4,72,225	...	2,92,984	
Total, Indirect charges	9,68,736	6,78,303	...	2,90,433	
Grand Total of Direct and Indirect charges	39,82,221	47,50,681	7,68,460	...	
Grand Total, Net excess	...	7,68,460	...	...	
Add old outlay on project.					
I. Works	21,529	21,529	...	...	
II. Establishment	1,51,065	1,51,065	...	...	
III. Tools and plant	6,440	6,440	...	...	
Total, Direct charges	1,79,034	1,79,034	...	...	
Indirect charges.					
VI. Leave and pension allowances	26,286	26,286	...	...	
VII. Interest during construction up to 1885-86	1,06,130	1,06,130	...	...	
Total, Indirect charges	1,32,416	1,32,416	...	...	
Total, old outlay	3,11,450	3,11,450	...	...	
Grand Total, cost of project	42,93,671	50,62,131	7,68,460	...	

BETWA CANAL PROJECT.

No. I.—*Summary of the estimated direct charges to capital account.*

Year.	Works.	Establishment.	Tools and Plant.	Total.
1	2	3	4	5
	₹	₹	₹	₹
1869-70	6,738	32,499	5,728	44,965
1870-71	3,141	14,969	...	18,110
1871-72	2,027	13,680	...	15,707
1872-73	1,337	8,580	293	10,210
1873-74	3,307	24,249	419	27,975
1874-75	2,231	22,278	...	24,509
1875-76	765	16,289	...	17,054
1876-77	573	14,117	...	14,690
1877-78	479	4,371	...	4,850
1878-79	414	16	...	430
1879-80	209	8	...	217
1880-81	205	6	...	211
1881-82	103	3	...	106
Total, old outlay	21,529	1,51,065	6,440	1,79,034
1881-82	94,398	39,876	31,873	1,66,147
1882-83	6,84,993	1,47,165	45,356	8,77,514
1883-84	9,21,175	1,79,002	16,770	11,17,007
1884-85	6,37,000	1,60,000	3,000	8,00,000
1885-86	4,80,000	1,17,200	2,800	6,00,000
1886-87	2,40,000	60,000	...	3,00,000
1887-88	40,650	9,350	...	50,000
1888-89	40,650	9,350	...	50,000
1889-90	32,520	7,480	...	40,000
1890-91	24,390	5,610	...	30,000
1891-92	20,325	4,675	...	25,000
1892-93	13,648	3,062	...	16,710
Total, present project	32,29,749	7,42,830	99,799	40,72,378
Grand Total, cost of project	32,51,278	8,93,895	1,06,239	42,51,412

No. II.—*Summary of the estimated indirect charges to capital, excluding interest.*

Year.	Capitalization of land revenue abated.	Loss by exchange on payments in England.	Charges for leave and pension allowances.	Total.
1	2	3	4	5
	₹	₹	₹	₹
1869-70	...	...	5,655	5,655
1870-71	...	...	2,605	2,605
1871-72	...	...	2,381	2,381
1872-73	...	...	1,493	1,493
1873-74	...	...	4,219	4,219
1874-75	...	...	3,877	3,877
1875-76	...	...	2,834	2,834
1876-77	...	...	2,456	2,456
1877-78	...	...	761	761
1878-79	...	...	3	3
1879-80	...	...	1	1
1880-81	...	...	1	1
1881-82	...	...	...	...
Total, old outlay	...	...	26,286	26,286
1881-82	...	...	6,590	6,590
1882-83	...	...	18,159	18,159
1883-84	23,685	...	25,069	48,754
1884-85	40,000	...	22,300	62,300
1885-86	30,000	...	16,350	46,350
1886-87	10,043	...	8,400	18,443
1887-88	...	...	1,300	1,300
1888-89	...	...	1,300	1,300
1889-90	...	...	1,040	1,040
1890-91	...	...	780	780
1891-92	...	...	650	650
1892-93	...	...	412	412
Total, present project	1,03,728	...	1,02,350	2,06,078
Grand Total on project	1,03,728	...	1,28,636	2,32,364

BETWA CANAL PROJECT.

No. III.—*Estimate of growth of irrigation and revenue receipts and charges.*

Year.	Irrigated area to end of year.	REVENUE RECEIPTS AND CHARGES.					
		Gross revenue due to works.			Charges both direct and indirect against revenue account.	Net revenue due to works.	
		Direct receipts.	Enhanced land revenue or indirect revenue.	Total.		Including enhanced land-revenue.	Excluding enhanced land-revenue.
1	2	3	4	5	6	7	8
	Acres.	R	R	R	R	R	R
1885-86	20,000	30,000	...	30,000	40 000	—10,000	—10,000
1886-87	35,000	70,000	...	70,000	85,000	—15,000	—15,000
1887-88	45,000	1,35,000	...	1,35,000	1,37,000	—2,000	2,000
1888-89	55,000	1,65,000	...	1,65,000	1,38,000	27,000	27.000
1889-90	65,000	1,95,000	...	1,95,000	1,39,000	56,000	56,000
1890-91	70,000	2,10,000	...	2,10,000	1,42,000	68,000	68,000
1891-92	75,000	2,25,000	...	2,25,000	1,43,000	82,000	82,000
1892-93	80,000	2,40,000	...	2,40,000	1,45,00	95,000	95,000
1893-94	85,000	2.55,000	...	2,55,000	1,48,000	1,07,000	1,07.000
1894-95	90,000	2,70,000	...	2,70,000	1,49,000	1,21,000	1,21,000
1895-96	95,000	2.85,000	...	2,85,000	1,50,000	1,35,000	1,35,000
1896-97	1,00,000	3,00,000	...	3,00,000	1,50,000	1,50,000	1,50,000
TOTAL	...	23,80,000	...	23,80,000	15,66,000	8,14,000	8,14,000

No. IV.—*Statement of net financial results from commencement to 1896-97.*

	Year.	Direct capital outlay during the year.	Direct capital outlay to end of the year.	Simple interest at 4 per cent. on capital outlay to end of previous year plus half outlay during year.	Net revenue, including enhanced land-revenue column 7 of Table III.	Simple interest less net revenue.	Net revenue less simple interest.
	1	2	3	4	5	6	7
		R	R	R	R	R	
Old outlay on project.	1869-70	44,965	44,965	1,051	...	1,051	
	1870-71	18,110	63,075	2,540	...	2,540	
	1871-72	15,707	78,782	3,260	...	3,260	
	1872-73	10,210	88,992	3,857	...	3,857	
	1873-74	27,975	1,16,967	4,949	...	4,949	
	1874-75	24,509	1,41,476	6,143	...	6,143	
	1875-76	17,054	1,58,530	7,051	...	7,051	
	1876-77	14,690	1,73,220	7,941	...	7,941	
	1877-78	4,850	1,78,070	8,348	...	8,348	
	1878-79	430	1,78,500	8,382	...	8,382	
	1879-80	217	1,78,717	8,396	...	8,396	
	1880-81	211	1.78.928	8,405	...	8,405	
	1881-82	106	1,79,034	} 10,482	...	10,482	
Outlay on current sanctions.	1881-82	1,66,147	3,45,181				
	1882-83	8,77,514	12,22,695	31,358	...	31,358	
	1883-84	11,17,007	23,39,702	71,249	...	71,249	
	1884-85	8,00,000	31.39,702	1,09,588	...	1,09,588	
	1885-86	6,00,000	37.39.702	1,37,588	—10,000	1,47,588	
	1886-87	3,00,000	40,39.702	1,55,588	—15.000	1,70,588	
	1887-88	50,000	40,89,702	1,62,588	—2,000	1,64,588	
	1888-89	50,000	41,39.702	1,64.588	27,000	1,37,588	
	1889-90	40,000	41,79,702	1,66,388	56,000	1,10,388	
	1890-91	30,000	42,09,702	1,67,788	68,000	99,788	
	1891-92	25,000	42,34,702	1,68,888	82,000	86,888	
	1892-93	16,710	42,51,412	1,69,722	95,000	74,722	
	1893-94	...	42,51,412	1,70,056	1,07,000	63,056	
	1894-95	...	42,51,412	1,70,056	1,21,000	49,056	
	1895-96	...	42,51,412	1,70,056	1.35,000	35,056	
	1896-97	...	42 51,412	1,70,056	1,50,000	20,056	
	TOTAL	42,51,412	...	22,66,362	8,14,000	14,52,362	

From the Government of India, Public Works Department, to Her Majesty's Secretary of State for India,—No. 42, dated Simla, the 12th October 1885.

WE have the honour to submit, for the approval and sanction of Her Majesty's Government, a revised estimate, amounting to R44,83,776, of which R42,51,412 represents the direct, and R2,32,364 the indirect, charges for the Betwa Canal project in the North-Western Provinces.

2. The project was sanctioned by Her Majesty's Government in Despatch No. 51P.W., dated 8th September 1881, as a protective public work, at an estimated total cost of R32,17,012, exclusive of the charges for interest. The excess of the present over the sanctioned estimate is R12,66,764, of which R2,05,320 is the amount of outlay incurred under grants from Ordinary revenues on surveys previous to the classification of the canal as protective. The excess which it is now proposed to charge to the protective grant amounts, therefore, to R10,61,444, being R10,58,893 for direct, and R2,551 for indirect charges. The excesses are fully and clearly explained in the accompanying note, dated 13th March 1885, by Colonel J. G. Forbes, R.E., Chief Engineer for Irrigation, North-Western Provinces. The causes of the excess expenditure on works may be briefly summarised as follows:—

The excess expenditure on works amounts to R7,15,258. Of this amount R1,61,403 are due to increase of rates almost entirely caused by the starting of the Jhansie-Manikpur Railway works and increase in value of land which could not have been foreseen when the estimate was framed. R6,08,412 are due to additions to the project subsequently undertaken, which add largely to its value and paying capacity. These works consist of deepening the canal at the head and pitching the slopes to secure an increased supply of water at the time when it will be most wanted and the extension of the distributary system to utilise to the best advantage the increased supply of water. The total of these two items (R1,61,403 + R6,08,412) amounts to R7,69,815, against which there is a net saving on the works as originally estimated of R54,557, reducing the total excess on works to R7,15,258. The remainder of the total excess in direct expenditure is due to an increase in the establishment charges, which are now allowed for at the normal rate.

3. Out of the estimated direct capital outlay of R42,51,412 R31,69,522 had been expended up to the end of 1884-85, leaving a balance of R10,81,890 for expenditure in subsequent years. The works will be virtually completed in 1886-87, although the capital account will not be finally closed until the end of 1892-93.

4. In the tenth year after the virtual completion of the works, *viz.*, 1896-97, the area irrigated is expected to amount to 100,000 acres, or 20,000 acres more than the area previously irrigated is expected to amount to 100,000 acres, or 20,000 acres more than the area previously estimated. This improvement is due to the increased supply which will be stored by deepening the head and to the greater length of distributaries now proposed.

5. The gross revenue is expected to amount to R3,00,000. The rates on which it is based have been arrived at after careful consideration by the Irrigation and Revenue authorities of the North-Western Provinces. The working expenses are estimated at R1,50,000, or at the rate of R1·5 per acre irrigated, which is the average incidence of maintenance charges per acre in the North-Western Provinces for the three years commencing from 1881-82. The net revenue will therefore amount to R1,50,000, which will give a return of 3·34 per cent. on R44,83,776, the total estimated direct and indirect capital outlay, and 2·52 per cent. on R59,36,138,* the total sum which will be at charge, including interest, in the tenth year after the practical completion of the project. The estimate of the growth of irrigation and revenue receipts and charges has been approved by the Revenue Department of the Local Government.

	R
* Capital outlay	44,83,776
Add simple interest less net revenue up to 1896-97	14,52,362
Total sum at charge	59,36,138

6. Having regard to the fact that the increase in cost is chiefly due to outlay which could not have been foreseen, and to the provision for additional works which are calculated to increase largely the paying capacity of the project, we have no hesitation in recommending the revised estimate to your Lordship for sanction.

7. A sketch map of the Betwa Canal, showing all channels constructed and proposed, is forwarded herewith. Plans of important works connected with the project have already been transmitted to the India Office with our Public Works Secretary's letter No. 189I., dated 16th July 1884.

DOCUMENTS ACCOMPANYING.

1. Letter from the Government of the North-Western Provinces and Oudh, No. C.205I., dated 27th March 1885, and enclosures.

2. Letter from the Government of the North-Western Provinces and Oudh, No. C.569I., dated 31st July 1885.

3. Sketch map.

From COLONEL J. G. FORBES, R.E., Joint Secretary to the Govt. of the N. W. P. and Oudh, P. W. Dept., to the Secretary to the Government of India, P. W. Dept., No. C.817I., dated the 29th October 1885.

I AM desired to report, for the information of His Excellency the Governor General in Council, that the Betwa Canal was opened on the 28th September 1885, and that water is running in 300 miles of channel, from 260 miles of which irrigation is now being afforded.

2. The weir 4,000 feet in length, with a *maximum* height of 60 feet in the deepest channel, has now stood the test of two rainy seasons with entire success, no damage of any kind having occurred. The leakage below the weir is practically nothing, and the wall itself is perfectly staunch. The calculated full supply of the river Betwa in flood is 750,000 cubic feet per second with an afflux on weir of 17 feet. The highest flood as yet passed was on 6th August 1884, when upwards of 520,000 cubic feet were discharged with a depth on crest of 13 feet.

3. The heavy gates and powerful lifting gear of the weir sluices and head-works of the canal were only fixed this year. They work satisfactorily and smoothly.

4. I am to bring to His Excellency's favourable notice the names of the following officers :—

Major Western, R.E., Superintendent of Works, who commenced the canal in November 1881, but who was transferred within a few months to the Punjab as Superintending Engineer.

Major Tickell, R.E., Superintendent of Works, who vigorously prosecuted the work until his death in July 1884.

Mr. J. S. Beresford, who acted with particular energy and capacity as Superintendent of Works for three months after Major Tickell's death, and whose labours and ability as Personal Assistant to the Chief Engineer are shown in the recorded calculations which were required when designing the weir and head-works.

Major Corbett, R.E., Superintendent of Works, from October 1884 until completion of canal.

Mr. W. Willcocks, Executive Engineer, by whom the weir was commenced, but whose services were lent to the Egyptian Government in November 1883.

Mr. R. L. Hawkins, Executive Engineer, who, in charge of the Lower Division, has worked well in lining out and executing the distributary system. Messrs. Boyce, Strickland, Strachey, Fagan, and Gordon, Assistant Engineers, are worthy of favourable mention, and of the subordinate establishment the names of Conductor Jackson, Sub-Engineer, Sergeant Lee and Adjudhia Pershad, Overseers, and of Mr. Hurley, temporary Supervisor, may be noted.

From the Government of India, P. W. Dept., to the Secretary to the Government of the N. W. P. and Oudh, P. W. Dept.,—No. 313 I., dated the 16th December 1885.

IN acknowledging the receipt of your letter No. C.817I., dated 29th October 1885, I am directed to express the satisfaction of the Government of India at the successful opening of the Betwa Canal, and to state that the names of the officers connected with its construction who are recommended in paragraph 4 of your letter have been duly noted.

Documents accompanying.

Nil.

From the Secretary of State for India to the Government of India.—No. 54 P. W., dated the 10th December 1885.

YOUR EXCELLENCY'S Public Works letter No. 42, dated 12th October 1885, submitting revised estimates for the Betwa Canal project in the North-West Provinces, has received my consideration in Council.

2. This work was sanctioned in 1881 as one of a protective character which called for early construction, at a total estimated cost of ₹39,82,221, of which ₹30,13,485 was estimated as direct, and the balance as indirect outlay. The present estimate is for a total outlay of ₹44,83,776, of which ₹42,51,412 represents direct, and ₹2,32,364 indirect outlay, or a total excess outlay over the original sanctioned estimate of ₹5,01,555.

3. The causes of this excess are explained fully in the note by the Irrigation Secretary to the Government of the North-West Provinces accompanying your letter, and, as must be anticipated in a work of this magnitude, are seen to arise from the adoption of improvements and alterations the necessity for which could not be foreseen when the project was first drawn out. I have no hesitation in according my sanction to the estimate in its revised form.

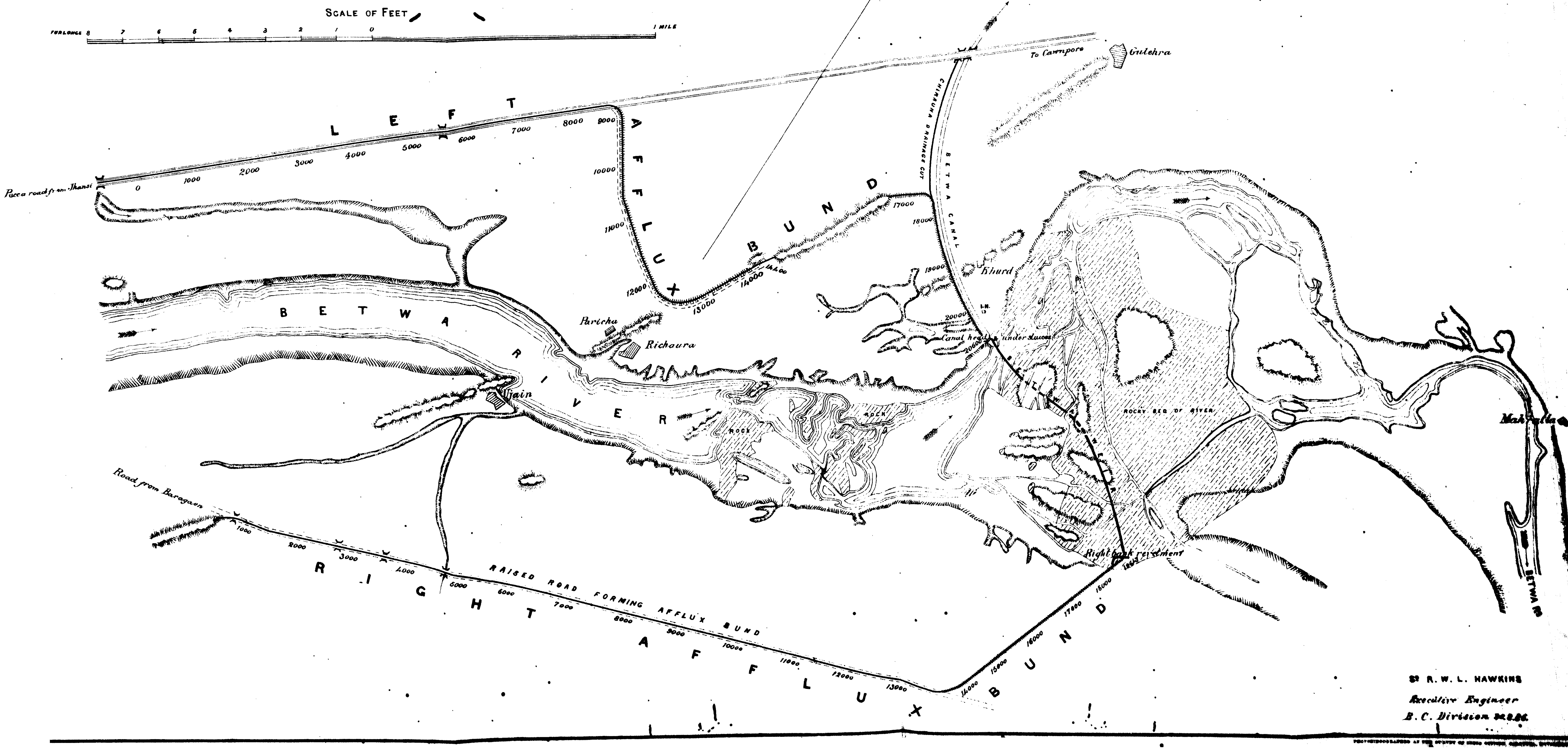
4. I am glad to learn from your letter and its enclosures that the distributaries from the canal will be considerably increased under the present scheme, and that the work, if not already partially open, will be so far completed in the course of 1886-87 as to admit of the general commencement of irrigation.

5. I observe that the direct returns from the operations of the canal are estimated somewhat more favourably than when the project was first framed. I trust this may prove to be the case; but whatever may be the direct returns eventually yielded, I do not doubt that the protection from drought of a large tract of country which has always been liable to scarcity and distress will fully justify the expenditure on this work.

Government of India Central Printing Office,—No. 61 P. W. D.—11-12.—100.

BETWA CANAL

GENERAL PLAN OF WORKS AT HEAD OF CANAL



SHEET Nº 2.

BETWA CANAL

PLAN OF PARICHA WEIR HEAD &

SCALE OF FEET

Ft 400 200 0 400 800 1200 1600 2000 Ft

ISLAND

SUBSIDIARY WEIR

640·00 HIGHEST FLOOD LEVEL

Bagh

Nursery

Godowns

Workshops

Khurd

Quarter for Officer in Charge of Head works

Inspection House

ROCK 638·00 WEIR

SUBSIDIARY WEIR

LEFT AFFLUX EMBANKMENT

650·00 ISLAND DRAIN

RIGHT AFFLUX EMBANKMENT

RIGHT WING WALL

Well

RESERVOIR WHEN FULL 631·50

648·00 HIGHEST FLOOD LEVEL

BETWA RIVER

Sd R. W. L. HAWKINS

Executive Engineer

B. C. Division 20.8.86.

PHOTOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICES, CALCUTTA, NOVEMBER 1887

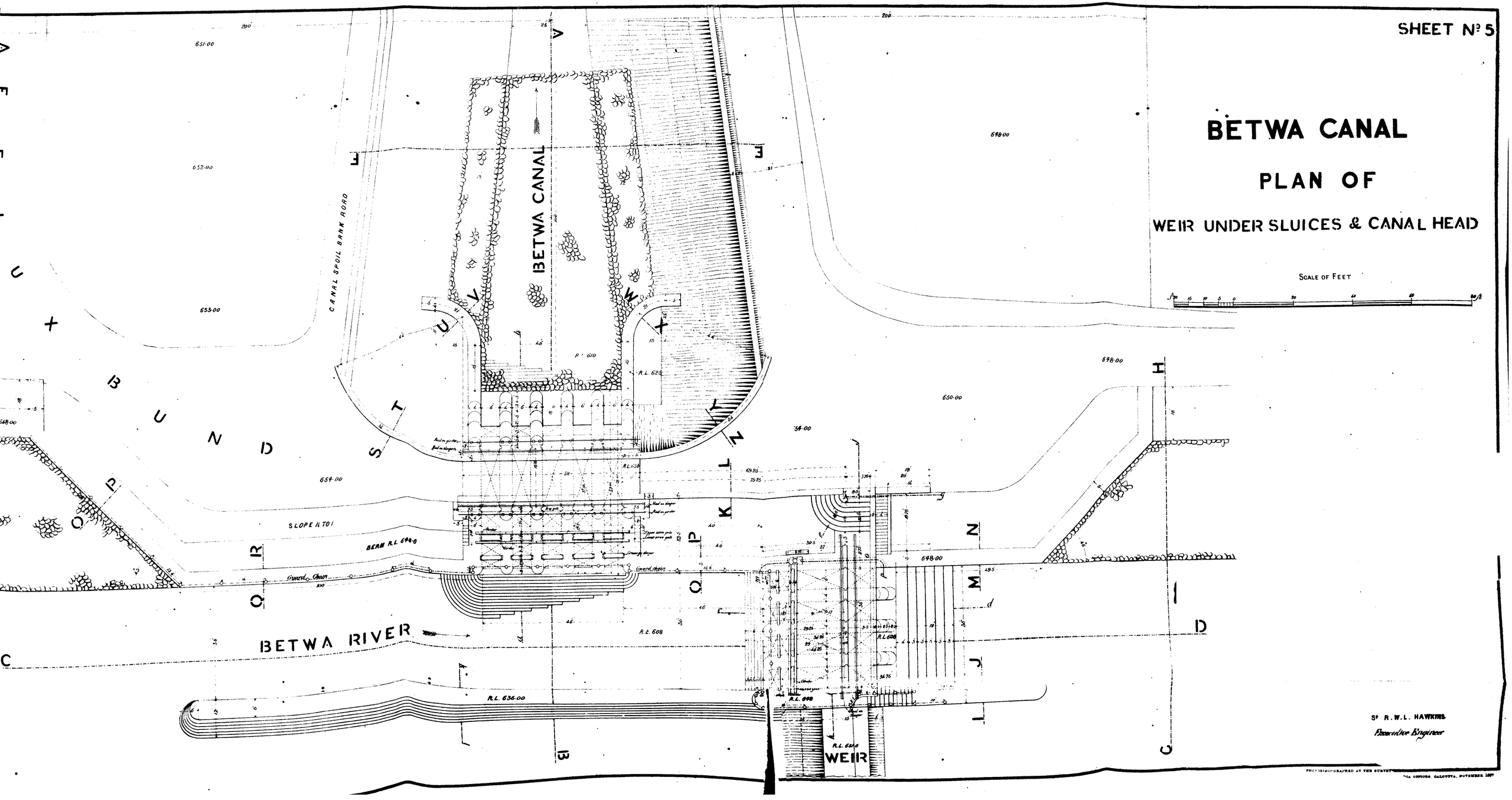
SHEET Nº 5

BETWA CANAL

PLAN OF

WEIR UNDER SLUICES & CANAL HEAD

SCALE OF FEET



Sd R.W.L. HAWKINS.
Executive Engineer

PHOTOLITHOGRAPHED AT THE SURVEY [illegible] OFFICES, CALCUTTA, NOVEMBER 1897

SHEET Nº 3.

BETWA CANAL

PLAN & SECTIONS OF PARICHA WEIR

SCALES FOR

Plan & Longitudinal Section

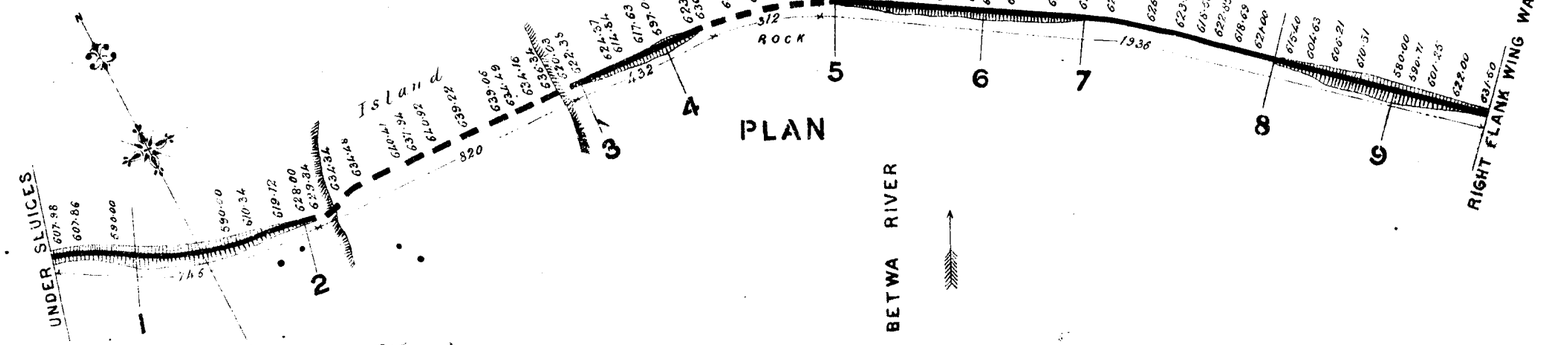
Vertical & Cross Section

REFERENCES

Masonry shown thus

Solid Rock ... dº

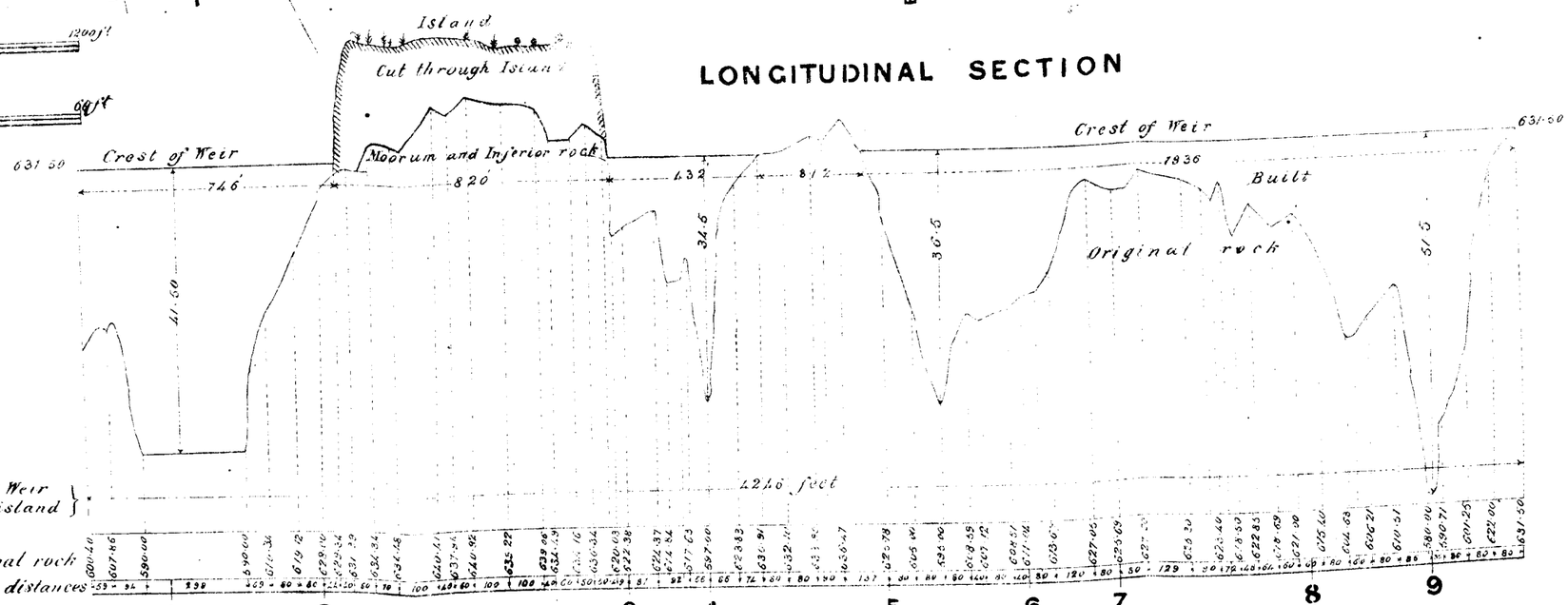
Inferior Rock ... dº



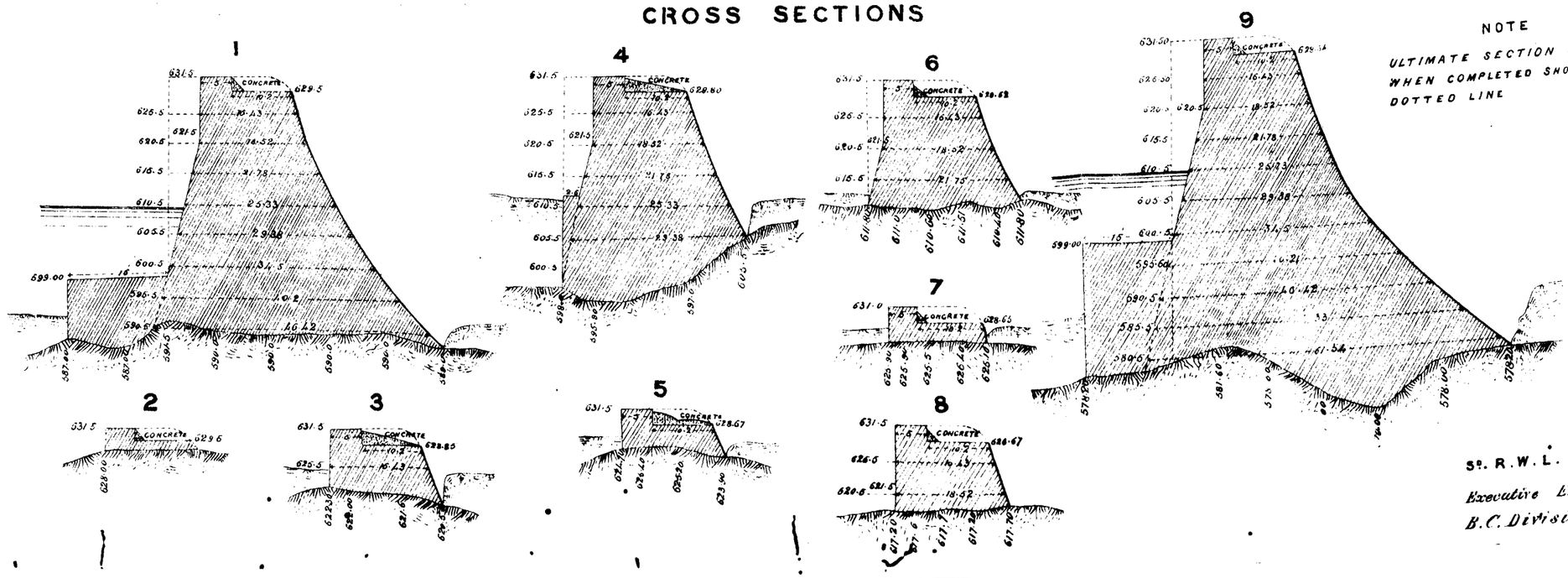
PLAN

BETWA RIVER

LONGITUDINAL SECTION



CROSS SECTIONS



NOTE

ULTIMATE SECTION OF WEIR WHEN COMPLETED SHOWN BY A DOTTED LINE

Sd. R.W.L. HAWKINS

Executive Engineer

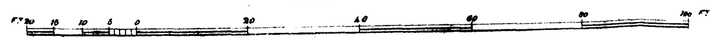
B.C. Division 26.0.86.

BETWA CANAL

SECTIONS

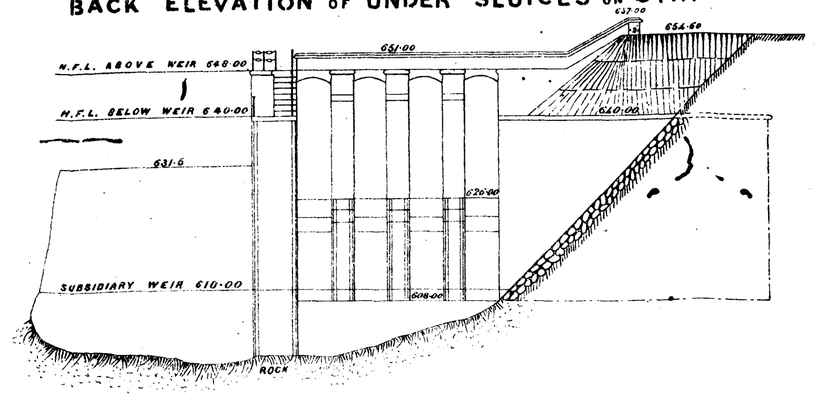
WEIR UNDER SLUICES & CANAL HEAD

SCALE OF FEET

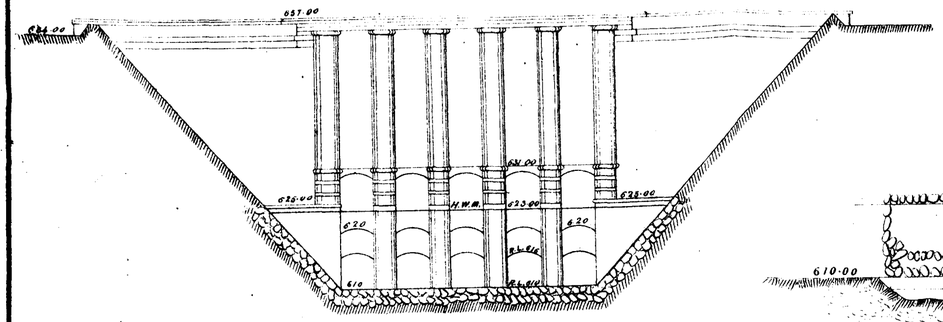


SHEET Nº 6.

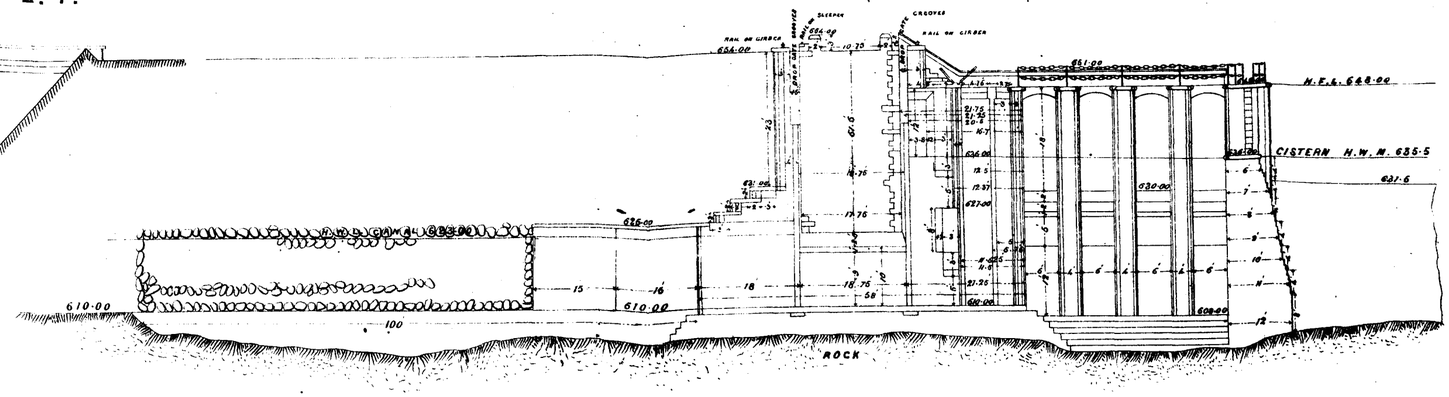
BACK ELEVATION OF UNDER SLUICES ON C.H.



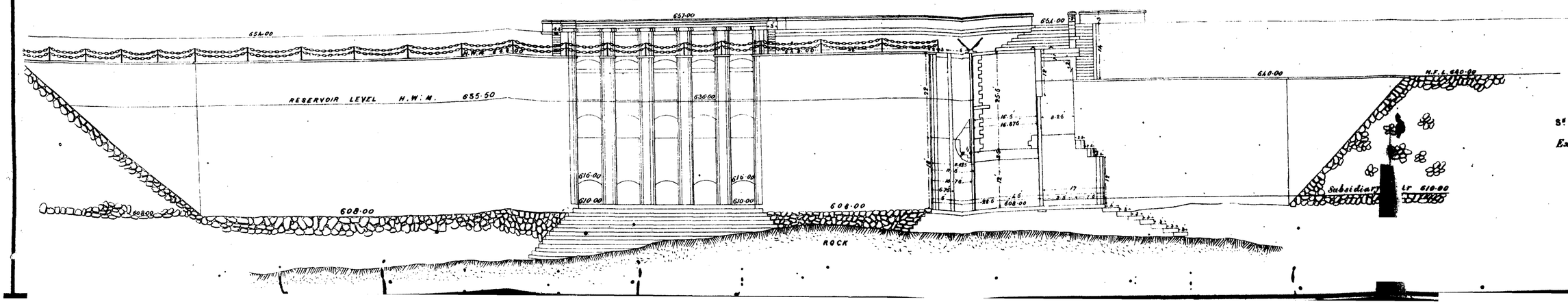
DOWN STREAM ELEVATION OF CANAL HEAD ON E. F.



SECTION & ELEVATION ON A. B.



SECTION & ELEVATION ON C. D.



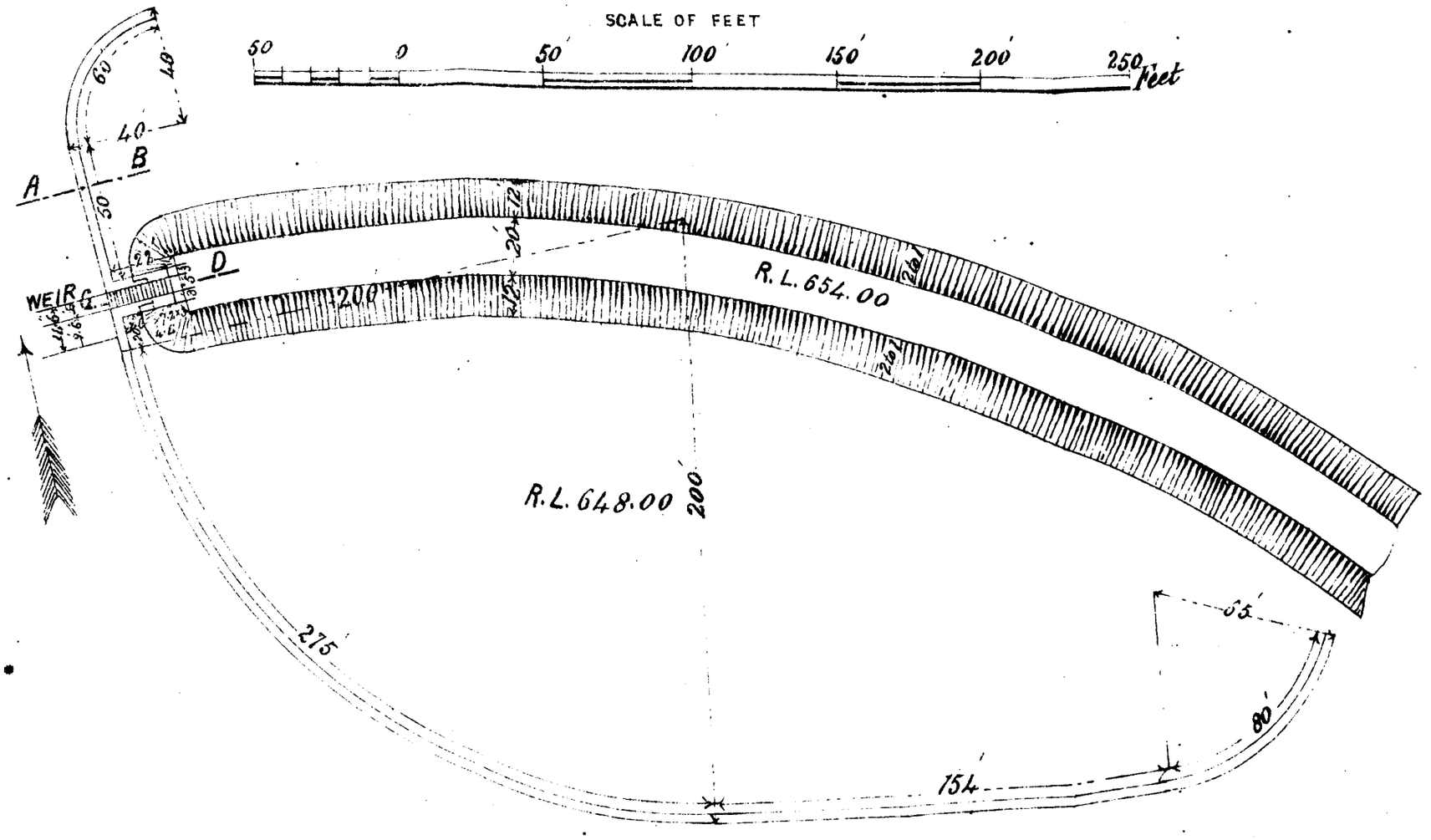
Sd R.W.L. HAWKINS

Executive Engineer

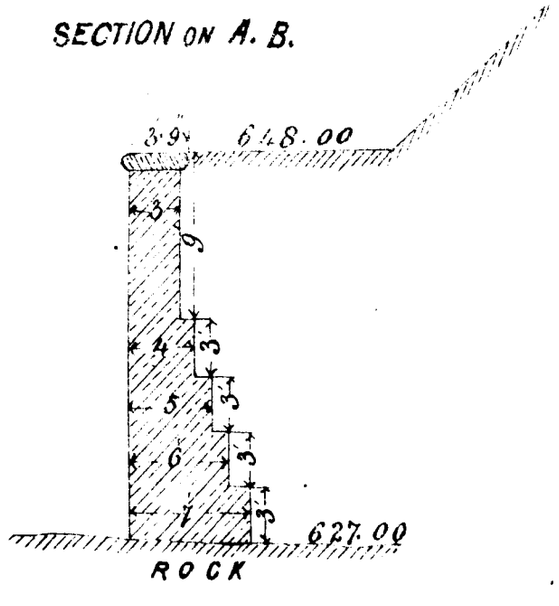
BETWA CANAL

RIGHT FLANK REVETMENT WALL

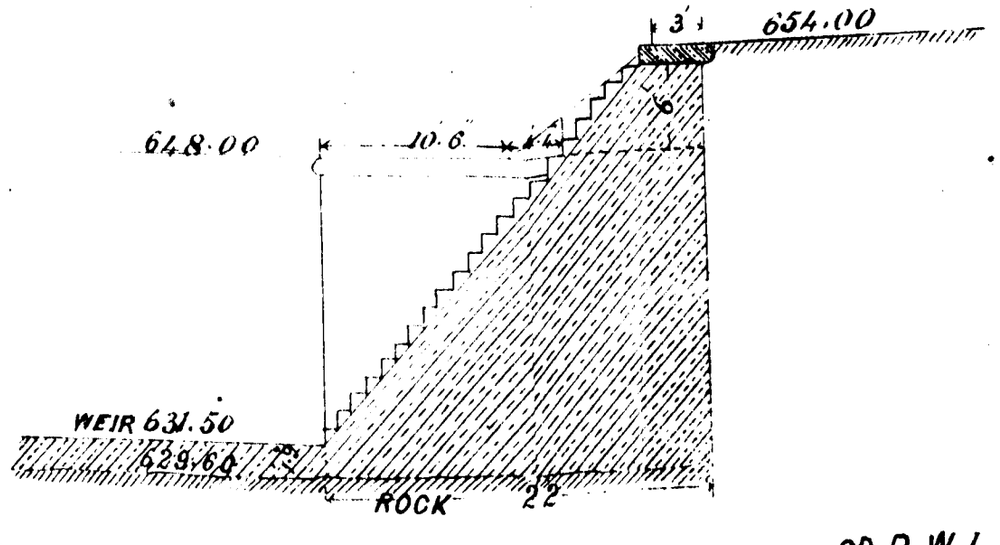
PARICHA WEIR



SECTION ON A. B.



SECTION ON C. D.



Scale 10 Ft = 1 inch.

SD R. W. L. HAWKINS
Executive Engineer

SHEET Nº 7.

148.61

BETWA CANAL

DETAILS

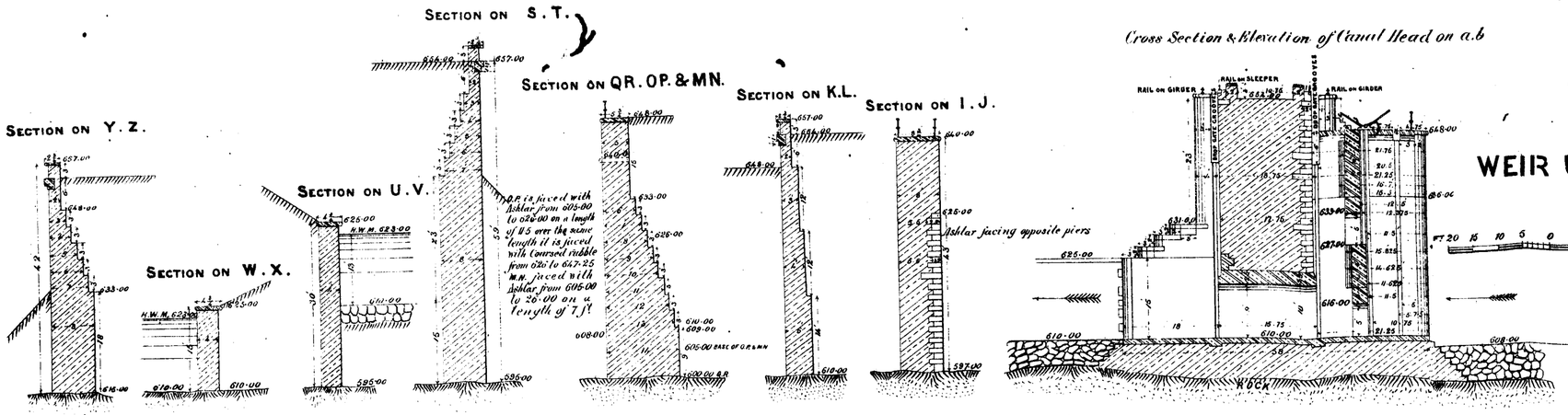
WEIR UNDER SLUICES & CANAL HEAD

SCALE OF FEET

FT 20 15 10 5 0 20 40 60 80 100 FT

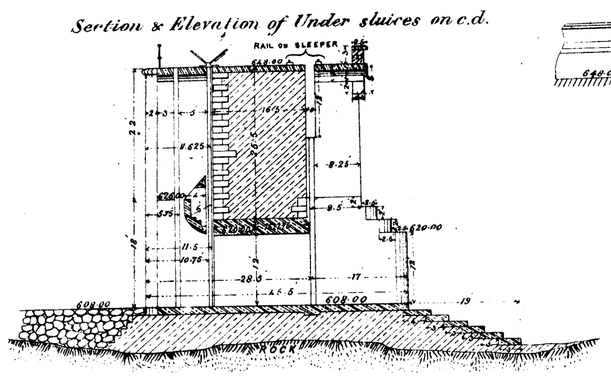
D2-71-24
MP7

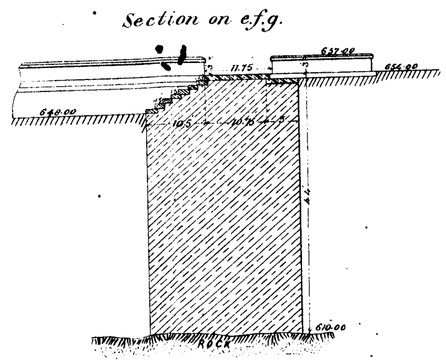
121358

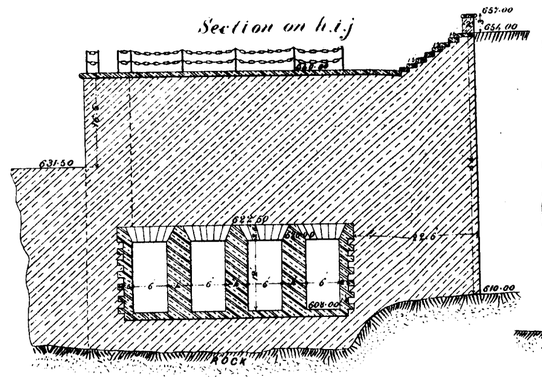


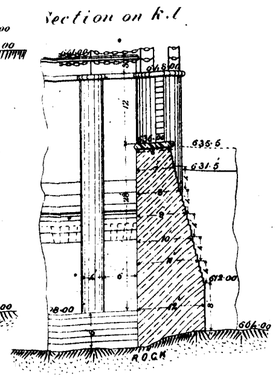
REFERENCES

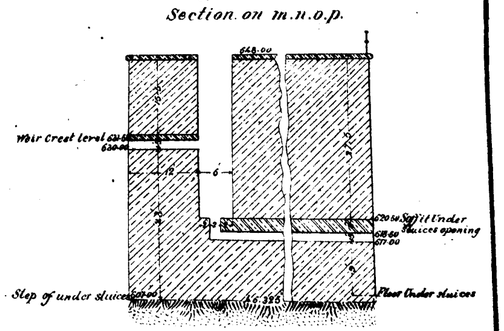
- Rubble Masonry
- Ashlar
- Dressed Rubble
- Iron Grooves











Sd R.W.L. HAWKINS

Executive Engineer

B.C. Division 20.8.86