Imperfect - 3 pages are wanting, see p. 101.

GOVERNMENT OF INDIA.

PUBLIC WORKS DEPARTMENT.

REPORT

ON

THE GANGES CANAL

BY

CAPT. J. CROFTON, R. E.,

WITH

ESTIMATES AND PLANS.

114/115

IN THREE VOLUMES.

VOL. I.—REPORT.

Calcutta:
PUBLIC WORKS DEPARTMENT,
1865.

Digitized by Google

Eng 988.65

~~VII. 1661~~

1883, June 13.
Gift of
The Govt. of India.
(I. - III.)
in 2 vols.

Digitized by Google

CONTENTS.

	Page.
Letter from CHIEF ENGINEER, Irrigation Works, N. W. P., to SECRETARY TO GOVERNMENT, N. W. P., forwarding CAPTAIN CROFTON'S letter and Report ...	1
Order of Government of N. W. P. thereon	3
Letter from Captain Crofton forwarding his Report, &c., on the Ganges Canal... ...	3
Index to paras. of Report	i
List of Plans accompanying Report	iv
List of Masonry works	v
List of Appendices	vi
Report	1
Appendix A—Memorandum of the measures recommended to be taken for Remodelling the Ganges Canal	85
„ B—Tabular Statement showing positions of Masonry works, &c.	91
„ C—Formulæ for discharges, &c.	118
„ D—Velocities of Currrent	120
„ E—Vertical falls with grating	122
„ F—Levels of the Surface of Springs along the line of the Ganges Canal ...	125
„ G—Statement of outlay on the Ganges Canal Works, &c.	127
„ H—Statement of land required for projected lines, Ganges Canal	128
General Abstract of Estimates	129

Digitized by Google

Digitized by Google

REPORT on the Ganges Canal, by CAPTAIN J. CROFTON, R. E., *on Special Duty, Ganges Canal,—dated 23rd November* 1864.

***Extract from the Proceedings of the Hon'ble the Lieutenant Governor, North-Western Provinces, in the Public Works Department, under date the 10th of December* 1864.**

COPY of a letter No. 4293, dated Roorkee, the 23rd November 1864, from the Chief Engineer of Irrigation Works, North-Western Provinces, to the Secretary to the Government of the North-Western Provinces, in the Public Works Department.

SIR,

I HAVE the honor to forward herewith in original Captain Crofton's letter No. 44 of this date, with his Report on the Ganges Canal works and collateral subjects, and the estimates and plans called for in letter No. 496, dated 1st February 1864, from the Secretary to Government of India, Public Works Department, to the Secretary to Government, North-Western Provinces, Public Works Department, copy of which was forwarded to this Office with your letter No. 781A, dated 1st March 1864.

2nd.—As it is of importance that not a day should be lost in obtaining the orders of Government on Captain Crofton's project now submitted, I have judged it best to send it in at once without waiting to study it in every detail. I have therefore merely read it carefully through, but I think I may say that I entirely agree with Captain Crofton in his view of the present state of the Ganges Canal, and of the best mode of putting it into good working order, for navigation as well as for irrigation. Differences may, and no doubt will, occur in actually carrying out the proposed works, but I believe the total amount of his estimate will not be exceeded. Knowing this, Government will probably have no difficulty in giving the necessary sanction for the preparation of working drawings, and for the collection of materials at sites of works proposed to be built or altered.

3rd.—Plan drawing and collection of materials would thus progress simultaneously, and on their completion we might have a working "bee," (as it is called in America), and assemble every available Engineer from the North-Western Provinces and from the Punjab. They should bring with them workmen and tools. To each Engineer, on arrival, would be allotted 1, 2, 3 or more works, according to their nature. The Engineer would study the working drawings and the work itself on the ground, and examine and check his material. As soon as this had been done, and everything reported clear, the Canal would be laid dry, and every man would go in at it. Thus emulation would give a spur to the work, and it would in all probability be got through in a minimum space of time. This arrangement is proposed merely for work below the water line, all work above the water line, or that can be executed without closing the Canal, being supposed to be done beforehand.

4th.—Captain Crofton has, in accordance with instructions conveyed in para. 2 of Government letter No. 496, prepared two alternative projects:—

I. For remodelling the present Canal, at an estimated cost of Rupees 52,68,063.

And, II. For the construction of a supplementary Canal, at an estimated cost of Rupees 81,43,858.

5th.—In the cost of Project I. is included the sum of Rupees 13,48,213, the estimated loss to Government in Canal Revenue, in enhanced land Revenue, and in compensation to Zemindars (to enable them to dig wells) supposing the Canal to be closed for a year during the progress of the work. No allowance of this nature has been made in the case of Project II. But as that project necessarily includes the remodelling of the present Canal between Hurdwar and Roorkee, it may, I think, be doubted

Digitized by Google

whether, in a comparison of the cost of the alternative projects, we can safely calculate on being able to carry out Project II. without closing the Canal, or, in other words, whether we can fairly exclude the consideration of possible loss during the execution of that project.

6th.—However, even if we do exclude this consideration, the difference of cost of the two projects is still Rupees 28,75,795 in favor of Project I. This difference, in addition to the reasons adduced by Captain Crofton for preferring Project I., is, I think, decisive in its favor.

7th.—With reference to Navigation (*see* para. 4 of Government letter No. 496, under reply), Captain Crofton has provided for navigation in the remodelled Channels, no separate channels of any length being found necessary. He has also worked out the cost of a separate Navigation Channel from Roorkee to Cawnpore, from which the following comparison is obtained :—

A.	Proportion of cost of Navigation arrangements on present Channel remodelled, Roorkee to Cawnpore	Rs. 15,71,531
B.	Cost of separate Navigation Channel...	„ 44,91,916
C.	Proportion of cost of Navigation arrangements on alternative line	„ 10,32,912

The above sums (A and C), representing proportion of cost of Navigation arrangements on present channel remodelled and on alternative line respectively, are included in the total estimated cost of Projects I. and II. as given in para. 3 of this letter.

8th.—Regarding the possibility of reinforcing the Ganges Canal in the rainy season with the waters of the Jumna river (*see* latter part of para. 4 of Government letter No. 496), Captain Crofton's observations show that it would not pay to take out at any place higher up the Jumna than the point where it receives the waters of the Hindun Nuddee, some 16 miles below Delhie; and he is of opinion that, if taken out there, or at any lower point, it would probably be better to keep the Canal thence derived entirely separate from the Ganges Canal, as far as irrigation is concerned. A Canal thence derived might irrigate during the rains the country between the East Kalee and the Eesun Nuddees, and it would afford a supply of water for continuing the navigation to Allahabad throughout the year.

9th.—Further remark on the project now submitted, beyond the points touched on in the Government letter under reply, appears to be unnecessary at present.

10th.—You are aware that Captain Crofton, though nominally reporting to this Office, has really had the undivided and independent charge and responsibility of the preparation of these projects. I may, however, express my sincere admiration of the energetic and able manner in which he has in so short a time accomplished a most arduous task. He has had to design not only an entirely new line of Canal, but also the works and the complicated managements required for remodelling an old one. The first-mentioned portion of his task is mere child's-play compared with the last. In work of this nature one moves as it were in fetters. An intimate knowledge of existing arrangements has first to be acquired down to the very smallest details, and the requisite additions and alterations have to be dove-tailed in with them in such a manner that the projected work shall be capable of being carried out at the smallest possible cost to Government, and without disturbing existing irrigation. I believe no one who has not attempted work of this nature can form any idea of the amount of thought, anxiety, and real toil it involves.

11th.—Captain Crofton has recorded his cordial appreciation of the assistance afforded him by Messrs. J. Hair and G. W. Mossop, and by Lieutenant W. Shepherd, R. E., and he has detailed the work done by each. I beg to recommend them to the favorable notice of Government.

12th.—The mode in which the services of these Officers (not set free for other work) have been disposed of will be reported separately.

13th.—Mr. Kelly continues to quarry stone in the neighbourhood of Hurdwar. The quantity of serviceable stone to be had at any one place is very small, and there are not

Digitized by Google

very many places within easy reach of the works, or of water carriage where it can be had. About ten thousand (10,000) cubic feet of roughly squared serviceable stone have already been landed at sites of works, and Mr. Kelly hopes to land thirty thousand (30,000) more before the 1st of May next, at from 12 annas to 1 Rupee a cubic foot. Mr. Kelly also has done good work.

I have the honor to be, &c.,

(Signed) J. H. DYAS, Captain, R. E.,

Chief Engr., Irrigation Works, N. W. P.

No. 5509A of 1864.

Order.—Ordered that a copy of the foregoing, with the Report in original, be forwarded to the Secretary to the Government of India in the Public Works Department, with the intimation that Captain Crofton has been permitted to take the plans himself to the Secretary, without any preliminary examination of them in this Office.

C. J. HODGSON, Lieut.-Col., R. E.,

Offg. Secy. to the Govt. of the N. W. P., in the P. W. D.

P. W. Dept., N. W. P.,
Camp Koomheer:
The 10th of December, 1864.

From—Captain J. Crofton, R. E., *On Special Duty, Ganges Canal, to* Captain J. H. Dyas, R., E., *Chief Engineer of Irrigation, N. W. Provinces,*—(*No.* 44 *of* 1864-65.)

Dated Roorkee, 23rd November 1864.

Sir,

I have the honor to forward the Report on the Ganges Canal Works and collateral subjects, with the estimates called for in letter No. 496, dated 1st February 1864, from the Secretary to the Government of India, to the Secretary to the Government, N. W. P., Public Works Department, forwarded with your predecessor's Docket No. 4472, dated 3rd March last.

2. On the 15th February last I was relieved by Lieutenant Moncrieff, r. e., of the charge of the Eastern Jumna Canal, having proceeded to Roorkee on the 13th, where two of the Officers, whose services had been previously placed at my disposal, Mr. J. Hair, Executive Engineer of the Bolundshuhur Division, Ganges Canal, and Lieutenant Shepherd, r. e., joined me.

As it was desirable to complete the field work before the regular setting in of the hot winds, when the accuracy of levelling operations becomes questionable, the establishments of the Ganges Canal, both European and Native, were subsequently indented on for a further supply of levellers.

3. To Mr. Hair was assigned the levelling for the alternative line from Roorkee to the Bolundshuhur Branch head, while Lieutenant Shepherd took the cross-sectioning in the Doab between the Hindun and West Kalee Nuddee. Mr. Hunt, assistant to Mr. W. Dodsworth, Supervisor of land measurements, Ganges Canal, carried on the alternative line levels from the Bolundshuhur Branch head to near Khoorja; also the trial level from opposite Mozuffernuggur *viâ* Khutowlee to the Futtehgurh Branch, as well as the line for the proposed navigation channel from above Deobund to Meerut; the remainder of both lines down to the Nanoon Regulating Bridge and that from the Futtehgurh Branch opposite Anoopshuhur were completed by Native Surveyors attached to Mr. Dodsworth's establishment. The levels from the Jumna at he head of the Eastern Jumna Canal and the Railway crossing opposite Saharunpoor, joining

Digitized by Google

on to Mr. Hair's line near Deobund, were taken by Mr. T. Jones, Assistant Engineer, Northern Division, Ganges Canal.

All this field work was completed by the latter end of April. In the mean time I had marched over the course of the proposed alternative line from Roorkee to Sirdhanna, and examined carefully the channel and works on the main line of the canal from the heads to below Allyghur, as well as the Cawnpore terminal works. The time at my disposal would not admit of a more extended inspection of the branch canals, as I was obliged to be back at Roorkee on the 4th April, for a committee on canal revenue matters previously ordered by Government.

4. In the beginning of May, we, (*i. e.*, Mr. Hair, Lieutenant Shepherd and I) reached Mussoorie, our head quarters for the hot season; Mr. Mossop joined us on the 20th June from the Punjaub.

The Ganges Canal was closed for repairs at the latter end of July, when I accompanied the late Superintendent General Colonel Turnbull, in his inspection of the works from Roorkee to Sirdhanna, and the last seven miles of the Cawnpore Branch, and subsequently examined the line between Myapoor and Roorkee. The submission of these projects has been somewhat delayed by the late closure of the canal, as it was impossible to settle the detail of alterations required for remodelling without knowing the actual condition of the works below the water line. Some of the details of information gathered by the Executive Officers, during the closure, have only come to hand within the last fortnight.

5. The levels taken specially for the projects now submitted have all been plotted on a scale of 1 mile to the inch, and put together on sheets of double elephant paper. They are shewn on a reduced scale in Plan No. II., which has been compiled chiefly from the "Atlas Sheets" of India and the Revenue Survey district maps. The other maps are compiled from this or existing records in the Canal Office at Roorkee.

6. The sections of the Ganges shown in Plan VIII. at Sookertal and Bysoomah, were taken, the former by Mr. Hair, the latter by Mr. Hunt; those at Gurmooktesur and Anoopshuhur, as well as all on the Jumna, were obtained from the Railway Department.

7. It only remains for me to state briefly the part taken by each in the preparation of the projects. Each surveyor or leveller plotted his own work. To Mr. Mossop is due the drawing up of the sections and compilation of most of them, as well as the three Maps which head the list.

The whole of the estimating was done by Mr. Hair and Lieutenant Shepherd, to whom the plans, and several of the designs of the Masonry works, are also due. To all three gentlemen every credit is to be given, for the very efficient manner in which they have performed their share of the work; Mr. Hair's engineering experience, gained both in India and England, has been especially valuable in working out the detail of the projected works and alterations. Without the incessant labour and attention they have given to it, the work, I have no hesitation in saying, could not have been completed for months to come.

The Officers of the Ganges Canal have contributed their quota of aid throughout the investigation. To them, and to our late ever-to-be-lamented Chief, Colonel A. D. Turnbull, much of the information, and several useful suggestions contained in the following Report, are due.

I have the honor to be,

Sir,

Your most obedient Servant,

J. CROFTON, *Captain*, R. E.,

On Special Duty, Ganges Canal.

Digitized by Google

INDEX TO PARAGRAPHS.

1 Subjects of the Report.
2 Present condition of Canal to be first described.
3 Head works on the Ganges not included.

CONDITION OF WORKS FROM HEAD TO ROORKEE.

4 Channel from Myapore to Roorkee.
5 Overfalls above the Rutmoo.
6 Rutmoo Works.
7 Myapore Regulator.
8 Solanee Aqueduct.
9 Bridges.
10 Bahadoorabad Lock Channel.
11 Available headway.
12 Hill torrent embankments.

WORKS FROM ROORKEE TO CAWNPORE AND ETAWAH BRANCH HEADS.

13 Channel.
14 Lock Channels.
15 Escape heads.
16 Bridges.
17 Branch heads.
18 Locks.
19 Available headway.
20 Overfalls, Muhmoodpore.
21 Remaining Overfalls.

CAWNPORE BRANCH.

22 Channel.
23 Masonry works.
24 Available headway.

ETAWAH BRANCH.

25 Channel and masonry works.
26 Obstructions to navigation.
27 Futtehgurh Branch.
28 Koel and Boolundshuhur Branches.
29 Causes of defective condition of channel.
30 Of channel from Myapore to Raneepore.
31 Deficiency of backwater on floorings.
32 Accelerated velocity at branch heads.
33 Covering material of flooring.
34 Headway under bridges insufficient.
35 Erosive action greater in former years.
36 Reduction of velocity the only permanent remedy.
37 Proposal for rectification.
38 Velocities of current recommended.
39 Best form of overfall.
40 Headway necessary for navigation.
41 Dimensions of locks.
42 Separate lock channels not advisable, and why.
43 General measures recommended for remodelling present line.
44 Volume of water to be provided for, and its distribution.

Digitized by Google

REMODELLING FROM MYAPORE TO ROORKEE.

45 Alterations in channel.
46 Lockage from Kunkhul to Puttree.
47 Myapore regulator.
48 Kunkhul bridge and lock.
49 Puttree and Raneepore works.
50 Bahadoorabad Falls and locks.
51 Rutmoo works.
52 Solanee Aqueduct.
53 Bridges.
54 Headway on remodelled line not uniform.

REMODELLING FROM ROORKEE TO HEAD OF CAWNPORE BRANCH.

55 Channel alterations.
56 New falls and locks.
57 Alterations to present falls.
58 Ditto to bridges.
59 Branch heads.
60 Escape heads.

REMODELLING CAWNPORE BRANCH.

61 Alteration in channel to Keylunpore Bridge.
62 Alterations to bridges generally.
63 Retention of present channel below Dubowlee Escape as navigable line recommended, and why.
64 New lock and alterations at Dubowlee Bridge.
65 Alterations to works in Cawnpore.
66 Waterway through Cawnpore may be found insufficient; remedy possible.
67 Alterations on branches.

THE ALTERNATIVE LINE.

68 New line into Futtehghur Branch not recommended, and why.
69 Discharge of alternative line, and re-distribution of supply.
70 Course of line.
71 Sections of channel and declivities.
72 Overfalls.
73 Aqueducts.
74 Roorkee regulator and branch heads.
75 Escape heads.
76 Bridges.
77 Drainage culverts.
78 Rajbuha inlets and outlets.
79 Chokies.
80 Metalling and well foundations.
81 Consequent alterations to main line.

SEPARATE NAVIGABLE LINE.

82 Course of line and how determined.
83 Section of channel and declivity.
84 Locks.
85 Aqueducts.
86 Drainage culverts, &c.
87 Chokies.
88 Well foundations.

Digitized by Google

RATES, MATERIALS, &c.

89 Rates how obtained.
90 Stone.
91 Bricks and brickwork.
92 Boulders.
93 Kunkur.
94 Wood and iron work.
95 Per centage for contingencies, and establishment.
96 Pumping.

COMPARISON OF PROJECTS AND TOTAL COST.

97 Advantages and disadvantages of alternative line project.
98 Effects of division of supply.
99 Alternative line non-irrigating for 60 miles.
100 Effect on irrigation.
101 Advantages of remodelling.
102 Probable necessity of closing the Canal temporarily.
103 Cost of each project compared.
104 Probable cost of diversions.
105 Navigation, general considerations.
106 Water communication, where required.
107 Comparison of cost.
108 Adaptation of irrigating channels preferable.
109 Connection with navigable system on West bank of Jumna feasible.
110 Navigation returns from Ganges Canal.
111 Total probable cost of Ganges Canal.
112 Discharge of Canal assumed as in original projection, and why.
113 Terminus of Futtehgurh Branch.

SUPPLY OF WATER FROM THE JUMNA FOR AUTUMN CROPS.

114 From Boodhee Jumna at Nyashuhur.
115 From Railway crossing opposite Saharunpoor.
116 From river at confluence of Hindun.
117 Of the Jumna below the Hindun.

CONCLUDING REMARKS.

118 Permanent head works.
119 System of general drainage required.
120 Remedial measures, why not adopted earlier.
121 Reply to objection that Canals are unremunerative.
122 Insufficiency of Establishment of European Officers.
123 Memorandum by Sir Arthur Cotton, enumeration of "fundamental mistakes."
124 Permanent head works.
125 Water carried "within soil."
126 Substitution of stone for brick.
127 Position of head of Canal.
128 Enumeration of "minor mistakes."
129 Weirs and velocity of current.
130 Silt.
131 Solanee Aqueduct.
132 Hindrances to navigation.
133 Irrigation returns affected by only two of the alleged defects.
134 Claim set up by Secretary to Irrigation Company.

Digitized by Google

LIST OF PLANS.

I. General Map of Ganges and Jumna Doab. Scale, 8 miles to an inch.

II. Map of part of Doab, shewing protraction of levels taken in 1864, with proposed alternative and navigable lines. Scale, 4 miles to an inch.

III. Enlarged Plan of Ganges Valley, &c., above Roorkee. Scale, 2000 feet to an inch.

IV. Lougitudinal Sections Horizontal Scale, 1 mile to an inch.
Vertical do., 100 times horizontal.

1 Ganges Canal Main Line	sheets	...	1 to 6
Cawnpore Branch	do.	...	7 to 11
Etawah Branch	do.	...	12 to 17
Futtehgurh Branch	do.	...	18 to 20
2 Alternative Line Junction from ditto to Ganges Canal Escapes	Sheets...	...	21 to 24
3 Separate navigable channel from Roorkee to Nanoon		...	25 to 28

4 Ditto ditto from 82nd mile on Futtehgurh Branch to Nanoon, Sheet 29.

5 On line levelled for proposed diversion of alternative line into Futtehgurh Branch, Sheet 30.

V. Cross Sections of Hindun and West Kalee Nuddee Doab. Scales as in Plan IV.

VI. Sections of Nullahs, &c.

VII. Cross Sections of Canal channels.

VIII. Cross Sections vallies of Ganges and Jumna rivers, in 3 sheets.

IX. Levels taken from Jumna river for proposed supplementary channel, 3 sheets.

X. Masonry works.

Remodelling Ganges Canal,	sheets	...	1 to 22
Alternative line	„	...	23 to 38
Navigable line	„	...	39 to 43

Digitized by Google

LIST OF MASONRY WORKS.

1 Myapoor Regulating Bridge.
2 Kunkhul Bridge.
3 Lock Channel, &c., at Kunkhul Bridge.
4 Bahadoorabad Fall No. 1.
5 & 6 Puttree Works.
7 Rutmoo Regulating Bridge.
8 Fall at Roorkee.
9 Munglour Bridge.
10 & 11 Mahmoodpoor Falls.
12 Toghulpoor Bridge and Falls.
13 Futtehgurh Branch Head.
14 Dukhera Bridge and Falls.
15 Girder Bridge and Towpath.
16 Bholah Falls.
17 Wullipoora Bridge and Falls.
18 Pulra Falls.
19 Burowlee Bridge and Falls.
20 Cawnpore and Etawah Branch Heads.
21 Duknapore Bridge, Cawnpore Branch.
22 Ghâts, &c., at Cawnpore.

ALTERNATIVE LINE.

23 Regulator at Roorkee.
24 Ditto at junction line.
25 Fall, Escape, &c., at Boolundshuhur Branch Head.
26 Falls, 6 feet, 11 bays of 15.
27 Ditto, 6 bays of 14, on junction line.
28 Fall, Escape and Dam Bridge at 51st mile.
29 Fall on Escape into West Kalee Nuddee.
30 Aqueduct over Kalee Nuddee upper crossing.
31 Ditto Ditto lower Ditto.
32 Bridge, 4 arches of 51′.
33 Ditto 3 arches of 40′.
34 Ditto 3 arches of 30′.
35 Culvert, 2 arches of 20′ and Inlet for drainage.
36 Syphon, 1 arch of 3′.
37 Rajbuha Outlets and Culvert for Escape.
38 Culvert, 1 arch of 10′, and 3rd class chokee.

NAVIGABLE LINE.

39 Double Lock Chamber at exit from Canal.
40 Double Locks.
41 Bridges, 1 arch of 34′.
42 Aqueduct over Kalee Nuddee.
43 Rajbuha Syphon.

Digitized by Google

LIST OF APPENDICES.

A Memorandum of the measures recommended for remodelling the Ganges Canal, and Sir P. T. Cautley's Memo. on Alternative Line Project.

B Tabular Statements of Works.

C Formulæ for discharges, &c.

D Velocities of Current.

E Captain Dyas's Memo. on vertical falls and grating.

F Levels of surface of springs.

G Expenditure on Ganges Canal Works and Irrigation from commencement up to 30th April 1863.

H Statement of land required for Alternative and Navigable Lines.

Digitized by Google

REPORT.

Subjects of the Report.

1. The subjects to be taken up in this Paper will be found briefly described in the accompanying Memorandum (Appendix A), forwarded for guidance by the Government of India. They may be classed generally under four heads.

1st. The possibility of rectifying existing evils on the Ganges Canal by alterations and additions to the present channels and masonry works.

2nd. The comparative advantages and disadvantages of effecting this by remodelling the present line in the Ganges Khadir, as far as Roorkee, where the Canal enters the bangur or high land of the Doab, thence dividing the supply as suggested by Sir Proby Cautley, and carrying a certain proportion of it in a new channel to run to the westward between the Hindun and West Kalee Nuddee, which should reunite with the original line at some point lower down its course, beyond which any alterations to existing works could be effected without much difficulty.

3rd. Whether a separate Canal for navigation only would be preferable to adapting the works of irrigating channels to that purpose; and—

4th. The feasibility of drawing an extra supply of water from the Jumna for an autumn crop, during the months when its volume is in excess of the requirements of the Eastern and Western Jumna Canals.

Present condition of Canal to be first described.

2. Before entering into the details of any of these questions, it will be advisable to describe briefly the condition of the Canal as it is.

The Tabular Statement (Appendix B) and the longitudinal sections (Sheets 1 to 20 Plan IV), together with the general plans of the course of the Canal, will, it is believed, supply all further minutiæ necessary to a clear understanding of the state of the works. In the longitudinal sections, the ground line shewn is that of the natural surface at the time of excavation of the channel; the straight black lines below, connecting the floorings of the bridges, show the level of the bed as originally excavated, the present level of the lowest line of channel opposite milestones and at bridges and falls being marked by an uneven black line either above or below this, as silting or erosion has taken place. Sir Proby Cautley's Report of 1860 (hereafter referred to as the "Ganges Canal Report") gives such ample detail of the existing masonry works that plans of any of them to accompany this Paper have been considered unnecessary, except for the purpose of elucidating extensive proposed alterations. All levels are reduced from a datum 200 feet *above* the flooring of the Myapoor Regulating Bridge, the original zero from which the levels in the Ganges Canal Report were calculated; the reason of this alteration being to admit of the levels of any part of the Doab up to the base of the hills being reduced to a common datum line without the introduction of

Digitized by Google

plus or minus signs, which might possibly lead to errors hereafter. This datum, by connections made here and there with permanent benchmarks, is 1121·37 feet *above* that of the series of levels brought up from the mean sea level at Kurrachee by the officers of the Great Trigonometrical Survey.

Head Works on the Ganges not included.

3. The Bridge at Myapoor below Hurdwar being the present regulator for admission of the supply of water, and the temporary arrangement for drawing it from the Ganges being sufficient for existing requirements, no remarks will be offered here on the channels above that point. Alterations to them or the Escape Dam attached to the Bridge will be more appropriately considered in conjunction with the question of a permanent Dam across the river, for which we have not sufficient data at present.

STATE OF WORKS FROM HEAD TO ROORKEE.

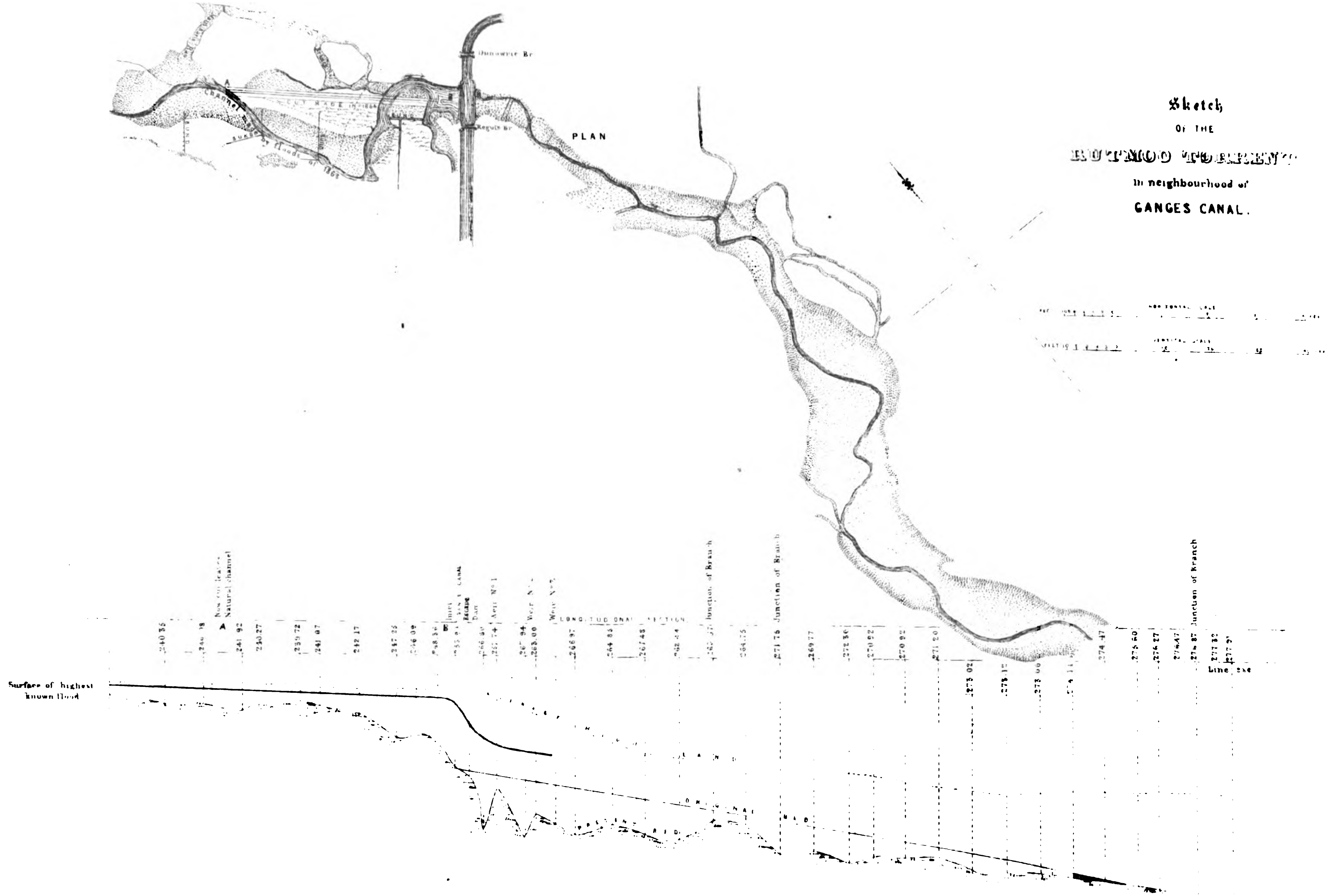
Channel from Myapoor to Roorkee.

4. From Myapoor to Kunkhul Bridge there has been little erosion on either bed or sides, the soil being chiefly shingle and earth. From this point to the Rutmoo torrent at the 13th mile, the soil is more or less mixed with sand, and deepening and widening has taken place extensively in parts, such as between Jowalapoor Bridge and the Upper Bahadoorabad Fall, and between the Puttree and Rutmoo Torrents; the channelling out here varies from 3 to 5 feet in depth, and in places the berm on both sides has been entirely cut away. From the Rutmoo to Muhewur Bridge,—the commencement of the Solanee Valley Aqueduct—the channelling and side cutting has been very trifling, the soil of the ridge through which the line passes being generally of a stiff tenacious clay. The bed of the Solanee Aqueduct, between the masonry revetments from Muhewur to the Roorkee Bridge, has been deepened on an average 3½ feet (*vide* annexed sketches.) The erosion on this portion of the line was at one time much more serious when the supply of water passing down was considerably larger than during the last two years; the deepest holes appear to have been gradually silted up since then.

The berms or towpaths between the head at Myapoor and the Rutmoo Torrent do not appear to have been originally excavated to a uniform height above the bed; where the depth of excavation was more than 12 feet,—the minimum height of the towpath above the bed as originally determined,—they were formed on the level of the natural surface. Between the Jowalapoor Bridge and the Puttree Works this was of no consequence, navigation being provided for here in a separate channel; but the irregularity of height of towing track above the surface of water cannot fail to be, and is, a hindrance to the traffic. It was done solely from economical motives, as Sir P. T. Cautley has explained with reference to this and other portions of the Canal in his Report. From the Rutmoo to the Solanee Valley Aqueduct revetments, the berms are maintained at a uniform level of 12 feet above the bed. Holes have been eroded in the bed below the Jowalapoor Bridge and all the falls to the depths shewn in the section.

Digitized by Google

Digitized by Google



To face Para 3 - Para 6.

Digitized by Google

In one instance, at the Upper Bahadoorabad Fall, the erosion extends considerably below the bottom level of the foundations; no injury, however, has resulted from this to any of the masonry works, the talus of boulders and crib work originally attached to each on the down stream side having transferred the excessive action of the current to a sufficient distance from the works themselves.

Overfalls above the Rutmoo.

5. The four overfalls on this section have suffered little injury, except in the brick on edge coverings on and at the foot of the ogees, where the action of the stream is most violent. This, in the falls at the Ranipoor and Puttree Works, has been stripped off to a considerable extent; the soundness of the brickwork (first-rate along this part of the Canal) has, however, prevented any dangerous results hitherto; the remainder of these massive works are in capital order, and their action in passing off the floods of the torrents has, up to the present time, been most satisfactory. Silt has been deposited to some extent on the upper channel of both (most on the Ranipoor super-passage). No retrogression of level whatever has taken place in the beds of the torrents below.

Rutmoo Works.

6. At the Rutmoo, the Escape Dam is in fair working order; below it, however, most serious retrogression of the levels of the torrent bed has been from the first taking place, and the Canal Works have only been preserved hitherto by temporary overfalls of piles and boulder work constructed, from time to time across the bed below, as shewn in the annexed sketch. In lieu of these a design for a permanent masonry overfall was, some months ago, submitted for the sanction of Government; its construction would probably secure the works from all future risk, and save any further outlay on this, the most troublesome and dangerous, portion of the Ganges Valley Works.

The Inlet Dam has been out of use for some time past, the water of the Canal being permitted to extend up the bed of the torrent: no inundation of the low lying adjacent lands has hitherto resulted from this, and it is clear from the longitudinal section along the banks that the surface level of the water at the Inlet Dam might be raised to 10 feet, the original full supply mark, without any risk of flooding the valley, which is similar in configuration to those of most silt-bearing streams, where the level of the banks on either side falls away from the channel. The inundation, which usually covers a large portion of the low lands in the valley in the rainy season, is caused by the floods of the torrent overflowing the banks at points considerably above the highest limit to which the Canal water at full supply would extend. The masonry passage for carrying drainage from the bed of the torrent above the Inlet Dam under the Regulating Bridge has, consequently, been closed for some time past. Much silt is constantly deposited in the bed of the torrent above the Inlet Dam owing to the diminution of waterway there, the effect of which is, and has been, very injurious, by contracting the channel of approach, and thus heading back the floods which have, on more occasions than one, cut into the banks of the torrents to a dangerous extent, and inundated a large area of the valley on the right bank of the Canal. It has also

Digitized by Google

tended to concentrate the action on the tail flooring of the Escape Dam, by increasing the height of fall there in the surface of the flood waters. The highest flood yet observed has not risen above the level of the top of the Dam piers (or 10 feet above the Canal bed) except on occasions when the Canal also is running full ; the water has then been known to rise 4 feet over the Inlet piers.

The Sluice apparatus, on the Regulating Bridge below the Dam, seems to require some modification ; experience has shown that the width of the gates and length of the sleepers (20 feet in the clear) is too great for economical working with reference to the depth of water to be controlled. The wooden gates in use are necessarily very heavy, the lifting gear must be correspondingly massive, and the number of men to work it large. If let fall when the supply of water is low, the vibration shakes the masonry, and, with a full supply, there is often considerable difficulty in closing the last two or three bays.

Myapoor Regulator.

7. At the Myapoor Regulating Bridge the inconvenience of the wide Sluice gates has been still more felt, from the greater depth of flood water to be dealt with, and the more frequent necessity of closing ; the vibration from the fall of the gates here loosened the stone linings of the gate grooves so much that iron had some time since to be substituted, which seems to have stood fairly ; the other evils, however, still remain, and unless the width be reduced, more powerful lifting machinery and stronger gates, must be substituted for those at present in use.

Solanee Aqueduct.

8. The Aqueduct over the Solanee torrent has stood well ; the state of the bed of the torrent above and below shows that the waterway under the Aqueduct is just sufficient, and no more ; there is no hole or retrogression of levels down stream, and little or no silt has been deposited except under the side arches, where a certain quantity would naturally be left on the subsidence of floods. The flooring of the Canal channel above requires some waterproof covering ; dripping still continues through the arches, though less than at first, the effect of which has been to loosen a considerable surface of the outside plaster, and here and there bricks of an inferior description (of which it is next to impossible to prevent a few finding their way into so great a mass of brickwork) may be seen slowly decomposing from the same cause. It was at one time supposed that the pores of the brickwork would gradually fill up and so stop the percolation, but the fact is, that even the very best of brickwork is of too absorbent a nature to be proof by itself against the constant pressure of a head of water even much less than that passing over this Aqueduct ; the bricks too vary in quality according to the mode of burning ; in some experiments made a few years ago on the Canal works in the Punjab, first class bricks burnt in the *Native* kiln were found to absorb one-thirteenth of their weight of water, while bricks of similar appearance burnt in " flame" kilns, in which the fuel was wood, took up as much as *one-seventh* of their weight. Sir P. T. Cautley anticipated the evil, and suggested the measures to be adopted as time

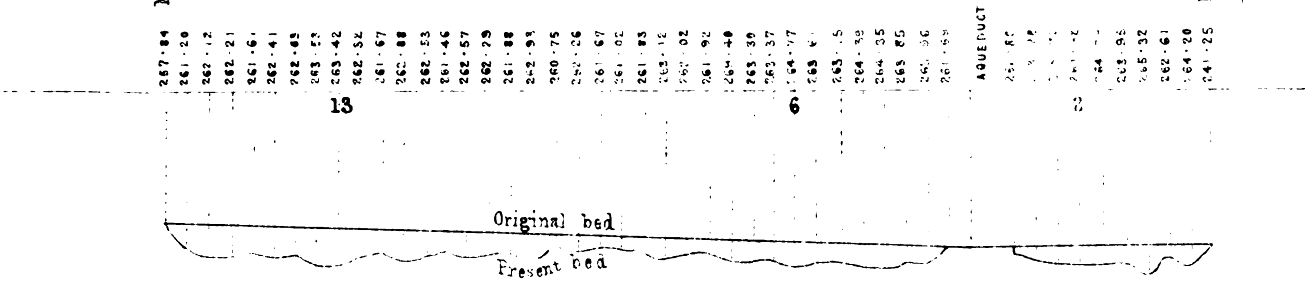
Digitized by Google

LONGITUDINAL SECTION OF SOLANEE VALLEY AQUEDUCT.

SCALES.

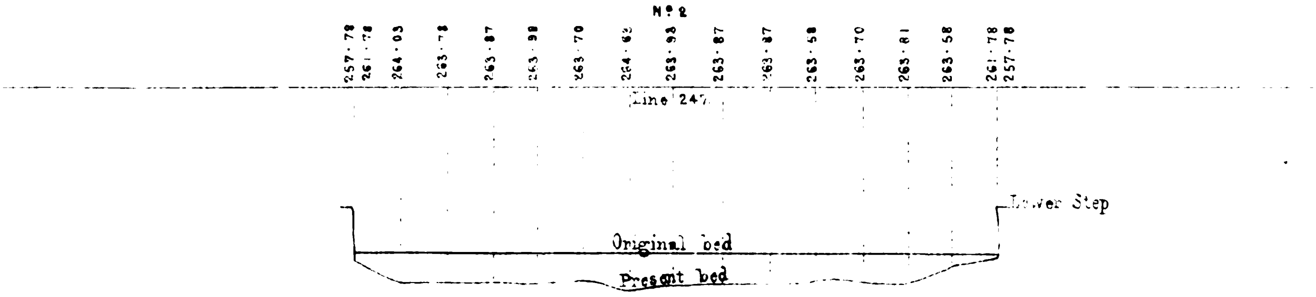
Horizontal _ 2 inches to a Mile

Vertical _ 100 Times Horizl

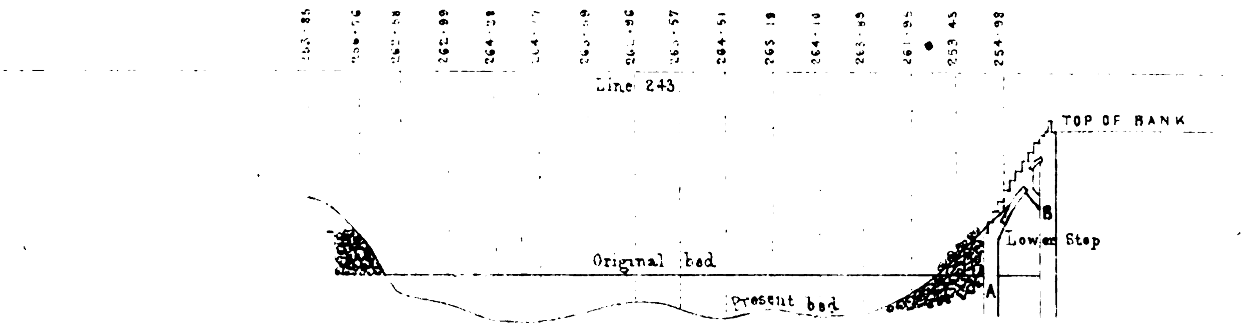


CROSS SECTIONS.

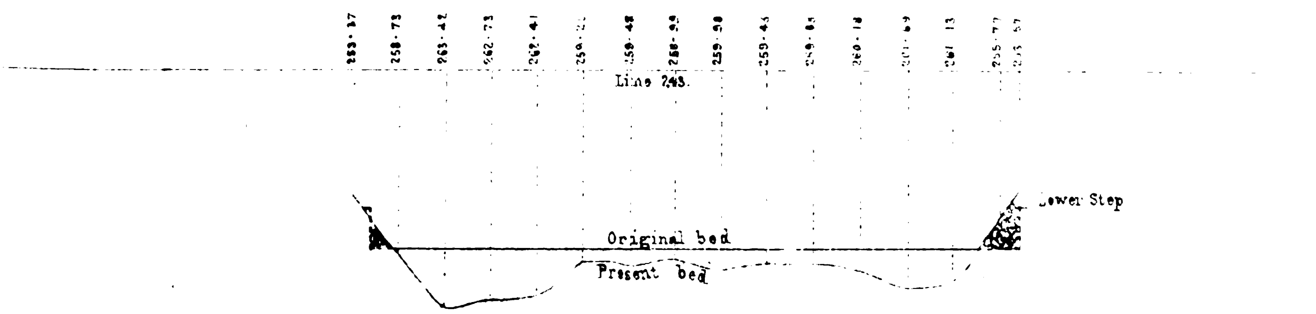
No. 2



No. 6.



No. 13



SCALE

Horizontal 500 to 1

Vertical 200 to 1

Digitized by Google

and opportunity might offer (*vide* Ganges Canal Report, Vol. II., pages 518 and 521). The masonry revetments or ghats, which form the sides of the channel along the raised earthen embankment across the valley, do not call for much remark ; a breach occurred some years since along a short portion of the right bank ghat, from the heeling over inwards (towards the channel) of the wall A (*vide* annexed sketch) from a point some four or five feet below the level of the bed ; the channel here had been considerably deepened, and the accident occurred just after the Canal had been laid dry ; the outer wall B was very little, if at all, affected. From the investigation made immediately after its occurrence, it appears to have been caused by the pressure of the earth filling between the walls which had become saturated by the percolation through the brickwork ; when the counteracting pressure of the water in the Canal was removed, the thin wall gave way, there being no weep holes through it by which the drainage from the backing could find an exit. The bed all along between these revetments was to have been protected by a layer of boulders (*vide* Ganges Canal Report, Vol. II., page 453): this, however, has been deferred from economical motives, the actual protecting work being confined to a sloping talus of boulders and brick kiln rubbish, thrown down from time to time along the foot of the ghats.

Bridges above Roorkee.

9. The Bridges from the head to Roorkee are all in good order. The towing track is carried under the left side arch of each, where the navigation is carried on in the main channels, either by arched masonry passages, or, as at the Peeran Kuliar Bridge, by temporary wooden scaffolding.

Bahadoorabad Lock Channel.

10. The navigable channel from the Jowalapoor Bridge to the Puttree does not work satisfactorily, from the quantity of silt constantly being deposited in it, especially on the Reach between the lower Bahadoorabad and Puttree Locks ; the velocity of current is necessarily less than that in the main channel causing the deposition of the silt which more or less enters with the supply at Jowalapoor Bridge ; the berm, originally excavated to a suitable level, is in places entirely cut away ; in others, the encroachments of weeds have narrowed the channel, so that a single boat has hardly room to pass.

Available Headway.

11. The headway for the passage of boats along this portion of the Canal was limited to 5 feet by the height under the arches of the Rutmoo Regulating Bridge, supposing the depth of water at full supply to be 10 feet as originally calculated ; elsewhere the headway varies from 5·34 under the Puttree super-passage to 12 feet under the Bridges generally ; the Bridge at Peeran Kuliar is, from the accident of its position, exceptionally high. The available headway at each work is obtainable from the tabular Statement (Appendix B) by subtracting the full supply depth in Canal from the total height of soffit of arches above the floorings.

Hill torrent embankments.

12. The embankment works and cuts for controlling the vagaries of the hill torrents have worked, on the whole, most satisfactorily ; breaches and consequent inundation of the adjacent lowlands have, it is true, occurred more than once in the Rutmoo and Solanee Valleys, but these have been due to want

Digitized by Google

of timely repairs or trifling additions, which subsequent experience shewed to be necessary, to the original bunds and spurs. Careful watching can never be dispensed with over works of this nature, and a comparatively trifling expenditure on timely repairs and small additions, as may appear necessary from time to time, will prove to be the best economy in the long run.

CONDITION OF WORKS FROM ROORKEE TO CAWNPORE AND ETAWAH BRANCH HEADS.

Channel from Roorkee to Nanoon Regulator.

13. These 162 miles comprise the remaining portion of the main line proper, and it is here that the works have suffered most. The nature of the country traversed by the Canal has been so minutely described in the Ganges Canal Report (Vol. I, page 191 and *passim*) that a very few remarks on it will suffice here. From Roorkee to the neighbourhood of Sirdhanna the soil is more or less sandy; ridges of light sand cross the line near Guneshpoor, Toghulpoor and Bailra Bridges, and again a little below the Futtehgurh Branch Head, and near the Khutowlee and Aternah Bridges; for some distance above and below the Chitowra and Sulawur Falls there is a large admixture of clay. About the Nanoon Bridge kunkur appears with the clay and sand, and from this to the Branch head below Allyghur the soil is fair, with occasional short intervals of light sand as at the Boolundshuhur Branch head, the Wullipoor and Urowlee Bridges, and again for some distance above the Cawnpore Branch head. "Oosur" makes its appearance about the Simra Falls, but to no great extent. The longitudinal section shows that erosion has taken place in the bed, more or less, all along the line; between Hafiznuggur and Nirgajnee the depth of channelling is greatest, in some parts as much as 4 or 5 feet below the original bed, and this extends, with little diminution, as far as Chitowrah. Again, for some distance below the Sulawur Falls, the depth has been increased by 3 feet and upwards. In the more sandy tracts, it will be observed that the declivity of the new bed is tolerably uniform, but the fall is less than that of the original channel. The width has altered little except through the sand hills; the edge of the towpath generally remains intact, the slopes abraded to a nearly perpendicular section. The annexed diagrams show the actual sections of channel at various points compared with those originally excavated. Other sections have been taken at each milestone for a considerable distance from the heads, to furnish data for estimating, but I have considered it needless to encumber this Report with them. Wherever any considerable widening of the channels has taken place the bed is higher than either above or below; the most remarkable instances of this occur at the sand hills above the Toghulpoor Bridge and a mile below the Futtehgurh Branch Head, sketches of which are annexed. This natural formation gives, I think, a useful hint in projecting artificial channels, which will be again referred to in considering the measures to be adopted for remodelling.

Below every fall the channel is widened for a considerable distance; in some cases, not only has the berm entirely disappeared, but a large width of the spoil banks has also been carried away.

Digitized by Google

CROSS SECTIONS
of the
GANGES CANAL

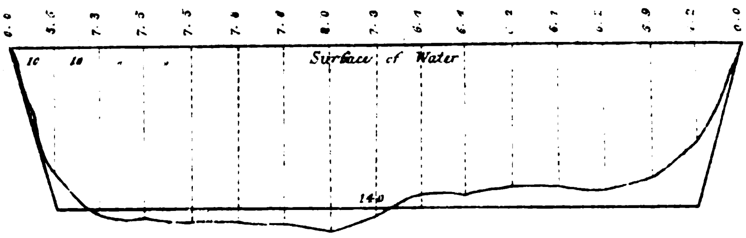
Scale
Horizontal = 500 to 1
Vertical = 5 times Hor.l

Below Myapoor at first Milestone

I

Myapoor Guage 7·15

Soil. Clay Sand & shingle

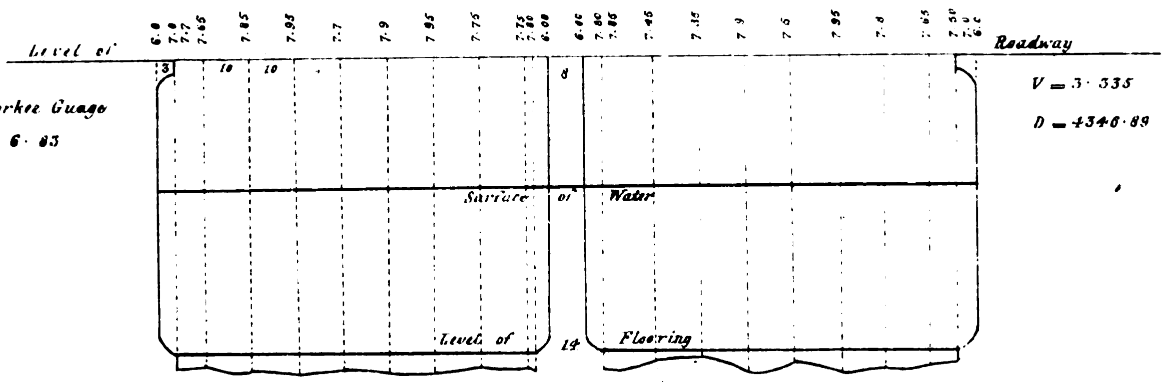


V = 4·709
D = 4815·28

SOLANI AQUEDUCT

II

Roorkee Guage 6·83



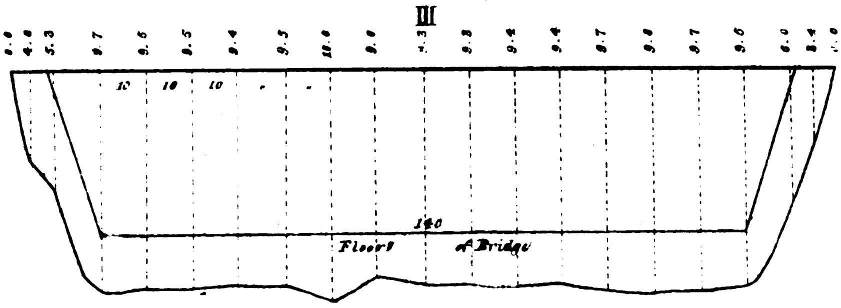
V = 3·335
D = 4346·89

2060 feet above Guneshpoor Bridge at 20th Mile

III

Roorkee Guage 6·83

Soil Sandy



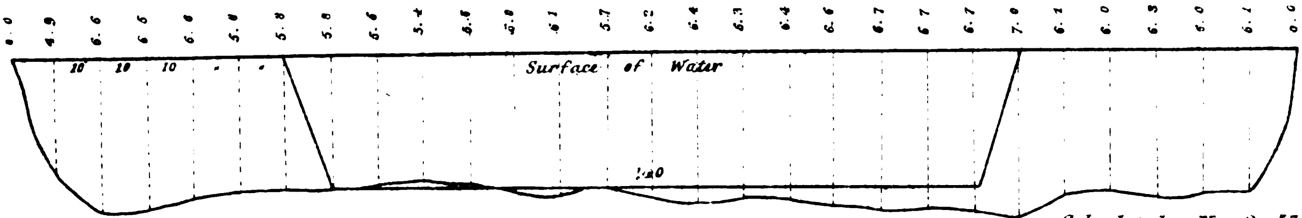
V = 2·92
D = 4460·97

at Tegulpoor Sandhills

IV

above Surface

Bank 30 ft. above Water S



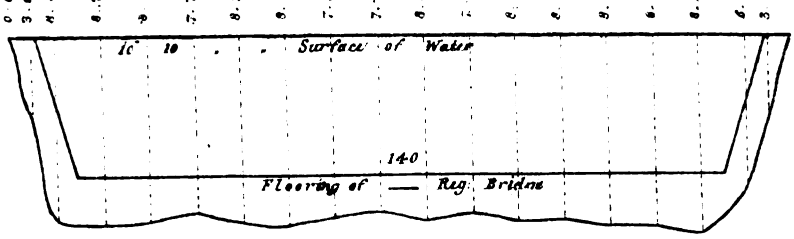
Soil light Sand

Calculated V = 2·532

2593 ft above Futtegurh Branch Head

V

Soil Sandy



V = 3·059
D = 3858·44

Digitized by Google

CROSS SECTIONS

OF THE

GANGES CANAL

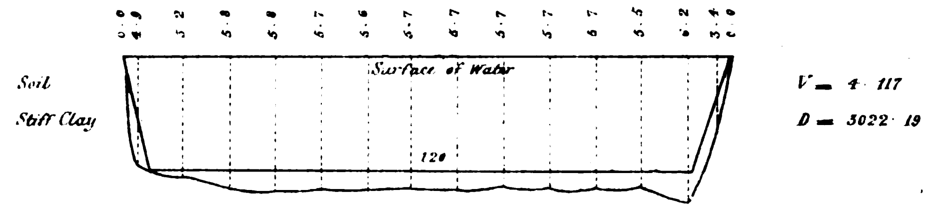
SCALES.

Horizontal 500 to 1.

Vertical 6 times Hor.l

173 feet above Newarew Bridge.

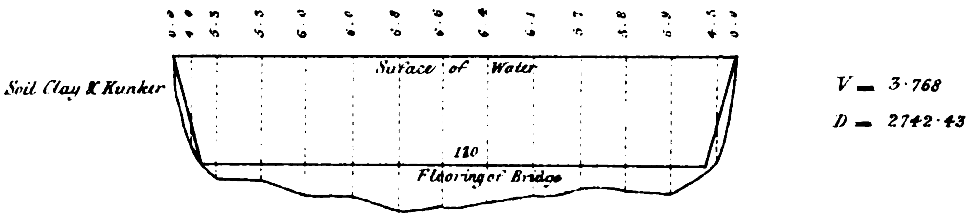
VI



Right Bank

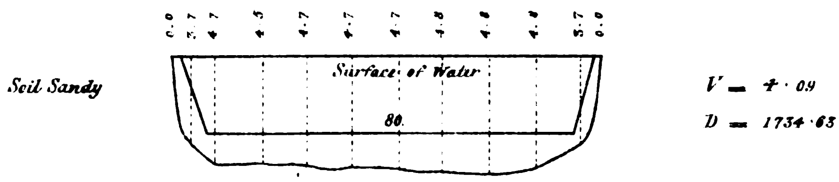
837 feet above Dumkoura Bridge.

VII



Below Nanoon Branch Head, Cawnpore Branch.

VIII



To face page 6 para 13

Digitized by Google

Digitized by Google

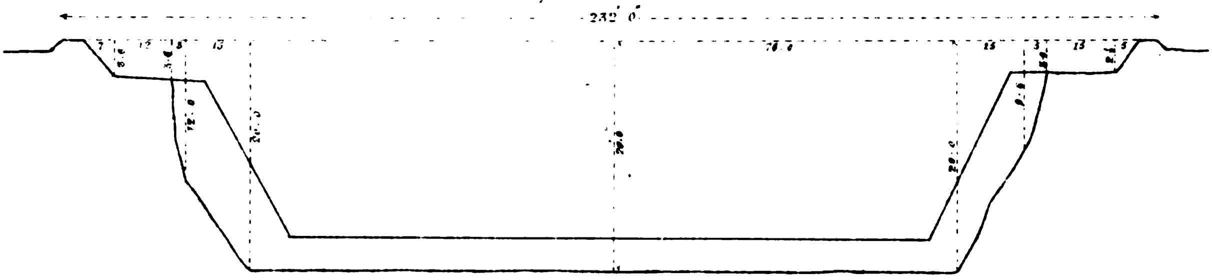
CROSS SECTIONS
OF THE
GANGES CANAL

Scales

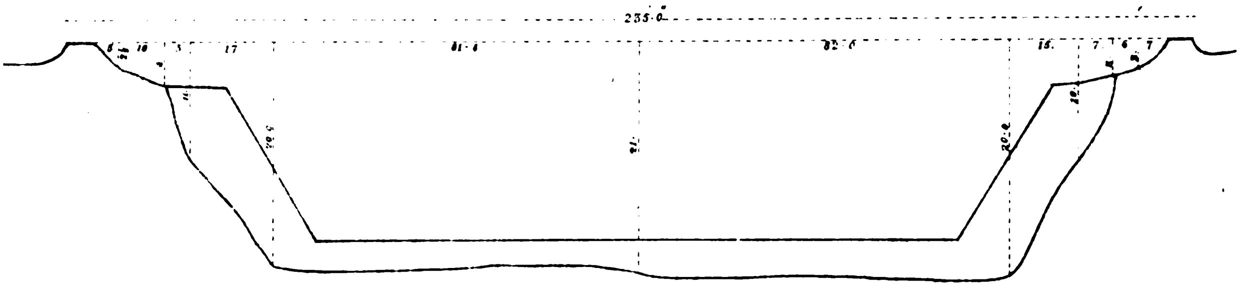
Horizontal = 500 to 1

Vertical = 200 to 1

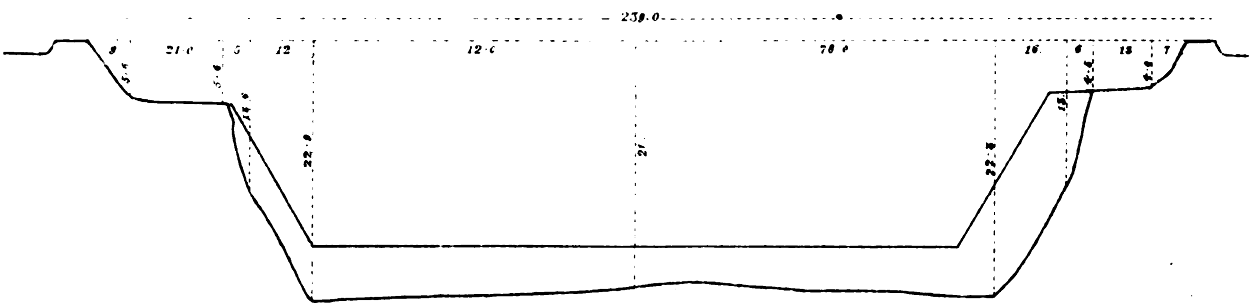
SECTIONS
1800 feet above Belrah Bridge



SECTION
700 feet below Belrah Bridge



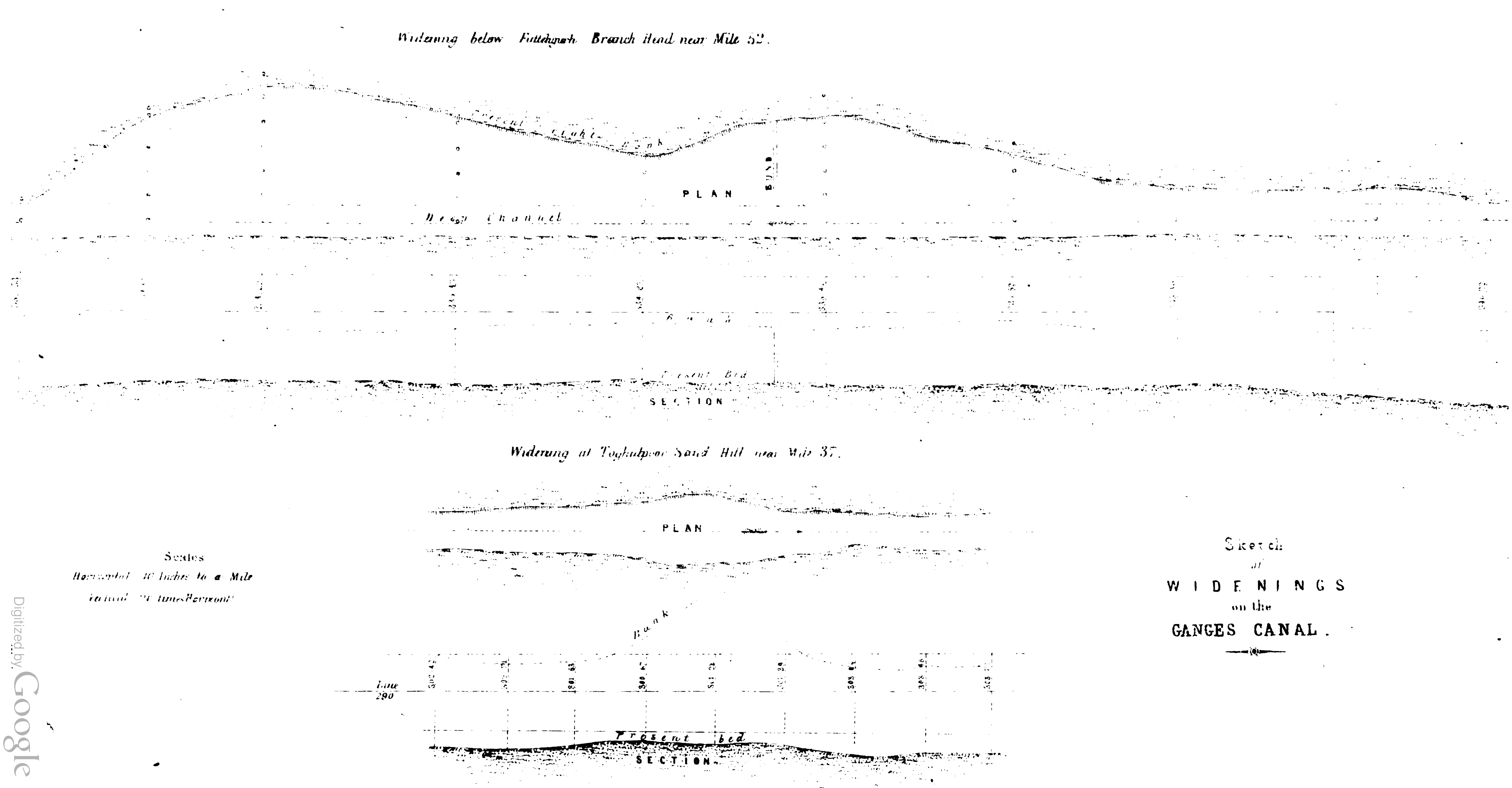
SECTION
560 feet below Jowlee Falls



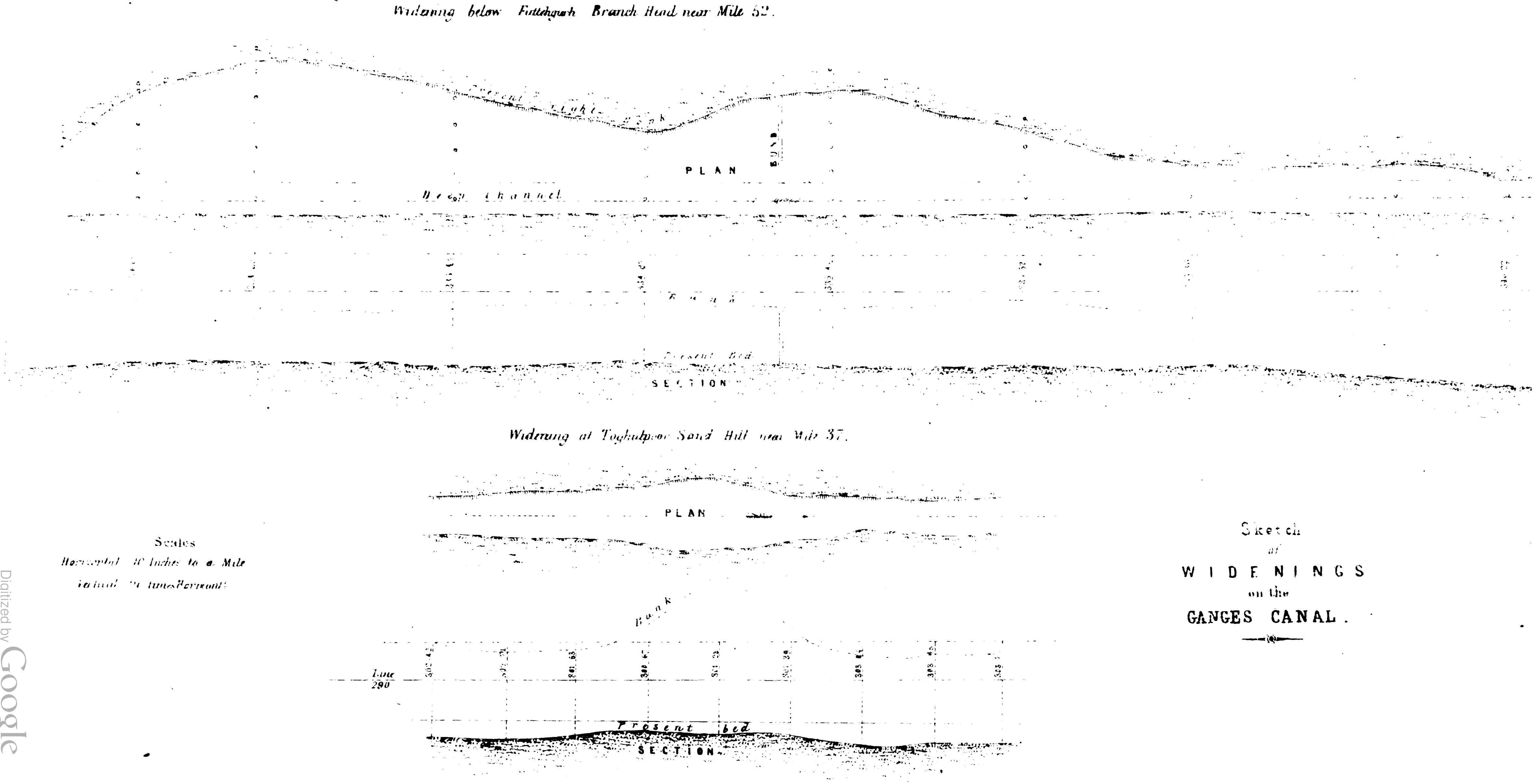
To face page 6 – para. 13.

Digitized by Google

Digitized by Google



Widening below Futtehgurh Branch Head near Mile 52.
Present Right Bank
BUND
PLAN
Deep Channel
Present Bed
SECTION
Widening at Toghulpoor Sand Hill near Mile 37.
PLAN
Bank
Line 290
Present bed
SECTION
Scales
Sketch of WIDENINGS on the GANGES CANAL.



To face Page 6 para 52

Digitized by Google

Digitized by Google

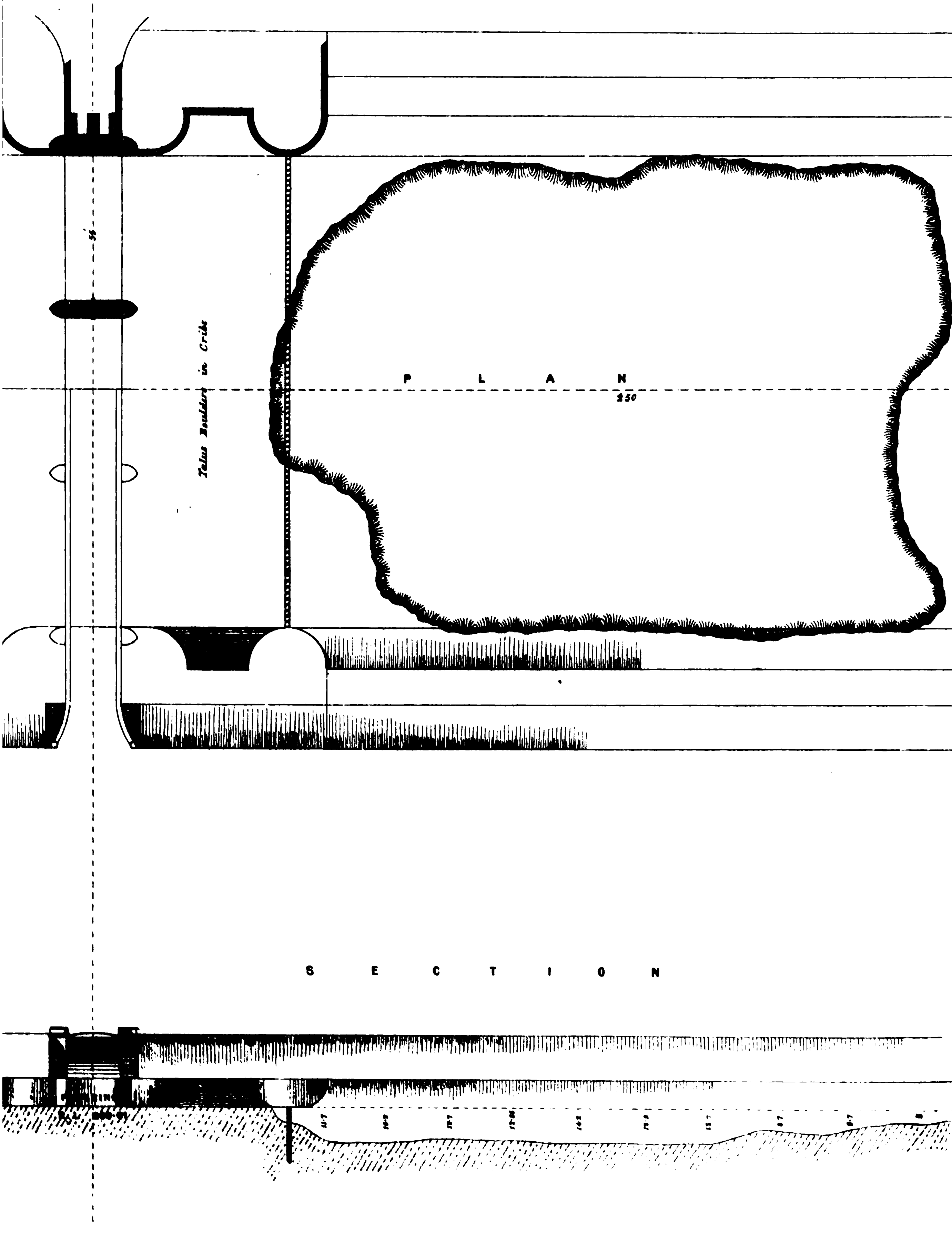
Sketch of

DIMAT BRIDGE

on the

GANGES CANAL

at 34th Mile Main Line.



Scale

50 feet to an inch

to face page -- para 16

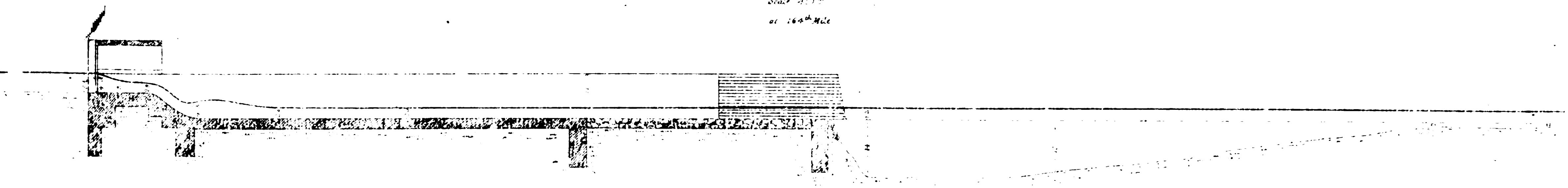
Digitized by Google

Digitized by Google

GANGES CANAL

Scale 1/...th

at 164th Mile



Sketch of

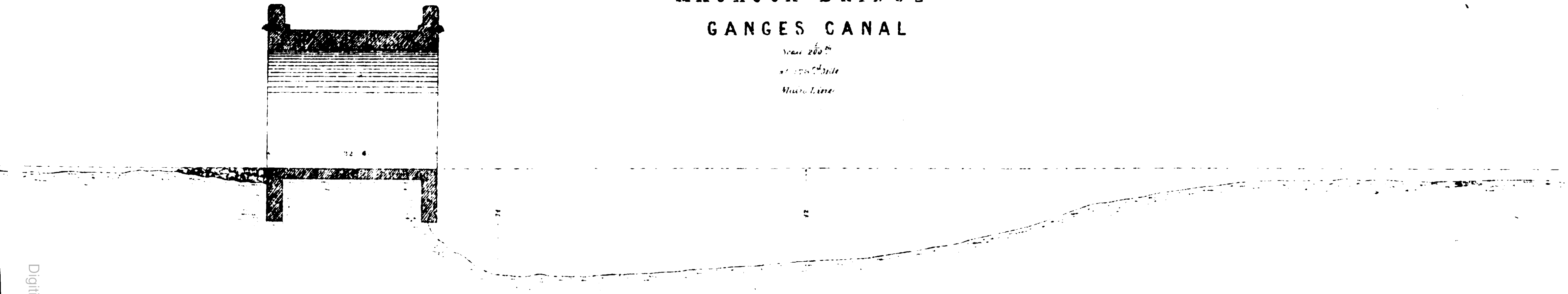
MACHOOA BRIDGE

GANGES CANAL

Scale 1/200th

at ...nd Mile

Main Line



Below the Simra Falls, and especially on the last few miles above the Cawnpore Branch Head, the berm is extensively cut into, in some places swept away quite up to the edge of the road bank.

The excavation on the portion from Roorkee to Sirdhanna as described in Ganges Canal Report (Vol. I, pages 191 and *passim*) trenches uniformly on the substratum of light sand; below this long intervals of firm clay are met with, as shewn in the sections at Newaree and Dumkoura Bridges, and here and there beds of kunkur. The velocity of current has been too great to admit of any silt deposits in the channel from the heads to the Cawnpore and Etawah Branch Regulator at the 181st mile.

Very deep holes have been formed, as the longitudinal section will show, below all the masonry works in the sandy tracts; in some instances, as at the Hafiznuggur Falls and the Bailra Bridge, extending several feet lower than the bottom of the foundations, but, as was observed before with regard to the line on the Ganges Khadir, in no case has this affected the stability of the masonry works; the talus of boulders or kunkur has everywhere proved its efficiency as a means of protection.

The berms or towpaths from Roorkee to the Boolundshuhur Branch Head at the 110th mile were not originally formed at a uniform height above the calculated full supply level of the Canal (Ganges Canal Report, Vol. I, page 240). In some places, as near Khutowlee, the height is much too great for towing. This, and the general condition of disrepair into which they have been suffered to fall from economical motives, makes tracking difficult with human labour, and quite impossible with cattle. Below the Boolundshuhur Branch Head the towpaths are at a uniform height above the bed, but there are the same obstructions as above from the cutting away and ravines in the sides all the way down.

14. The lock channels round the falls have nowhere worked satisfactorily from the constant tendency to silt up; this in the reaches above the locks might be obviated by keeping the lock gates or sluices, when not in use, *constantly* open (or partially so) so as to cause a scour along the channel; but this would affect the working of the mills attached to the locks by lowering the head of water; below the locks silt is deposited with a full supply in the Canal by the action of the backwater; with a low supply the velocity is excessive, causing considerable erosion from both bed and banks; the deepening of the bed of the main Canal has led to another evil with a low supply, by diminishing the depth of water at the extremities of the lock channels; boats are constantly obstructed in the upward passage by grounding at these points. Lock Channel.

15. The three escapes on the upper portion of the line at Khutowlee, Aboo Nulla and Jannee Khoord have, for some time past, been practically useless from the accumulations of silt at their heads; those at Moonda Khera and Kasimpoor work very fairly. Escape Heads.

16. The Bridges are throughout in good order; where erosion seemed to be taking place on the down stream side to Bridges.

Digitized by Google

a dangerous extent the boulder or kunkur protective talus has been supplemented by piling and cribwork across the bed ; no signs of settlement have appeared, nor have the floorings been injured in any way hitherto. The annexed sketches of one or two bridges will sufficiently illustrate the state of matters in these cases.

Branch Heads.

17. At the Regulating Bridges at the bifurcations of the branches, the same difficulties have been experienced in working the sluice machinery as in the case of the Rutmoo Bridge described above ; the width of the gates is inconveniently great for the depth of water to be dammed up; where sleepers are employed a section of eight inches square of salwood is not found sufficient to stand the pressure without bending.

Locks.

18. The locks are generally in fair working order ; the gate and sluice work here and there seems to require some modifications to ensure perfect efficiency : the wooden sluices or stop-cocks for filling and emptying the chambers, the idea of which was taken from the Italian works (Ganges Canal Report, Vol II, page 303) do not answer well with water so loaded with silt, as is always the case more or less in these Canals ; they are constantly getting jammed up, and the silt is with difficulty removed unless the water in the chamber falls below the lower outlet.

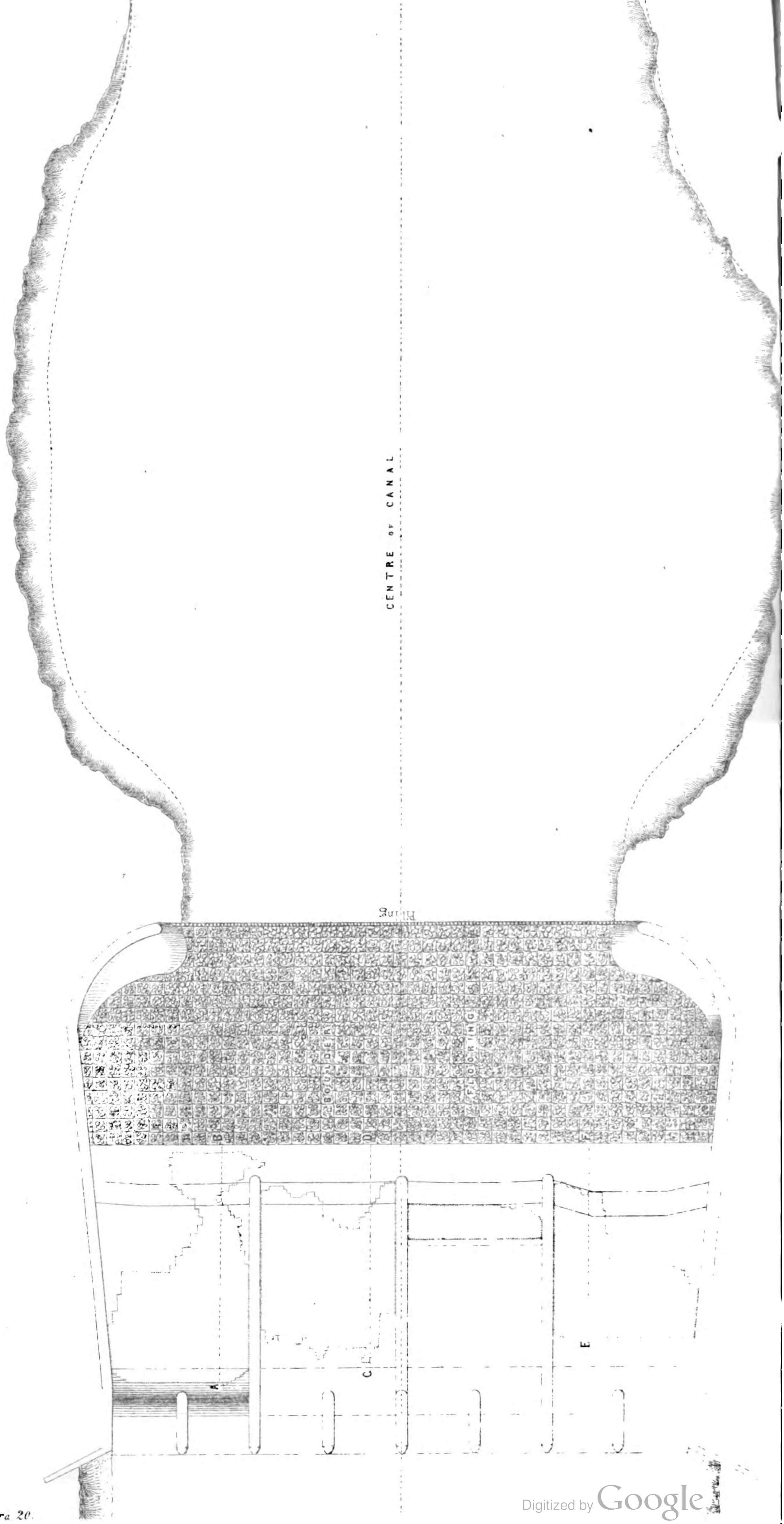
The masonry passages at the heads of the lock channels have been found to be great obstructions to boats entering from the Canal ; their width is the same as that of the lock chambers to which the loading of the boats is consequently very closely adapted ; where the velocity of the boat is very small, as in passing through locks, this is of no consequence, but it is obvious that a much larger margin is necessary where that velocity is considerable, and the direction of the current, as at the entrances of these lock channels, is not in the central line of the stream. In one case, where the left revetment of the passage has been removed, the increased facility of entrance is evident. Boat Bridges across the main channel immediately below these entrances were projected by Sir P. T. Cautley (*vide* Ganges Canal Report, Vol II, page 297) to prevent any risk of boats or rafts being carried down to the falls. Since the heading up of the water there however, by which the acceleration of velocity in the channels above the falls has been neutralised, at least so far up as the entrances to the lock channels, the necessity was considered to have passed away, and their construction has hitherto been held in abeyance. A boat is said once to have been allowed to go over one of the falls, but whether this occurred before or subsequent to the raising of the crests of the falls I know not. That boats can, with perfect safety, be brought down close to the present falls is shewn by the fact of a portion of the material for the repairs of a fall some months ago being thus carried to within 150 or 200 feet of the crest.

Available Headway.

19. The headway at full supply on this portion of the line varied from 12 feet in some of the bridges above Sirdhanna to 5·0 feet under the lock bridge opposite the Pulra falls. Towing paths have been constructed under the left arches of all the bridges from Roorkee to Sirdhanna, the 75th mile (inclusive) ; below this the lowness of the crowns and form of the arches

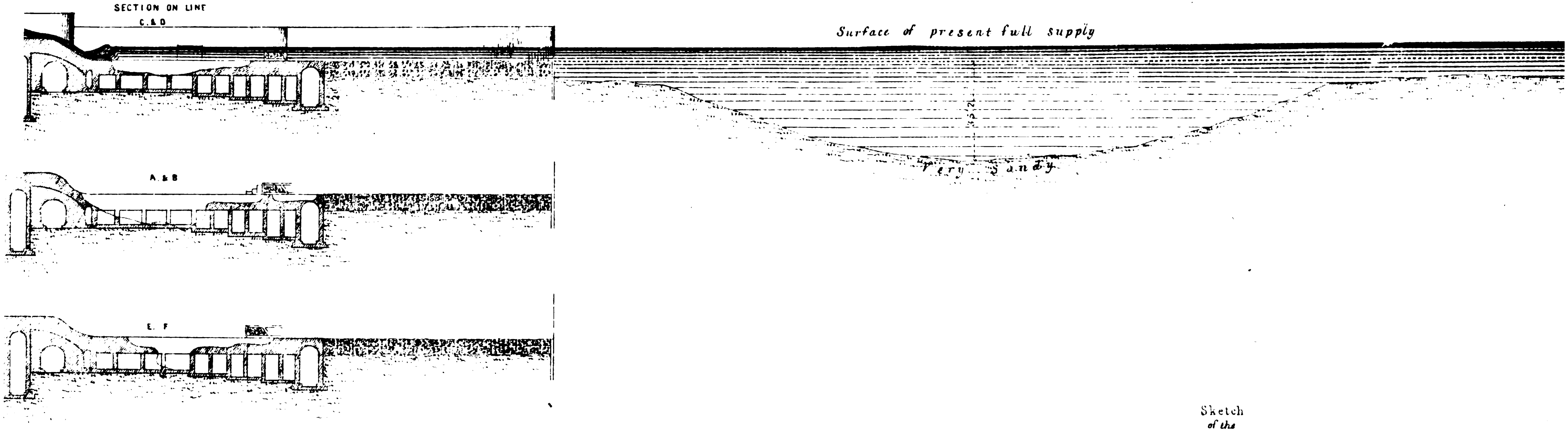
Digitized by Google

Digitized by Google



para 20.

Digitized by Google



Sketch
of the
MUHMOODPOOR FALLS
on the
GANGES CANAL.

Scale 50 F.t to an Inch

Digitized by Google

Digitized by Google

would not admit of it, and the communication along the towing path is kept up as described in the Ganges Canal Report (Vol II, page 319 and *passim*) by flank arches under the roadway behind the abutment. This, if the navigation is to be carried on by tracking, involves the necessity of unhooking the rope from the towing cattle at each Bridge, or at intervals of every two or three miles, often less; whatever arrangements might be adopted for carrying the rope under the Bridge, one of which was suggested by Sir P. T. Cautley in the passage above quoted, the delay thus caused must always be, and is, a great hindrance to free navigation; the inconvenience is still more felt now, no method of passing the rope under any of the Bridges having been yet brought into use.

Overfalls Muhmoodpoor.

20. The falls on this section are ten in number (For their waterways, &c., *vide* Appendix B.) *viz.*:—

1. Hafiznuggur (or Asoffnuggur).
2. Muhmoodpore.
3. Nirgajnee (or Bailra).
4. Jaolee.
5. Chitoura.
6. Sulawur.
7. Bhola.
8. Mussoorie (or Dasna).
9. Pulra.
10. Simra (or Jooeon).

The first seven have suffered injury, more or less severe, in their lower floorings from the action of the water; in one or two cases the brick on edge covering to the ogees was stripped off, but timely repairs and protection saved the evil from spreading. Not to encumber this Report too much with detail, a few general remarks on each, and an account of the present state of and injuries sustained by one, will, I think, answer every purpose. In the annexed diagram is shewn a plan and section of the Muhmoodpoor Fall, where the action of the water appears to have been most violent, and the injuries to masonry and channel most serious. The flooring in all the chambers was more or less extensively ploughed up; in the left chamber the floor, the least thickness of which is 6 feet, was cut quite through, and a hole some 15 feet deep eroded in the sandy substratum; the brickwork under the brick on edge covering was found to be very inferior, some of it so bad as to be dug out without difficulty by a phaorah; the masonry of the ogees was comparatively little injured, owing to its better construction and the less violent action of the water there; in places, however, the floor at the top of the ogees, where the water falls over the temporary weir from a height of 4 or 5 feet, was stripped of its brick on edge covering. These latter injuries were repaired by a fresh coating of brick on edge, covered with planking, to protect the green masonry from the scour of the water. The holes in the flooring were filled up with hard material, on which was laid sound brickwork, sandstone from the Delhi quarries forming the covering over all in the most exposed portions, the rest being faced with brick on edge as before, on which were fastened down bars of wood and iron to secure it from being torn up before the mortar had time to harden

Digitized by Google

properly, as it was necessary to turn the water into the Canal with as little delay as possible after the completion of the repairs; with the view of diminishing the scour over the injured parts, temporary weirs were constructed, as shewn in the diagram, across and close to the extremity of the flooring. These repairs were executed about the close of the year 1862, and have stood, with a few comparatively trifling additions, up to the present date. The hole in the bed below the tail revetments is, as will be seen by a reference to the longitudinal section, somewhat deeper than the lower foundations of the work, though the well foundations were here carried down to a depth of 32 feet below the bed level. With the view of preventing further erosion so close to the work, a temporary weir was thrown across the channel a few hundred feet lower down; this has apparently answered its purpose for the present, though matters are still in a very unsatisfactory state here, as in some of the other falls. The curved terminations to the tail revetments, adopted in this and all the other falls except Nirgajnee, have not fulfilled the projector's expectation (*vide* description in Ganges Canal Report, Vol. II., page 169); they cause apparently violent eddies, by which the bed and banks below are in every case extensively eroded.

Remaining Overfalls.

21. The Hafiznuggur Falls were damaged about the same period similarly to those above described, but to a comparatively trifling extent; the brickwork on the injured floorings was renewed, and the work, at the closure in August last, appeared in fair order. The action of the water here is fully as violent as at Muhmoodpoor, but the masonry is very superior, especially the brick on edge covering. The cutting away of the sides of the channel below the tail walls is more extensive than at any fall except Muhmoodpoor; and the channelling out of the bed appears, from the longitudinal section (Plan IV.) to be the deepest along the whole line.

The Nirgajnee Fall is in better condition than any of the first seven, owing doubtless to the greater depth of back-water on the flooring, which is due to the very trifling extent of channelling down stream, where the bed is on a stratum of clay, and the extra width to which the channel was excavated originally. The terminations of the tail revetments were here formed in a curve outwards, instead of towards the centre of the stream as in the other overfalls, thus forming a large basin, in which the accelerated velocity of the water shot down the ogee fall is destroyed, and the boils and eddies lose themselves.

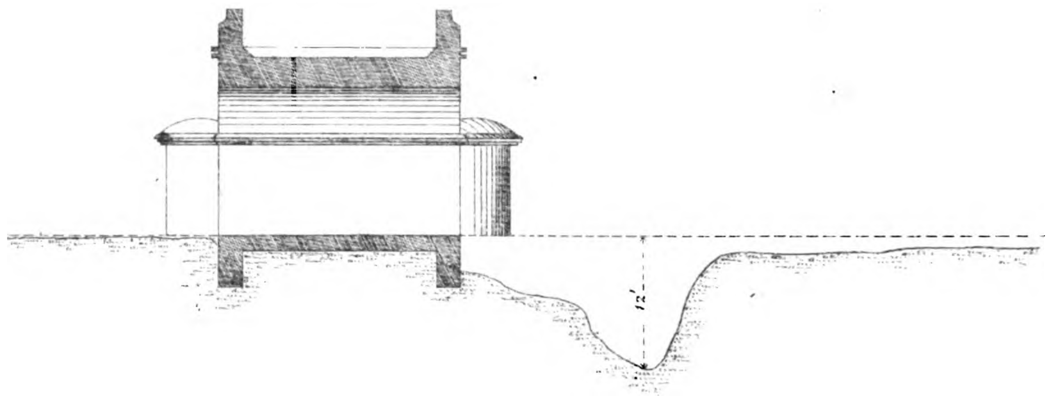
That the back water, and that alone, has been the salvation of this fall is evident, for the brickwork is very inferior, especially that on the ogee curves.

The injuries to the Jaolee Falls were little less serious than to those at Muhmoodpoor, and an additional difficulty presented itself in executing the repairs in the height of the springs above the level of the lower flooring. The brick on edge covering was in places bulged upwards as if blown up from below, and water was seen to spirt through the side walls 3 or 4 feet above the flooring; in making the repairs, small holes were left through the thickness of the floor for the escape of these springs, which has apparently stopped

Digitized by Google

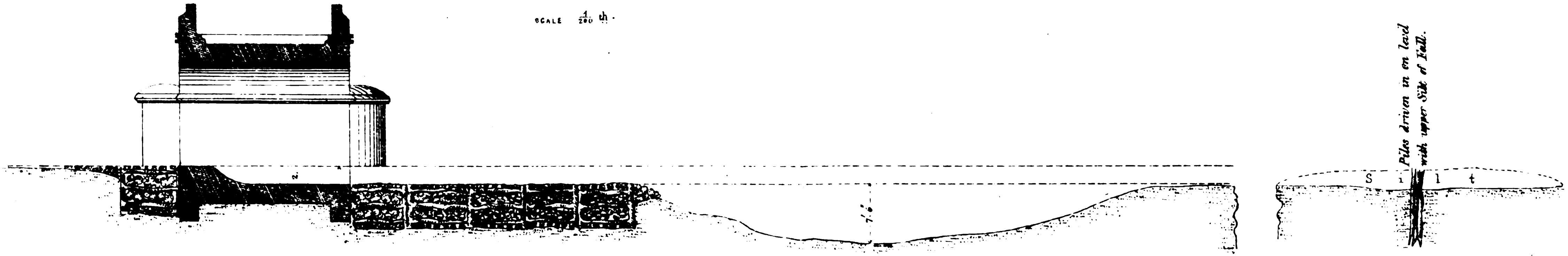
PUTEEKRA BRIDGE ETAWA BRANCH 47th Mile

SCALE 1/200 th.



KEYLUNPOOR BRIDGE CAWNPOOR BRANCH 3rd Mile.

SCALE 1/200 th.



To face page 11. para. 22

Digitized by Google

the tendency to blow up. No issue of water from the side walls was apparent when I saw the work at the commencement of the late closure in August ; shortly afterwards, however, I was informed by the officer in charge, springs showed themselves in the old spots, owing probably to heavy and continued rain. The covering of the injured flooring is for the most part of Delhi sandstone carefully laid, yet, spite of every care in the construction and selection of the stones, blocks weighing from 13 to 15 cwt. were washed out when the water was re-admitted into the Canal last September. This has occurred here as well as at other falls before, and in every instance when the supply of water in the Canal was less than usual.

The Chitowrah Falls seemed to stand fairly until just before the last closure, when the flooring in the left chamber gave way ; and, on the Canal being laid dry, a large hole was found right through the masonry. The old brickwork of this fall is little better than at Muhmoodpoor ; in fact, from Muhmoodpoor to Sulawur inclusive, the falls seem to have been constructed with less care than any other works on the Canal.

The floorings at Sulawur have long been in a damaged state ; in the closure of April 1863, there was not time for completing the repairs, and blocks of stone were thrown in loosely, which, with few exceptions, were found to have remained unmoved when the Canal was again laid dry in August last. From the diminished volume of water to be dealt with here, however, and the better quality of soil in the channel, the injuries do not seem to have extended. A few blocks of stone, as at Jaolee, were displaced at the point of greatest scour, and turned over on the top of the flooring below. This stone covering was relaid last August. The brick on edge covering in this fall was very inferior indeed ; some of the mortar joints on the ogees were so wide as to admit of a hand being passed with ease between the bricks, nor was the mortar even of tolerably fair quality.

At Bhola the injuries to the floorings were never of much consequence ; comparatively trifling repairs have sufficed to keep the works efficient.

The three remaining falls at Mussoorie, Pulra and Simra have remained in good order from the first, owing chiefly to the diminished volume of water passing over them, but also to the better quality of the workmanship.

WORKS ON CAWNPORE BRANCH.

22. The longitudinal section shows erosion in the bed more or less from the head to the 60th mile, but nowhere to any serious extent. Below this, to the Cawnpore lockage, silt is deposited generally ; on many of the bridge floorings to a depth of two feet. The channel here and watercourses are the receptacles for the silt deposits brought down from the upper portion of the Canal ; many of the latter, even at this early period of their existence, are lined for some distance from their heads by large ridges of silt, the result of the Channel.

Digitized by Google

necessarily frequent periodical clearances. A fall constructed in the flooring of the Keylunpoor Bridge about 3 miles from the head, has been the cause of much erosion from bed and banks both above and below. With the view of lessening the evil, weirs were built some time since across the floorings of the three bridges next in order, of heights proportioned to the distances of each and the fall to be overcome, thus distributing the fall over a greater length. This, however, though supplemented by lines of piling at intervals across the bed, has only had the effect of reducing the action of the water at the Keylunpoor Bridge; the velocity of the current is still greater than bed and banks can stand, besides being a great obstruction to the navigation.

The berms or towpaths along a large proportion of the line, especially in the "Oosur" soil, need repairs much if they are to be used for tracking.

Masonry Works.

23. The masonry works throughout are in good condition. The lower chamber of the Cawnpore lockage nearest to the river, for some time subsequent to the completion of the works, gave much trouble, from the difficulty of working hinged gates where silt was constantly being deposited to a considerable depth on the floorings. The adoption of vertical iron drop gates has, however, effectually obviated the difficulty; and for the past year or so there has been no obstruction to the passage of rafts or boats.

Available Headway.

24. The headway at full supply under the bridges on the line varied originally from 7½ to 6 feet. This was considerably diminished at several points on the lower portions by the silt deposits on the bed; as, for instance, at the Bhawunt and Aima Bridges, where the water, I was informed by the late Executive Engineer, Mr. Anderson, has often been known to stand 8 feet above the floorings, thus leaving only 5½ feet clear headway under the arches. The Aima Bridge in particular proved so great an obstruction to the passage of laden boats, that it was lately found necessary to remove the brick arches, and substitute iron girders at a higher elevation.

ETAWAH BRANCH.

25. The declivity of the bed on this Branch was originally projected (*vide* Ganges Canal Report, Vol. II, page 377) at 1 in 4224 (or 1·25 feet per mile) from the head to the 54th mile; below this to the terminal lockage, at 1 in 5280; the superfluous fall in the ground surface being disposed of by an 8 feet overfall at the Nubbeepoor Bridge, mile 154 (*vide* Ganges Canal Report, Vol. II, page 375, and Atlas Plate V). It has been excavated, however, on declivities somewhat greater than these, and the overfall at Nubbeepoor dispensed with, the flooring of the present bridge being 5·5 feet lower than the crest of the projected overfall. The section for the first 51 miles shows trifling erosion in the bed, below which to the end silt is more or less deposited; in some places the depth of the deposit is as much as 2·8 feet. The berms below the Gikror Escape, 57th mile, are in fair order; above that they have been cut

Digitized by Google

into here and there. About five-sixths of the calculated full supply appears to be the maximum which has hitherto been admitted, and this irregularly, alternating week about with the Cawnpore Branch, as the supply in the Main Canal which reaches the Branch Head at Nanoon is seldom sufficient, in the height of the irrigating season, to give their full allowance to both branches simultaneously.

The works (both excavation and masonry) are complete down to the Kerown Escape, 170th mile. The channel has been excavated for three miles further to the head of the terminal lockage, which has been commenced. Irrigation, however, has not yet been much developed below the 119th mile (Devipoora Bridge), and at the Jheenjuck Bridge, 131st mile, ceases entirely.

Holes of considerable depth have been eroded below some of the bridges on the upper portion; but as the bed has not been deepened generally for any length, undermining of the foundations may be effectually prevented by a short talus of kunkur blocks.

26. The obstructions to navigation in absence of tow-paths under bridges, insufficient headway, &c., are similar to those on the Cawnpore Branch.

FUTTEHGURH BRANCH.

Futtehgurh Branch.

27. The works on this Branch have been completed, with the exception of locks, only as far as the 40th mile; below this, as far as the 80th mile opposite Anoopshuhur, works are in progress. All were reported by the Executive Engineer, Mr. Parker, in good order, at the date of the closure of the Canal in August last. The supply of water hitherto admitted being only sufficient for the irrigation down to the 40th mile, none of the works have yet been fully tested. The first 17 miles from the head are excavated in soil similar to that above Sirdhanna on the main line; it is therefore tolerably certain that erosion of bed and banks will take place along this portion when the full supply is admitted.

KOEL AND BOOLUNDSHUHUR BRANCHES.

Boolundshuhur and Koel Branches.

28. Of the two remaining branches originally projected, the Koel has not yet been commenced; the Boolundshuhur has been completed for eleven miles as at first designed, below which it has been divided into two forks, each about 17 miles in length as finished up to date; these forks, however, can hardly be termed Branch Canals; they are rather large rajbuhas or main water-courses.

Cause of defective condition of Channels.

29. Now as to the causes of the defective state of the works on the main line, the primary one has been, and is, undoubtedly the excessive velocity of the current, owing to the original projection of the bed on too great a declivity; and in the earlier period of the

Digitized by Google

Canal's existence, to the absence of means for counteracting the accelerated velocity caused by the undue depression of the surface of the water at the overfalls. The normal mean velocities of the current, where unaffected by overfalls, varied as originally calculated (*vide* Ganges Canal Report, Vol. I, page 243) from 4·04 to 3·53 feet per second. In observations for discharge taken by myself last spring at various points along the line, I found mean velocities varying from 4·7 feet per second below the Myapore Regulating Head to 3 feet at Roorkee; and in the central portions, and even as far down as the head of the Cawnpore and Etawah Branches at the 181st mile, 4 feet and upwards per second (*vide* cross sections at para. 13); and this with only about 2-3rds of the full supply of water in the Canal; these are evidently greater than the soil, more or less sandy, can stand without erosion, and the results are evident in the extensive channelling out of the bed, and, in some parts, widening of the channel. Sir. P. T. Cautley anticipated the occurrence of this channelling to some extent (*vide* Ganges Canal Report, Vol. II, pages 158 and *passim*) and his idea was, that the bridge floorings would "act as retainers of the slopes so that were a retrogression of levels equal to the whole amount of the fall between two bridges to take place, the maximum declivity upon the flooring could not exceed 3·75 feet," these bars being situated at intervals of three miles or less. Bars across the bed at sufficiently short intervals would doubtless prevent erosion, but in this case it is clear that the bridges are too far apart for the purpose. A reference to the longitudinal section (Plate IV), will show that the bed has been channelled out in the sandy tracts on a tolerably uniform declivity, but less than that originally projected, from the foot of one fall to the crest of the next, and that the bridge floorings project from this bed without affecting its general level: the observed consequence of which is that the surface of the stream all along is depressed below its normal level; the velocity of the current is uniform except quite close to the bridges where the raised floorings act as weirs, heading up the water slightly and causing a rush through, which entails in some cases very violent action on the bed immediately down stream. The heading up, which produces accelerated velocity through the arches, is very slight in every case; at some bridges it can hardly be detected by the levelling instrument.

When the Canal was first opened the water was allowed to pass freely over the crests of the overfalls which were laid on the level of the bed of the earthen channel; erosion of bed and sides for some miles up rapidly followed, and it soon became apparent that means must be adopted for raising the surface of the stream at these points; planks were accordingly fixed in the grooves above the bridge arches, or temporary weirs formed, over which the water was allowed to fall; in some cases the surfaee of the water was thus raised considerably above its normal height, causing a backwater in the channel above, as in the reach from the Rutmoo Regulating Bridge to the Hafiznuggur Falls, where the water stands on the three bridges above the Solanee Aque-

Digitized by Google

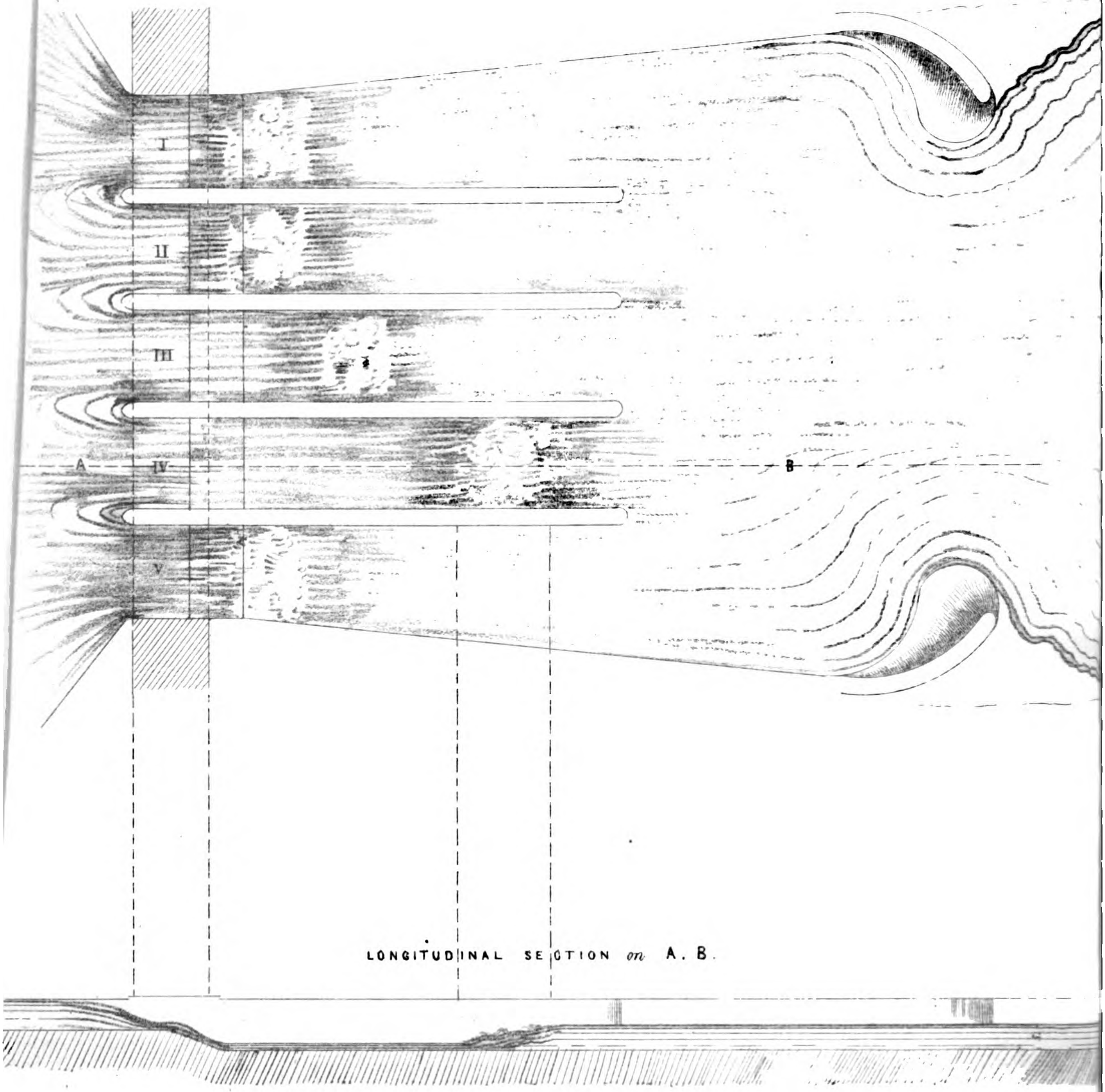
Digitized by Google

SKETCH OF

PULRA FALLS

GANGES CANAL.

Scale 400 to One.



Height of top of planking above crest of Fall

In bay No.	*I*	=	2·5
„	*II*	=	3·0
„	*III*	=	2·4
„	*IV*	=	1·8
„	*V*	=	3·0

Depth of water above upstream cutwaters of Fall = 5·5.

To face page 15 para 31.

Digitized by Google

duct at about 6½ feet at the same time that the guage at Roorkee shows 7 feet, and that above the Hafiznuggur Falls 7·8; this, however, has been beneficial in diminishing the velocity of current due to the excessive declivity of the bed for a considerable distance above the overfalls. The widening of channel immediately below the falls is obviously due to the accelerated velocity there from the shoot over the ogees and deficiency of backwater.

Of Channel from Myapoor to Ranipoor.

30. The bed between the Myapoor Regulator and the Khunkul Bridge was projected on a declivity of 1 in 2640 (or 2 feet per mile), the velocity due to which has not yet caused any serious erosion in the stiff soil there. Below Khunkul Bridge and onwards to the Ranipoor super-passage the soil is more or less light and sandy, and though the declivity of bed was here reduced to 1 in 3403 (or about 1½ feet per mile) the velocity of the current is so accelerated by the stream from above the Khunkul Bridge that bed and banks have been and are still being extensively cut into.

Deficiency of backwater on floorings.

31. The deficiency of backwater, caused by the general depression of the surface of the stream below, on the floorings of the overfalls, has evidently been one, if not *the* chief cause of their failure; the injuries have generally been observed to take place with a low supply in the Canal; in other words, when the depth of the backwater on the fall floorings was less than usual; and in a report dated 18th of last month (September) from Lieutenant Forbes, the Superintendent of the Northern Division of the Canal, he states that "in each of the instances in which damage has occurred to the Jaolee Falls, it has invariably happened when the supply in the Canal on the Roorkee gauge has been reduced to 5½ feet or less; when the Canal was opened on the 27th ultimo, the supply was kept up to 7 feet, it was then lowered to 6 feet, and eventually to 5½ feet, and within three or four days (I write from memory) the damage took place." The Nirgajnee Fall, it has been noted above in para. 21, is in better condition than any of the others in the sandy tract below Roorkee, though the brickwork is no better than in those which have been seriously damaged, the only difference observable in their condition being the greater depth of the backwater on the Nirgajnee flooring. The ploughing up of these floors has, with few exceptions, been observed to commence at the point of greatest scour, or meeting place of the backwater with the stream shot off the ogee curve; the shoot or scouring has undoubtedly been lessened by raising the crests of the Falls, though increased action has thereby been brought on the floors above the ogee curves; the few instances in which injuries to the masonry have resulted from this have, however, been easily repaired, and further extension prevented by a covering of wood or similar material.

To illustrate the effect of the raising of the crests in altering the velocity and direction of the falling water, and thus lessening the extent of scour on the floorings, a sketch of the Pulra Falls is annexed, showing, from actual measure-

Digitized by Google

ments, the positions of the meeting points of the backwater and shoot from the fall in each bay, with the depths of both measured by myself. The length of the scour, it will be observed, is in inverse proportion to the height of raising of the crests.

Accelerated velocity at branch heads.

32. Another cause of accelerated velocity which has, however, as yet been observable only above and below the Cawnpore Branch Head, is the difference of the normal depth of water in the channels above and below the bifurcations of the Branches.

For instance, at the Nanoon Regulating Bridge, the depth in the main channel up stream at full supply would by calculation be 8 feet, while that in the Cawnpore Branch immediately below the Bridge would be 6 feet, which, as the bed of the latter is formed on a continuous declivity with the main Canal, gives a fall in the surface at that point of 2 feet.

To neutralize this no provision has been made in the construction of the Bridge, and to it must be attributed, in great measure, the extensive erosion of the bed and banks for a considerable distance above and below, though the 2 feet fall at the Keylunpoor Bridge on the Cawnpore Branch has also had its share in producing the evil.

Covering material of floorings.

33. The use of stone or other similar hard material, in the first instance, as a covering for the brickwork would, in all probability, have preserved the fall floorings from injury, but the outlay for such a purpose at the time of the construction of the works, when land carriage alone was available, and the distances from which any material of the kind was procurable were long, would have been enormous, greater than the projector considered himself justified in incurring, especially when he had had long experience of *good* brickwork having lasted well in similar circumstances elsewhere.

To show what brick on edge facing will stand if of first-rate material and workmanship; at the Ghoona Falls, on the Eastern Jumna Canal, where the depth of fall is 8 feet, I found the velocity of the current on the lower flooring below the ogee curve to be 15 feet per second, and at the Belka Falls on the same Canal where the drop is 15 feet in two descents, one over an ogee curve, the other immediately in advance down an inclined plane, the velocity at the foot of the latter was found by the Superintendent, Lieut. Moncrieff, to be not less than 20 feet per second.

Now the maximum velocity on the flooring of the Muhmoodpoor Falls described above, calculated from the discharge in the channel at Roorkee and the observed depth on the flooring of the fall, cannot exceed 14 feet per second. It is clear from this, I think, that inferior workmanship and material have had a large share in the causes of injury to these falls. The greater quantity of silt in the Ganges Canal water will also account, in some measure, for the difference in the wearing qualities of the works on the two Canals.

Digitized by Google

The action of the springs at the Jaolee Falls might, perhaps, have been obviated by a layer of puddle under the masonry of the flooring.

The above remarks will, I trust, explain with sufficient clearness the nature of the defects which impair the efficiency of the Canal as an irrigating conduit; others there are, but they are solely connected with its navigable capabilities.

Headway under Bridges insufficient.

34. The headway under the Bridges available for the "through" traffic is limited, it will be observed from the description of the works before given, to 5, or at most $5\frac{1}{2}$ feet, by the state of some of the bridges on the Cawnpore Branch. Six feet appears to have been considered the minimum limit in the construction of the works generally (*vide* Ganges Canal Report, Vol. II, page 73), but even this subsequent experience has proved to be too little.

The absence of towing-paths *under all the bridge* arches below Sirdhanna, the 75th mile on the main line, has been another source of great obstruction, as well as the irregularity of height of the towpaths or earthen berms along the line from Roorkee to the Boolundshuhur Branch Head at the 110th mile. These last, I understand from Sir P. T. Cautley, were to have been cut down to a uniform level as time and opportunity permitted, but from motives of economy, this, as well as repairs to the existing berms the whole way from the Heads to the Cawnpore Terminus, has hitherto been held in abeyance.

35. I omitted above to mention that the erosive action was much greater some three years ago, from the larger volume of water then allowed to pass down for the relief of the parched districts, during the late terrible famine. By observations taken in the beginning of 1861 by Mr. Login, then the Superintendent of the Northern Division, and his Assistant Mr. Hair, the discharge immediately below the Myapoor Regulating Bridge amounted to 6,710 cubic feet per second, while the volume obtained by me, at the same place last spring, with the water standing at the maximum height allowed during the past two years or thereabouts, was only 4,813 cubic feet per second. The channelling out of the bed was then, in consequence, deeper than it is now. The longitudinal section does not shew the full depth to which the evil at one time extended, the bed having silted up latterly to some extent, owing to the reduced velocity generally. It has also been observed, that silt is more or less deposited in the few days previous to the closure of the Canal, when the supply is being gradually reduced.

Reduction of velocity the only permanent remedy.

36. The unanimous opinion of the Committee of Engineer Officers assembled in January last, to consider the question was, it will be seen from their Memorandum (Appendix A), that it is hopeless to expect a permanent rectification of the evils above enumerated without a reduction of the velocity of the current—the primary cause of those evils—to one which the soil will stand without erosion. Nor do I suppose their judgment will be questioned by any one acquainted with the present condition of the Canal.

Digitized by Google

The erosion would not so much affect the stability of the works were it confined merely to holes in the bed immediately below; a talus of hard material will, in every case as shewn by the facts, transfer the erosive action to a safe distance from the floorings; it is the channelling out of the bed on long lines which produces the *dangerous* action. Attempts have been made at various times to arrest this by driving lines of stakes at intervals across the bed, their tops cut off level with the original bed, but they have hitherto failed to effect the object in view, and the similar temporary expedients adopted below the floorings of the falls and bridges where undermining was apprehended, require constant and anxious care to keep them efficient.

The reduction of the velocity necessary to the efficiency of the Canal simply as a water carrying channel, will also facilitate navigation, which is now much obstructed by the excessive velocity at certain points on the main channel. In the Cawnpore Branch, except for the few miles near the Head, no complaints have been made on this score.

Another improvement of no slight importance which will undoubtedly result from this reduction of velocity is the diminution of the silt now carried down in such enormous quantities to the lower districts of the Canal. That this is chiefly, if not entirely, due to erosion from the banks and bed above, is evident from the fact that the water for seven or eight months in the year when the largest supply is required for irrigation, enters from the Ganges at the Heads clear as crystal; by the time it reaches Roorkee, the extremity of the Ganges Valley, it has assumed a leaden colour; from Roorkee downwards it gradually becomes thicker and thicker, the colour changing to that of pea soup as it passes through the light sandy soil, nor does it appear to part with much of the matter thus taken up till it has advanced some miles down the Cawnpore and Etawah Branches.

The Futtehgurh Branch, for the first 17 miles, will, I have before observed, require some alteration to admit of the full supply being safely passed down; with this exception, remedial measures (affecting the Canal as an irrigating conduit) are necessary only on the main line from the Heads to the bifurcation below Allyghur, a distance of 181 miles.

Proposals for rectification.

37. Supposing the volume of water in the Canal to remain as projected the reduction of velocity can be effected only by diminishing the declivity of the bed, or increasing the width of channel section, or by a combination of both. Above Roorkee (the 19th mile) from the difficult nature of the country and the magnitude of the works remedial measures must obviously be confined to the existing channel; below that point two courses are open, one to continue the remodelling down to the Allyghur (or Nanoon) bifurcation; the other, (suggested by Sir P. T. Cautley) to divide the supply by carrying a new channel to the westward on the water-shed between the Hindun and West Kalee Nuddee Rivers, which should rejoin the present line at some suitable point lower down its course. Sir P. T.

Digitized by Google

Cautley proposed that this alternative channel should have a capacity of 3,000 cubic feet per second, leaving 3,750 cubic feet per second (the full supply passing the Solanee Aqueduct being 6,750 cubic feet per second) to be conveyed by the present line. Another proposition was subsequently made by Colonel Strachey to carry the alternative line across the present channel above Meerut leading it into the Futtehgurh Branch, whence it would issue lower down and rejoin the present channel above Nanoon. The principle of both, however, is the same, *i. e.*, division of the supply.

It will be shewn hereafter that the present channel at Roorkee can safely carry only 1,870 cubic feet per second; if this be much exceeded, and certainly with a supply of 3,750 cubic feet per second, it would be necessary to reduce the declivity of the bed, and the number of overfalls required in consequence would be nearly the same as in remodelling the channel for the full supply, though the height of each would be less.

Now, as the main difficulty and expense of the construction of such works with a running Canal are in the laying of the foundations, it appears to me unadvisable, on the score of economy, to attempt any remodelling of the existing line involving a reduction of declivity of bed, short of enabling it safely to carry the entire supply; any necessary repairs to the present bed and works can be easily effected by closing the Canal for a month or so at a time without injury to the irrigation.

The two projects, then, to be worked out are:—

1st. The remodelling of the existing line to enable it to carry the full supply.

2nd. The remodelling of the line above Roorkee, and the construction below that of an alternative line, of sufficient capacity to convey the difference of volume between the full supply and that which the existing line can safely carry without alteration of declivity, with the repairs and additions necessary to the latter.

Sir Proby Cautley's views are given in detail in the copy of his memo. dated 8th April, attached to Appendix A.

Before touching on the relative merits or demerits of either, I think it will be best to give the detail of each as now submitted. Provision has been made in both for uninterrupted navigation from the Heads to the Cawnpore Terminus, the cost of which is shewn separately in the abstracts to the estimates.

38. The first point to be determined was the velocity of current which the soil will stand. This has been fixed, from actual observations, given in detail in Appendix D, at 2·5 feet per second for the worst soil we have to deal with, such as the Toghulpoor sand hills at the 37th mile; at 2·7 for sandy soil generally; and at 3 feet per second for soil such as is met with below Sirdhanna. Now, in laying down these data as the safe velocities with a full supply, it is not intended to assert that no erosion will take place anywhere, but that the extent will, under any circumstances, be trifling, and

Velocities of current recommended.

Digitized by Google

with a diminished supply, silt will, to a certain extent, be deposited. Perfect freedom from the latter evil can never be expected ; the alternate rising and falling of the supply in the Canal will always cause abrasion of banks more or less ; besides which, the water from the Ganges entering at the Heads during the rainy months is never entirely free from silt.

Best form of Overfall.

39. The best form of overfall is the next point to be considered.

The objects to be kept in view in any design for such works are, I conceive—

1st. To disturb the normal condition of the stream, both above and below the fall, as little as possible.

2nd. To reduce the increased action of the falling water on the masonry works to a minimum.

The first object will be attained by maintaining the depth of the water on the crest of the fall, or close to it, the same as in the channel above, where the velocity of current is " in train " or uniform ; and by so deadening the accelerated velocity immediately at the foot of the fall, that the water should issue from the masonry work with the normal velocity in the channel below.

Now the only means of maintaining a constant depth above the fall, or the declivity of the water surface up to the fall uniform, is by contracting the waterway at that point. This may be done from above, from the bed, or from the sides. The first would cause an excessive scour on the bed close to the fall, and is otherwise objectionable ; the second is the method adopted on the Ganges Canal, by raising the crests of the falls ; and the third by narrowing the width of the crest, which was proposed some time since, and a design submitted, for the Futtehgurh Branch Falls, by Mr. J. Parker, the Superintendent of that Division of the Canal. All these constructions have, I believe, been previously in use elsewhere ; but the most efficient we know of yet is a modification of the last described, designed by Captain Dyas, the projector of the Baree Doab Canal Works in the Punjaub (now Chief Engineer of Irrigation in the North-Western Provinces), in which the water falls through an inclined grating similar to the teeth of a comb, a full description of which will be found in the copy of his memo. (Appendix E). By regulating the spaces between the bars of the grating, the water can be kept at any required height, and the velocity of the water in the channel above is maintained sensibly uniform till within a few feet of the fall ; its greatest advantages, however, lie in the division of the water into thin films, and the extension of the space over which it falls, thus materially diminishing the action at the foot of the fall.

As to the form to be given to the actual overfall, much difference of opinion has existed. Sir P. T. Cautley has given his views on the question, and reasons for preferring the ogee curve to either an inclined plane or a vertical drop in the Ganges Canal Report (Vol. II, page 159). Subsequent experience, however, has shewn clearly the superiority of the

Digitized by Google

latter. The scour of water, especially when loaded with silt, over an ogee curve or an inclined plane, must inevitably, in the course of time, wear out the hardest material, besides the evil effects of the accelerated velocity for a considerable distance in the channel below in the erosion of the bed and banks, which is well exemplified in the case of the Muhmoodpoor Falls (*vide* diagram at para. 20.)

On the Eastern Jumna Canal, it is true, the falls of this form have acted efficiently for many years ; but spite of the best of workmanship, and the comparatively small body of water passing over them, repairs more or less are periodically necessary. On the Baree Doab Canal in the Punjaub, all our falls with one exception were built with a vertical drop ; and this, constructed on the general design of the Ganges Canal Falls, is the only one which has been a source of constant trouble from the first. A vertical drop fall, with a cistern of sufficient width at the foot, is undoubtedly the best form, by giving a wide and deep basin for the backwater, in which the falling water may expend its violent action before issuing from the masonry work. It also effects a second desideratum in diminishing the impact of the falling water on the masonry.

The action of water falling thus has been compared to that of a pile being driven close to masonry, which is felt to vibrate with every blow of the ram. This is not, however, a fair comparison ; the actual result being analogous to the impact of one elastic body in motion on another at rest, in which the moving body loses a considerable portion of its velocity, the other acting as a cushion or buffer. What the depth or surface area of the lower water should be to protect the masonry from all injurious action we have no data yet to determine accurately ; but from Captain Dyas's memorandum, above referred to, it will be seen that the dimensions adopted in his works have answered with the supply of water hitherto flowing in the Baree Doab Canal.

It is clear that, in a vertical fall with a "grating," the action below must be much less than in either a "weir" fall, or one in which the water passes through a single contracted opening ; the form possesses also the additional advantage, incalculable in a navigable channel, of preventing any acceleration of the surface velocity, further than a few feet from the actual crest of the fall. The size of the basin below must be the same for all.

Headway necessary for navigation.

40. The headway for navigation under the bridges has been fixed at a minimum of 10 feet for the following reasons :—I found, by enquiry among the boatmen on the Ganges at Cawnpore, and measurements on their boats, that the highest load above the gunwale they carry even on the river is limited to three bales of cotton laid one over the other, the thickness of a bale of unpressed cotton being $2\frac{3}{4}$ feet generally ; this would give a clear height of $8\frac{1}{4}$ feet, and if the deck or gunwale of the boat when laden be 1 foot above the water surface the total height should be $9\frac{1}{4}$ feet. Ten feet, therefore, appears ample for every purpose, and this would admit of the passage of small steamers and passenger boats.

Digitized by Google

On English navigable canals the height allowed is generally from 10 to 11 feet.

Dimensions of locks.

41. The proper dimensions, especially the width, to be given to the lock chambers were not so easily determined. With the boats at present in use on the Canal, varying in width up to 12 feet, unpressed cotton, the most bulky material hitherto carried, is loaded on the deck or gunwale to a width of 15 feet, or three bales, each bale being about 5 feet in length; the present locks being 16 feet wide, this passes easily.

If large and powerful steamers are to be employed, 16 feet is not sufficient. Judging from Canal works in America and elsewhere, nothing under 20 or even 25 feet will answer; yet screw steamers navigate the Forth and Clyde Canal throughout, where the width of the locks is only 15 feet. Small steamers, and tracking by men or cattle, seem to me most suitable to the present condition and habits of the natives of the country; and as the navigation will be carried on chiefly, if not entirely, by them, I have retained Sir P. Cautley's width of lock as sufficient for all purposes. These two last points, however, are open to discussion.

Separate lock channels not advisable, and why.

42. Separate lock channels round the falls have been avoided, except in one or two instances, throughout the projects now submitted, from their unavoidable tendency to silt, especially in the lower reaches. With a velocity in the channel maintained uniform up to the fall crest, and gratings or other protection, there can be no risk in attaching the lock chamber to the side of the fall, and the construction is much less expensive.

General measures recommended for remodelling present line.

43. The measures, then, recommended for remodelling the existing line are generally as follows:—

1. Reduction of the declivity of bed, and increase to the sectional area of channel.

2. Construction of new overfalls, with vertical drop and gratings.

3. Alteration to existing falls; making the drop vertical, and attaching gratings.

4. Raising bridges, &c., wherever the headway is insufficient.

5. Constructing towpaths under the left arches of all bridges now without them.

6. Repairing the berms throughout.

7. New sluice apparatus at all Regulating Bridges, and means of counteracting the effect of difference of surface level above and below. The main difficulty in projecting the alterations has been to utilize existing works to the utmost extent, each bridge and fall requiring separate consideration; the new levels of the bed have been adjusted chiefly with reference to the depth of the bridge foundations. Whatever is deficient in the following details will, I think, be found in the Tabular Statement (Appendix B.)

Volume of water to be provided for and its distribution.

44. The volume of water to be provided for and its distribution has been assumed as originally determined by Sir P. T. Cautley (*vide* annexed Statement), with the addition above

Digitized by Google

Distribution of Water in Original Project for Ganges Canal.

Localities.	Position in Miles from Head.		Length in Miles.			Discharge C. Ft. p. Second.				Remarks.
	From.	To.	Total.	Irrigating.	Non-irrigating.	Allowance per mile.	Expenditure.	Required capacity.	Actual capacity.	
Main Line.—Heads to Futtehgurh Branch Head...	0	50·5	50·5	23·0	27·5	8·0	330	6750		Rajbuha outlets confined to overfalls.
" Thence to Boolundshuhur Branch Head...	50·5	110·3	59·8	59·8	...		330	5180		
" Thence to Koel Branch Head..	110·3	152·0	41·7	41·7	...	8·0	328	4330		
" Thence to Nanoon Branch Head	152·0	180·9	28·9	28·9	...	8·0	232	3482		
Cawnpore Branch	0	170·0	170	170	...	8·0	1360	1610		50 c. ft. reserved for navigation between Eesun and Rinde. 200 c. ft. for navigation.
Etawah Branch	0	180·0	180	180	...	8·0	1440	1640		200 c. ft. reserved for navigation.
Futtehgurh Branch	0	155·0	155	155	...	8·0	1240	1240		
Boolundshuhur Branch	0	65·0	65	65	...	8·0	520	520		
Koel Branch	0	65·0	65	65	...	8·0	520	520		

Digitized by Google

the Rutmoo of the approximate expenditure in irrigation and loss by absorption on the line between that and the Heads. This, according to Mr. Login's experiments above quoted, amounts to 430 cubic feet per second; and my own observations taken last spring give about the same proportion. The maximum discharge at Myapoor should therefore be 6750 + 430 = 7180 cubic feet per second. Between the Rutmoo and Roorkee the absorption must be very inconsiderable; irrigation there is none, and the capacity of the Solanee Aqueduct is an absolute limit to the supply at that point; the full supply of the original project, 6750 cubic feet per second is (*vide* Appendix B.) the maximum which can pass there. The actual expenditure for irrigation in the sandy tracts below Roorkee is much above that originally allotted being upwards of 800 cubic feet by Mr. Login's observations (instead of 330 cubic feet); the total approximate diminution in the 30 miles to the Futtehgurh Branch Head being 1004 cubic feet per second. My own experiments give a somewhat less result; they were not, however, very satisfactory, as I could not obtain the discharge at the lower extremity with the rajbuha heads closed above, the Canal not being considered in a fit state to carry the additional supply with safety. The abnormal rate of diminution of supply on this portion of the line will not, however, I think, affect the quantity originally calculated on as available for the lower districts. When the soil of the irrigated districts becomes fully saturated, a very small supply will be sufficient to maintain the saturation; and the allowance of water for irrigation can be regulated by periodical closures of the watercourses. as has long been customary on the older Canals in these Provinces.

REMODELLING FROM MYAPOOR TO ROORKEE.

Alterations in Channel. 45. The present waterway of the bridges, 165 feet, has been taken as the limiting width of the cross section of the earthen channel except in the reach from the Rutmoo to the Roorkee Bridge, where the available area between the ghât revetments on the Solanee valley embankment has been taken as the basis of calculation.

The reach above the Khunkul Bridge has been left in *statu quo*. The calculated velocity at full supply will be about 5 feet per second, which the stiff soil there will apparently stand; below this, and on to Roorkee, the safe velocity has been assumed at a little over 3 feet per second, which I found to be the maximum in the present channel, where the bed and banks appeared to stand fairly.

From the crest of the Ranipoor Falls the bed will be carried backward on the new declivity of 1 in 8,500, producing a drop at the Khunkul Bridge of 3·07 feet. The depth of water in this reach being 13 feet, while that above the bridge is 9 feet, the surface at full supply of the lower water will meet that above a considerable distance above the drop. The backwater being thus ample, it does not appear necessary to construct a fall here. Provision is made under the arches of the present bridge to prevent undue acceleration of velocity in the channel below.

Digitized by Google

The alterations in channel down to the Puttree Works need no remark.

From the flooring of the Roorkee Bridge upwards, the new bed is projected on a declivity of 1 in 9000, which produces a drop at the Rutmoo Works of 3·64 feet; at the Puttree, 6·06 feet below the floorings. The level of the floorings of the Rutmoo Works, it is evident, cannot be altered. The surface of the water at full supply would therefore stand here (12·8—3·64=) 9·16 feet above those floorings. Now, as the width between the revetments *above* the Regulating Bridge is 236 feet, the velocity of current here cannot exceed ($\frac{6800}{236 \times 9 \cdot 16}$ =) 3·145 feet per second, almost identical (*vide* Tabular Statement) with the calculated velocity in the channel below.

It has been stated before (para. 13) that, wherever an abnormal widening of the Canal channel has taken place, the bed is at a higher level there than either above or below. In these places the current has formed its own channel, the declivity of the surface of the water remaining uniform. This being the observed result of natural operations, it seems to me clear that, in projecting the levels of an artificial channel for a uniform velocity of current, wherever abnormal widening is necessary, there the bed should not be formed on the usual level, but be raised to such a height that the areas of water section in the ordinary channel and the widened portions should nearly correspond, or rather that the velocity of current through either should remain uniform. The bed between the Puttree and the Rutmoo, it will be seen from the section, has already been channelled out to nearly the full extent required for this alteration; and as the declivity of the surface of the water through the Regulating Bridge will remain unaltered, the action there will be inconsiderable; a talus of boulder work will answer every purpose of protection. Two other incidental advantages of no slight importance may be mentioned here:—The water at full supply will stand below the tops of the piers of the Rutmoo Dams, now ten feet above the flooring; and the headway under the lock passage at the Puttree at full supply will be 8·4 feet instead of 2-34, as it would be with 13 feet of water on the flooring there.

Though the channel through the stiff soil of the Peeran Kulliar Bridge is apparently proof against the effects of a higher velocity than that calculated in the remodelling; and though the bed of the Solanee embankment might be protected, as Sir P. T. Cautley at first proposed, by a layer of boulders,—the velocity which would obtain at full supply, 4·091 feet per second, with the present declivity of bed, appears to me hazardous. I have therefore preferred to reduce it to the normal limit. Protective measures to the bed and banks will thus also be unnecessary.

The estimate provides for the widening and deepening of the present channel, and the repair of the towpath on the left, or tracking bank, as well as cutting it down where necessary to a constant level of 2 feet or thereabouts above the calculated full supply level.

46. The navigation is provided for, in addition to alterations at some of the bridges, by a new lock channel — Lockage from Khunkul to Puttree.

Digitized by Google

[illegible]

Myapoor Regulator. [illegible] which will be [illegible] backwater [illegible] 4 feet [illegible] shown in the plan [illegible] navigation, the new apparatus for [illegible] consisting of iron [illegible] gates [illegible] shown in the plan worked by windlasses from above. [illegible] gates of this form and material have been adopted at the lower end of the [illegible] Terminal and have been found to work well. [illegible] will be of wood worked each by a separate windlass from the roadway above.

Other methods of working these shutters have been suggested, some of which have been in use elsewhere; the windlass however is at once the simplest and least liable to get out of order. I have therefore retained it in all these designs. [illegible] of different dimensions and strength, will not [illegible] other apparatus for a similar purpose.

[illegible] Bridge and Lock. 43. Plate 2 of the masonry works shows the proposed alterations at the [illegible] Bridge.

The masonry tongues will be removed here as well as in every other masonry bridge on the line to give as great a width of waterway as possible through the arches. The floor to be lowered to the new level of the bed down stream leaving 4 feet in width at the up stream side; the width of each arch to be divided into four parts by masonry piers, which will serve as supports to the wooden girders on which the grating bars rest. The masonry standing up above the surface of the lower water level here will not exceed (approximately) one foot, so that, with such a depth of backwater, no further protection to the bed below seems necessary than relaying

Digitized by Google

the talus of boulders. The waterwings and ghâts must be raised slightly to suit the increased height of water.

A separate lock channel (Sheet 3), for the reasons given before, has been projected on the left bank ; the lock chamber situated at the junction with the Canal below the bridge to allow of a scour throughout ; a bridge will be required in prolongation of the present one over the Canal ; the channel, to save excavation, is designed with boulder masonry revetments on both sides.

Puttree and Ranipoor Locks.

49. The alterations at the Puttree and Ranipoor Works may be described together, being to a great extent similar ; Sheets 5 and 6 shew the proposed additions, &c., at the former: the masonry of the fall ogees to be removed, thus making the drop vertical; new flooring laid in below and covered with stone at the point of greatest action. Piers to be built in the centre of each opening supported on flying arches abutting on the drop walls and faces of the super-passage arches ; between these gratings, of sal wood, to be fixed as shewn in plan.

Similar gratings to be attached at the extremities of the arches on the down stream side, in order to diminish the velocity under the super-passage, and prevent acceleration of velocity in the channel below.

The boulder talus to be lowered 6·06 feet and relaid ; the lowest layers in mortar; the upper, of the largest stones carefully packed together ; and to secure this from all risk of being undermined, a row of wells to be sunk 50 feet below the head wall of the super-passage, right across the channel. Round wells have been projected for all such work in preference to the " blocks" of the original design from the very superior facility with which they can be undersunk. With these protections and the amount of backwater here, no apprehensions need, I think, be entertained for the safety of the work.

Piers and waterwings up stream must be raised to suit the increased height of water in the channel.

The alterations for the navigation are as follow. A portion of the outer revetment of the masonry channel above the lock to be removed to give direct access from the Canal, the old navigable channel being embanked across higher up, and a culvert constructed under the embankment for the escape of drainage water ; lock chamber walls and gates to be raised slightly above full supply mark. As with a less supply in the Canal than 9 feet the depth of water on the lower flooring will not be sufficient to float a laden boat, the formation of a second lock chamber below the arches of the super-passage becomes a necessity; the proposed design of this will be seen in the plan ; with a higher supply in the Canal than 9 feet the use of these gates will be unnecessary.

At the Ranipoor Works similar alterations are required, with the exception of the down stream gratings, additional lock chamber, and new boulder talus and curtain ; the present talus to be lowered one foot. The headway under these arrangements at full supply will be but 4 feet; if the bed from this point to the upper Bahadoorabad Fall be depressed 4 feet (it is at present channelled out to a greater depth), and

Digitized by Google

additions be made down stream as at the Puttree, a similar extent of headway will be available. This would add about Rs. 15,000 to the aggregate of the present estimates: I have not therefore included it in the alterations, not being necessary to the water carrying capability of the Canal. If, however, a free passage for boats be considered a necessity, it is the most economical way of effecting it. The only other course open is to carry a separate lock channel round the works, crossing under the torrent at some distance higher up on the right bank of the Canal, the cost of which, I need hardly say, would be very great.

Bahadoorabad Falls and Locks.

50. The Upper Bahadoorabad Falls will be altered as follows (*vide* Sheet 4): masonry weirs to be built on the ogees to convert the fall into a vertical one. The bridge piers to be lengthened and short piers built in the centre of each bay to support gratings similar to those designed by Captain Dyas. These will consist of wooden bars resting on wrought iron girders, as described hereafter for the Muhmoodpoor Falls: the bridge arches to be raised 5·86 feet to suit the increased height of water up stream; water wings raised 7 feet down stream; revetments 2 feet.

Similar alterations generally to the lower Bahadoorabad Fall, but no raising of revetments down stream necessary, boulder talus to be lowered 1·4 feet.

If the bed, as suggested in last para., be lowered 4 feet above the Upper Bahadoorabad Falls, the raising of the arches there will not be necessary.

At the upper lock on the separate channel new gates will be required to suit the increased depth of water, and the chamber walls must be raised 3·5 feet. Alteration at the lower lock will be confined to raising the bridge 3·5 feet.

Rutmoo Falls.

51. At the Rutmoo Regulating Bridge the headway at full supply under the present arches being only 5·84 feet, it is proposed to raise the side arches, or rather to remove them, and build new ones of greater height and span; the increased width will allow of a narrow passage under the arch to admit of the towing lines being carried through by hand. This involves raising the entire roadway of the bridge, but it appeared, after careful consideration, to be the most economical mode of effecting the object in view.

The sluice apparatus will be altered similarly to that at Myapoor.

The boulder talus to be removed and relaid at a level of 3·64 feet lower, and a row of piles driven across the bed below the bridge as shown (*vide* Sheet 7).

A new entry to the drainage culvert under the bridge flooring has been projected from the down stream approach on the right bank to carry off drainage which collects there from the low land near; the inlet on the torrent side having been, as before stated, closed for some time past. I have not estimated for removing the piers of the Inlet Dam; if decided on, the cost of demolition would be trifling.

Solanee Aqueduct.

52. At the earthen embankment across the Solanee valley, the only additions which appear necessary are rows of stakes driven across the bed between the ghât revetments at intervals of 200 feet level with the remodelled bed; this, with

Digitized by Google

the reduced velocity of current, will gradually silt up the intervening spaces, and so protect the foot of the masonry ghats.

In the Aqueduct itself, the water at full supply will stand at the level of the roadways; a low parapet will therefore be necessary along the edges on either side ; for this a height of one foot will suffice, the entire flooring to be covered with a layer of well puddled clay covered with brick on edge; the action of the current here will be so slight that little beyond a water tight covering, is necessary. Seyssel asphalte would doubtless be the best material for the purpose, but the cost would be greater perhaps than the circumstances call for. According to data brought from England by Captain C. S. Thomason, R. E., the cost of a half inch layer of the material could not be less than one rupee per superficial foot, or Rs. 1,55,380 for the whole Aqueduct.

Bridges.

53. The alterations to the bridges along this section consist of removals of floorings where necessary, and relaying at the level of the remodelled bed, as well as constructing towpaths, as shewn in Sheet 15, under the left arches for which iron uprights supporting girders, and a wooden pathway have been preferred to any other construction, from the slight obstruction they offer to the passage of the water.

Headway on remodelled line not uniform.

54. The headway available for navigation under the remodelled works on this section is not, it will be observed, uniformly up to the prescribed limit of 10 feet :—

At	Myapoor it is	...	7·5	feet.
„	Jowalapoor do.	...	8·13	„
„	Ranipoor do.	...	4·00	„
„	Puttree do.	...	8·40	„
„	Dhunowri do.	...	10·00	„
„	Muhewur do.	...	11·00	„
„	Roorkee do.	...	9·20	„

As it has been shewn above that the Ranipoor Works can be altered, the height available under the Puttree super-passage, 8·40 feet, must be taken as the absolute limit for through traffic along this portion of the line. Heavily laden boats seldom pass under the Myapoor Regulator, so that the headway there may be considered sufficient; and considering the nature and extent of the traffic likely at any time to pass above Roorkee, the Puttree limit will, I believe, be ample.

REMODELLING FROM ROORKEE TO CAWNPORE BRANCH.

Channel Alterations.

55. The mean velocities of current which the soil will stand without erosion in the channel below Roorkee have been determined at 2·7 feet per second for the portion from Roorkee to the new falls below Sirdhanna at the 76th mile, excepting the very sandy reach between the Muhmoodpoor and Nirgajnee Falls, where it does not appear safe to allow a higher velocity than 2·5 feet per second.

Below the Sirdhanna Falls, the mean velocity is uniformly assumed at 3 feet per second.

Digitized by Google

Between Roorkee and the Futtehgurh Branch Head, if the waterway of the present bridges be taken as the limit of the mean width of section in the earthen channel, the full supply depth of water, with mean velocities of 2·7 and 2·5 feet per second, would be 15·15 and 16·36 feet respectively, which would necessitate lowering the bed above the falls from 7 to 8 feet if the bridge arches there be not raised. If the bed be retained at the level of the crests of the falls, the surface of the stream at full supply would stand much above the level of the country, and from 5 to 6 feet above the springings of the bridge arches higher up, causing an afflux (though slight); the headway for navigation would then also be insufficient. By depressing the bed 7 or 8 feet, the floorings of the bridges would be lowered to a dangerous extent, and much excavation would be necessary, and that too, in all probability, below the level of the surface of the springs. It becomes, then, an obvious necessity to increase the width of waterway at the bridges along these 30 miles. Another arch of 55 feet span (there are now three arches of 55 feet span) gives a mean width of 220 feet, which has been taken as the basis of calculation.

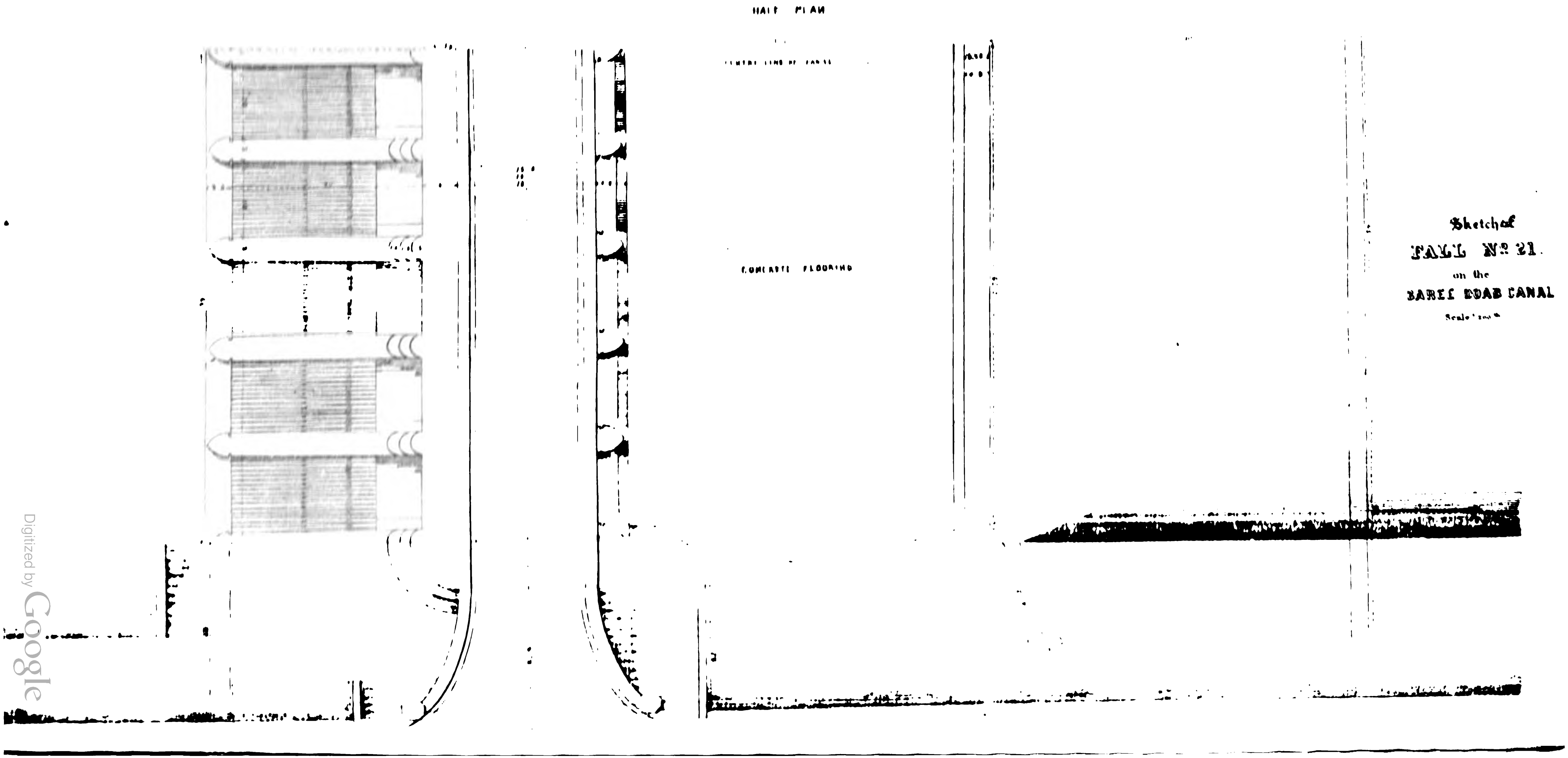
The consequent declivities, (*vide* Tabular Statement) vary from 1 in 11,000 to 1 in 13,000, with depths of water from 11·3 to 12 feet. The side slopes of the channel are projected at 1 in 2; the berms are estimated at 15 feet in width on the left or towing bank, and 5 feet on the other; tops to be two feet or thereabouts above surface of full supply in the Canal. In very light sandy soil the side slopes will be cut to 1 in 3; and where erosion is likely to take place, spite of the reduced velocity, a protection of grass ropes laid closely together and pegged into the slopes, such as is in use on the Dutch Canals and elsewhere, has been included in the estimate. When the traffic becomes extensive, as I have no doubt it eventually will, some such protection as this will be necessary in all sandy soil to prevent erosion from the wash along the sides. Wherever excessive widening of the channel has taken place, the estimate provides for narrowing and forming banks to the proper section.

Below the Futtehgurh Branch Head, the waterways of the present bridges have been taken as the limiting mean width of cross section. Into the detail of the new projection of bed it does not appear necessary to enter here. Above most of the old falls the bed has been depressed to admit of the water at full supply passing through clear of the soffit of the arches, though in some cases above the springings. At the Bolundshuhur and Koel Branch Heads, the bed is lowered up stream to an extent equal to the difference between the depth of high water up and down stream; elsewhere the levels of the bridge floorings have been retained wherever possible, or if altered, only to such an extent as was considered safe; a boulder or kunkur talus will, it is believed, be a sufficient protection in any case.

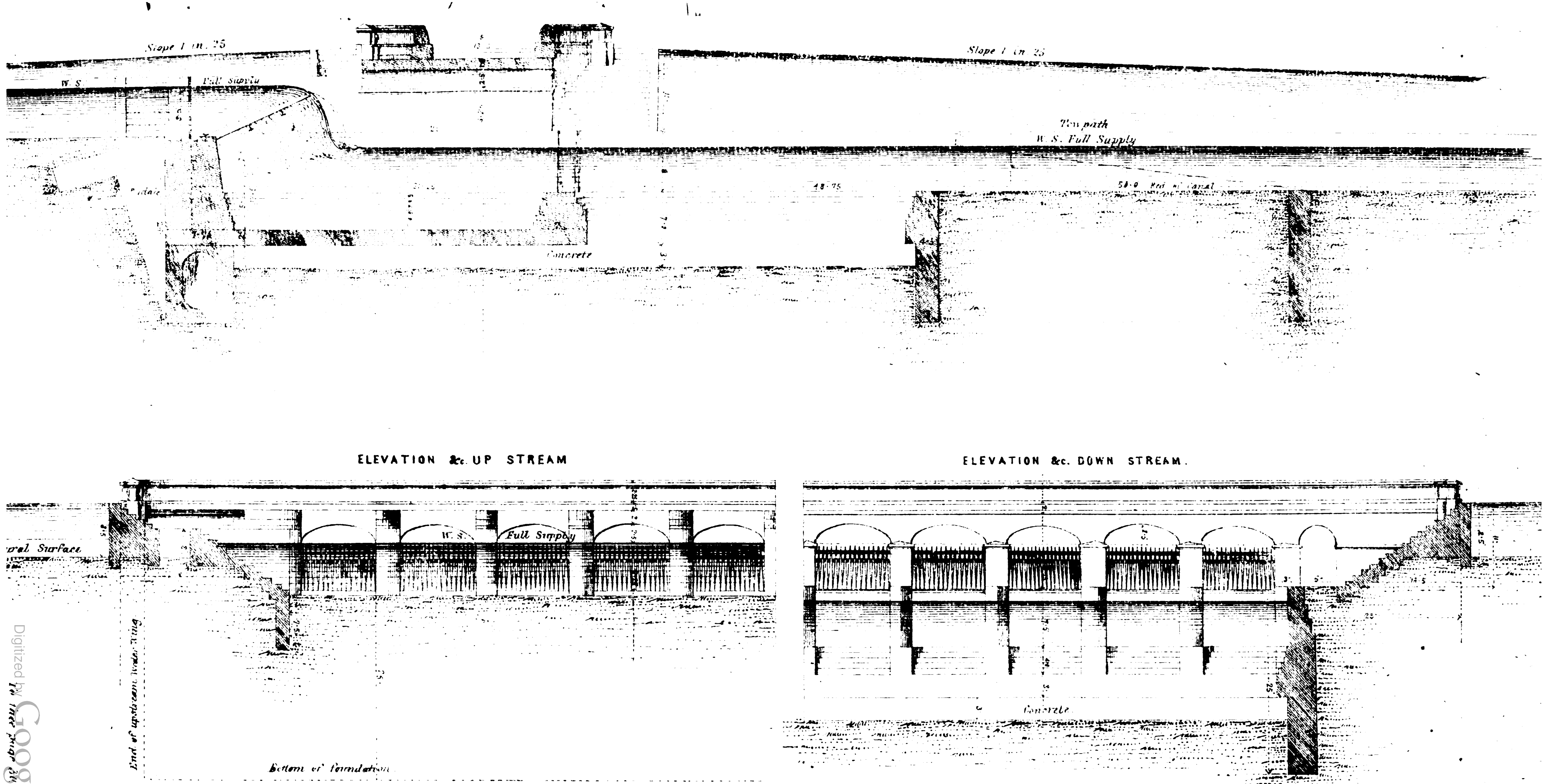
New Falls and Locks projected.

56. The number of new falls on this line will be 15, height of descent varying from 3·53 to 8·54 feet, making a total of 29 from Myapoor to Nanoon.

Digitized by Google



Digitized by Google

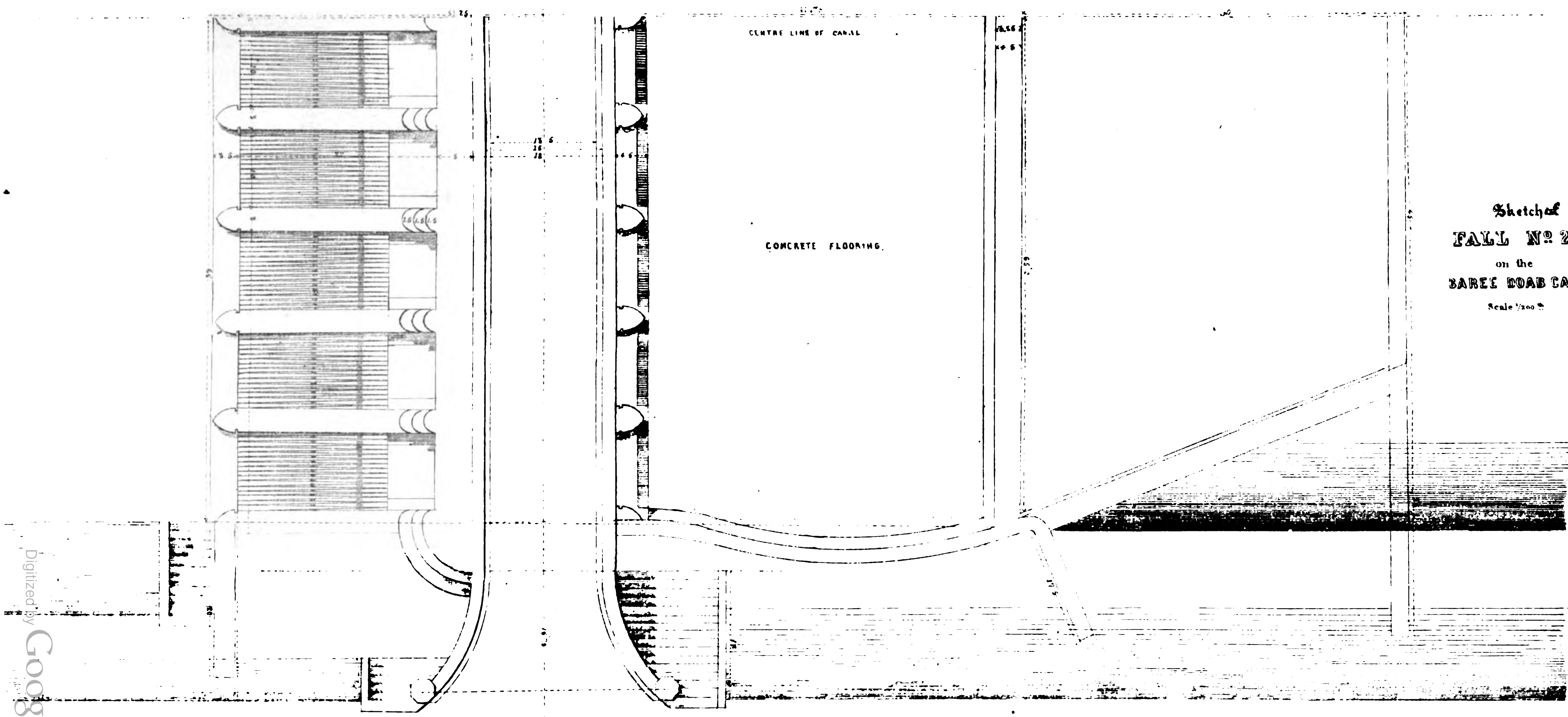


ELEVATION &c. UP STREAM

ELEVATION &c. DOWN STREAM.

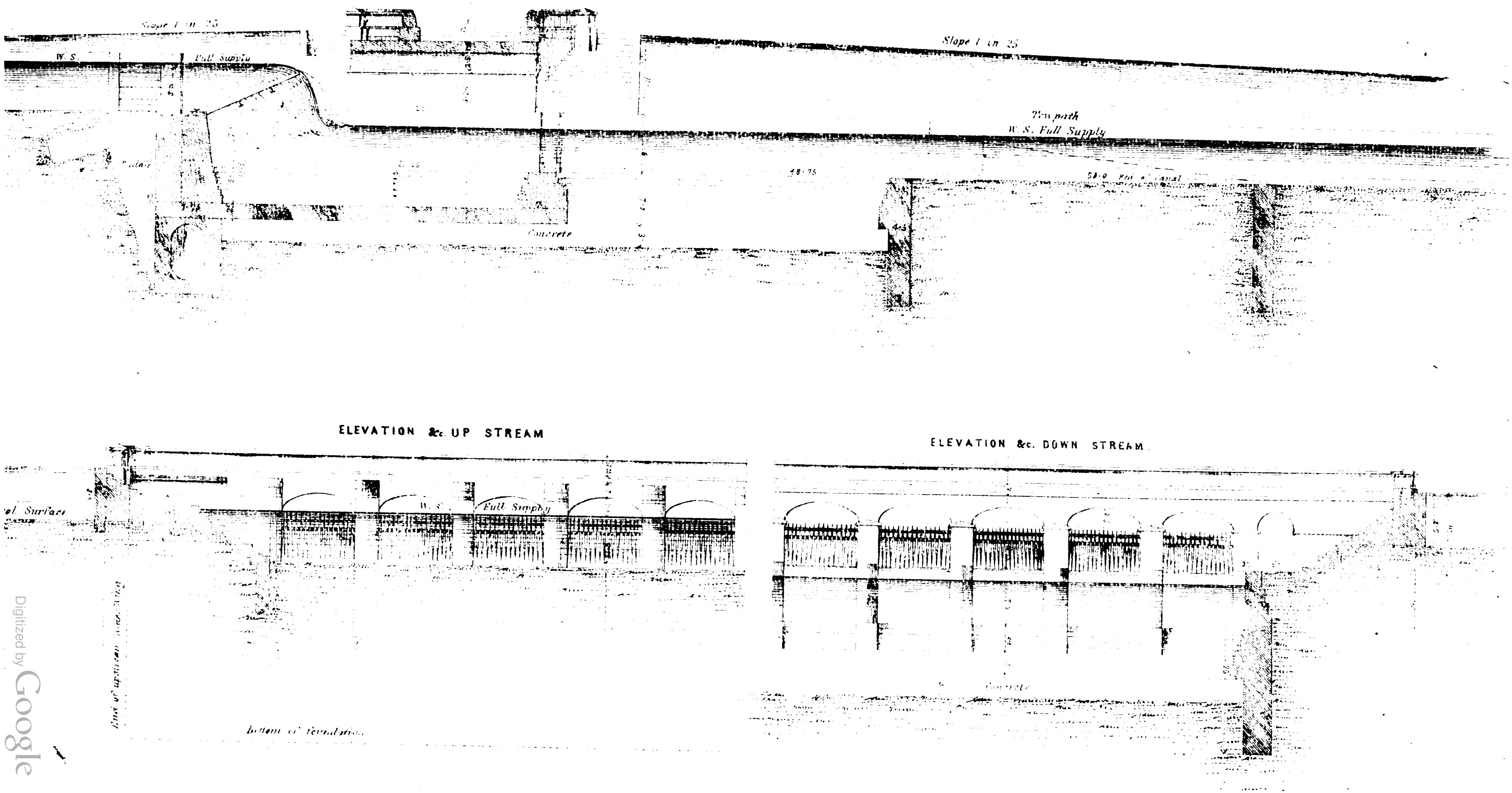
Digitized by Google

HALF PLAN



Sketch of
FALL No. 21.
on the
BAREE DOAB CANAL
Scale 1/200 ft.

LONGITUDINAL SECTION



Digitized by Google

Digitized by Google

The first will be situated at the extremity of the curved revetment wall below the Roorkee bridge where the straight reach to Hafiznuggur commences ; that near Sirdhanna, at the point where the sandy merges into stiff soil: near the escapes, they have been projected immediately below and in connection with the Escape heads, to give the means of damming the Canal across when it is desirable to lay it dry below. At Moonda Khera and Kasimpoor it would have been more economical to have placed the new falls between the ghât revetments above the bridges; the restricted width there, however, necessitates their transfer below the bridge in each case ; elsewhere the new works are projected above and in connection with existing bridges.

The waterway has been fixed generally by making the width between the waterwings up stream equal, or as nearly so as possible, to the mean width of water section in the channel above, so that there should be no tendency to acceleration of velocity until quite close to the crest of the fall. The navigation has been provided for by locks on either side (*vide* Sheet 8), the entrance to which is upwards of 105 feet above the drop at the fall, a distance quite sufficient, I think, to obviate any risk of boats or rafts being carried within the influence of the accelerated velocity. Should, however, further protection be found desirable hereafter, a floating boom, in the form of an arrow head, with the apex up stream, and fastened to the bed in the centre and the extremities of the lock chamber walls on either side, or a boat bridge, as projected by Sir Proby Cautley, will answer every purpose. Double lockage has, in every case, excepting the old falls, been estimated for ; a single lock at each fall will not, in my opinion, be adequate to the wants of the traffic which may ultimately be expected on the Canal. The overfall is constructed on the general design of those on the Baree Doab Canal, of which a plan is annexed, except that the piers are of the shortest possible length, to give the fullest effect to the backwater in the cistern and basin below; the bridge, wherever there is one, being situated at the extremity of the tail basin. A short talus of boulders or kunkur blocks is attached to the down stream wall of the cistern ; with such a protection there, and considering the reduced action of the water with this form of fall, a depth of eight to ten feet may be considered ample for the deepest foundations. The floorings of existing bridges in connection with these falls will, I believe, be sufficiently protected by relaying the talus down stream. The width of the fall bays has been projected generally at fifteen feet, and the total number estimated for (*vide* abstracts of estimates) in 5 sets, varying in width of waterway. For the purpose of an estimate this may be taken as sufficiently accurate ; but in practice it will, of course, be most economical to adjust the waterways to the mean widths of channel immediately above.

Iron lock gates are estimated for, on account of their superior durability and lightness of construction.

The various forms of these works, according to locality, from which the estimates have been framed, will be found in Sheets 8, 12, 14, 17 and 19 of Plan X, and their several waterways in Appendix B.

Digitized by Google

Alterations to present falls.

57. The existing falls, ten in number, it is proposed to alter or add to more or less extensively. It would extend this Paper to an inconvenient length to enter into the detail of alterations at each; suffice it to state, that each has been carefully considered and estimated for separately. Sheets 10 and 11, 16 and 18, and the following description of one, will sufficiently explain the nature of the proposed remodelling generally.

A plan and sections of the Muhmoodpoor Falls will be found in Sheet 10. The waterway is two hundred feet, divided into 8 bays of 25 feet each; the entire height under the arches being only 11·35 feet, and the depth of water at full supply with the remodelled bed being calculated at 11·3 feet. The bed up stream has been projected at a level 2 feet below the present crest of the fall; the water will thus stand 9·3 above the flooring of the bridge. The lower flooring must be depressed to the level of the new bed, or 2·56 feet; the depression being carried above the foot of the ogee as shewn; immediately above this a vertical drop wall to be built across each of the bays, the top flush with the present bridge flooring; the bridge piers to be produced, and new piers in the centre of each bay to be constructed for the support of the grating girders; (the width, 25 feet, of the original bays would require too costly a section of girders); sections, &c., of the latter are shewn separately on an enlarged scale. The new piers will be hollowed out underneath to allow the utmost possible freedom to the backwater below the fall; and as it is doubtful whether a cistern could be formed under the fall with the present height of spring level, a covering of stone for a length of 50 feet below this drop wall has been estimated for. With the extent of backwater shewn here, well executed brick on end will be amply strong enough to face the rest of the work with. The boulder talus to be removed to the level of the new bed, and relaid, if the remaining thickness be found to be less than 3 feet. The curved extremities of the tail revetments to be cut away to the width and the shape of the sides of the channel below, and the earthen slopes pitched with boulders or kunkur for a length of 100 feet below the fall. At the entrance to the lock channels it will be seen, from the annexed sketch, that the stream is confined between masonry revetments to a width which in no case is equal to the increased mean waterway of the earthen channel, and above the Futtehgurh Branch Head very much less. The estimate provides for removing one side and the attached rajbuha head, as well as replacing the latter and removing the left revetment of the masonry passage at the entrance to the lock channel, where the contracted width has been found so great an inconvenience. A new exit channel has been projected below the lock, rejoining the Canal in the shortest possible distance (*vide* annexed sketch).

Though the bed immediately in advance of the lock must be depressed 2·56 feet below the level of the flooring, the backwater, except with a *very* low supply, will be sufficient to float a laden boat in the lock chamber. The lock bridge must be raised 1·44 feet to give a ten feet headway at full supply.

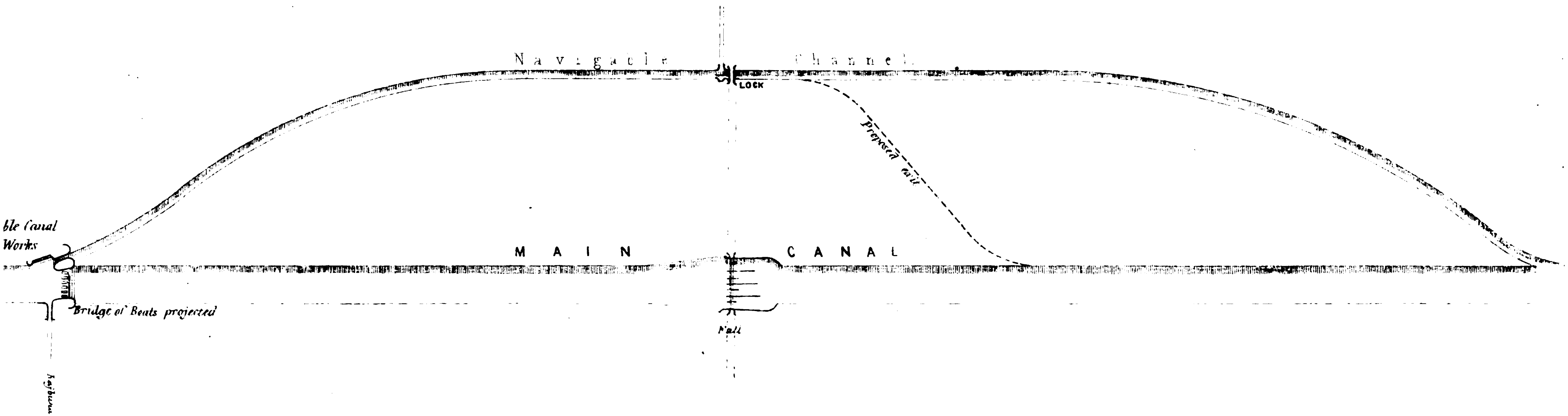
Digitized by Google

Sketch of

PRESENT LOCK CHANNEL

GANGES CANAL.

Scale 600 feet to an inch



To face Page 32. Para 67

Digitized by Google

The fall gratings estimated for throughout these projects are, as I have stated elsewhere, on a general design which has worked successfully elsewhere; constructions for which we have not a precedent, I have thought it best under the circumstances to avoid. It appears to me, however, possible to improve on the form and material of these gratings, substituting masonry in place of iron and wood.

A design for such a grating is shewn on Sheet 11, adapted for one entire bay of the Muhmoodpoor Falls (for, with masonry, it would not be necessary to build intermediate piers).

The arch shewn might be built of brickwork, overlaid on the top with stone. It would abut on the edge of the drop wall, supported at the crown by the head wall of a light bridge thrown across the extremity of the piers. Vertical slits in this arch, of suitable form and dimensions, would give the necessary waterway, and though the exact form of the curve to be given to the sides of the slits or notches and their width is as yet undetermined, the co-efficient of discharge not being accurately known, regulation of the height of water surface above can at any time be effected without difficulty. The strength of the abutting bridge between the piers need not be great, as the super-incumbent weight on the arch decreases rapidly towards the crown. The absence of the intermediate pier will obviously increase the effective backwater.

With the high rate of stone now procurable, the difference of cost (in favour of the new design) cannot be estimated higher than one-ninth; but its superior durability will not, I think, be questioned.

I have, from a desire to utilize to the fullest extent all existing works, retained in this estimate the present lock channels and locks; but considering the inconveniences and obstructions caused by them, I believe it would be preferable to construct new lock chambers in the side bays of the existing falls. A design for this is shewn in the plan of the Muhmoodpoor Falls in dotted lines. It would be necessary to raise the side arches some eight feet to obtain the full amount of headway; to effect this a drawbridge has been projected and estimated for, the thrust of the other arches thus left without sufficient support being counteracted by the lock chamber walls built up against the side piers. Protection to craft above the fall might be afforded at a small expense by a line of piling extending up stream in the prolongation of the lock wall, the top raised two or three feet above full supply level. This arrangement for the lockage would raise the present estimate for each fall by about Rs. seven thousand (7,000).

58. The proposed alterations to the Bridges are as follow :— **Alterations to Bridges.**
An arch of fifty-five feet span to be added to each of the bridges (eight in number) between Roorkee and the Futtehgurh Branch Head. The general design is shewn in Sheet 9, which gives plans and sections of the Munglour Bridge. Towpaths will be added under the left arch, as shewn in Sheet 15; floors lowered and relaid, and waterways, &c., raised where necessary. From the Futtehgurh Branch Head to the Sirdhanna Bridge, alteration will be confined to removing and

Digitized by Google

relaying floorings, raising waterwings where necessary, and attaching towpaths; the latter under all the arched bridges along this portion of the line are projected at a width of twelve feet, the curve of the arches not allowing of sufficient headway closer to the abutment.

Along the entire line from the bridge below Sirdhanna to Nanoon, the headway, I have before stated, is deficient. It is proposed to remove the arches, substituting iron girders and roadways of kunkur over sheet iron plates, the general design of which is shewn in Sheet 15. Another method of getting over the difficulty was by the excavation of a navigable channel bridged at a sufficient elevation, round each bridge on the Canal, and this would undoubtedly be the least costly; but the constant petty expenses and inconvenience such channels would inevitably cause make the former method preferable as a permanency. The towpaths under these girder bridges need not project more than seven feet. The other alterations are similar to those at the bridges higher up.

The flooring of the Sirdhanna bridge, which is of kunkur masonry, has remained in first-rate order, spite of a constant rush of water through the arches. I have therefore estimated for new floorings of similar material, wherever it is procurable at a moderate cost.

New masonry arches might be constructed at half the expense of girders, and would be more durable; but the time occupied in the manufacture of bricks and of erection would be much longer, and it would be necessary to raise the approaches, which with girders would generally be retained at their present levels.

Branch Heads.

59. At the Branch Heads, similar changes are required as at the Rutmoo Regulating Bridge, with the addition of gratings and lockage into the branch lines.

Sheet 13 shews the proposed alterations at the Futtehgurh Branch Head. The two side arches of the bridge over the main channel to be raised sufficiently to give the normal headway of ten feet; iron drop gates to be fitted to these openings; each of the remaining arches to be divided into three parts by iron uprights grooved for the reception of wooden sluice gates. The left arch of the Futtehgurh Branch Bridge to be similarly raised, and the remaining superstructure of both bridges, and the curved connecting wall with a roadway, to be made up to the same height. A weir two feet in height to be built across the floorings of the other arches on the Futtehgurh Branch, immediately under the upstream head wall; iron girders to be attached to these arches as on the main regulator; the necessary heading up of the water to be effected by vertical wooden gratings let into the grooves, similarly to sluice gates. A lock chamber to be constructed as shewn, formed partially by the left bay of the bridge, the upper gates being placed close to the up stream headwall.

The floor of the lock chamber to be level with the top of the weir.

The side slopes of the channels down stream to be pitched for a length of 50 feet with kunkur blocks or boul-

Digitized by Google

ders. Ghât revetments and waterwings on Main Channel to be raised 2 feet. Alterations and additions at the Bolundshuhur and Koel Branch Heads to be similar, except in height of raising. The lock chambers here are restricted to 15 feet in width by the spans of the existing side arches.

Single lockage only, it will be observed, has been provided for the Branch Canals ; the traffic there will be small compared with that on the trunk line.

At the Cawnpore and Etawah Branch Regulator, the surface of full supply down stream in the Etawah branch will be eight feet below the soffit of the arches ; in the Cawnpore Branch, ten feet, as the bed there will be depressed two feet. The bridges may, therefore, I think, remain as at present. If the headway under the Etawah Branch Bridge be hereafter found too little, a navigable communication may be made between the branches lower down, or a channel cut round the bridge, unless it be found practicable to depress the bed for some distance below the head.

Double lockage provided for (*vide* Sheet 20) on the main line regulator ; single on the Etawah branch ; the locks in both cases to be constructed in the main channel *above* the bridges, to admit of boats passing under the bridges at the level of the lower water, and also to keep them out of the influence of the accelerated velocity close to the bridges.

As the difference of level up and down stream at full supply will be, in the Etawah Branch 3½ feet, in the Cawnpore Branch 5½ feet, gratings similar to those for the Puttree Works are designed in all except the lock bridge arches ; to support these, piers to be built in the centre of each arch up to the level of the top of the up stream waterwings. The edges of ghât walls up stream to be raised two feet.

The inverts of the bridge flooring on the Cawnpore Branch to be removed ; and flat flooring, covered with brick on edge, substituted. A line of piling to be driven across the bed of both branches at the extremities of the waterwings, and the bed between them and the bridge curtains to be covered with a four feet layer of kunkur blocks.

Escape Heads.

60. At the escape heads no alteration appears necessary, except lowering the floorings in four bays of the Khutowlee, Aboo Nulla and Jannee Khoord works, to admit of laying the Canal below them dry when necessary. From the silted-up condition of these escape heads, the lower districts of the Canal are frequently overloaded, when irrigation is not required above, by a five feet supply on the Roorkee gauge (the present full supply being seven feet). Store rooms, as described hereafter for the alternative line, are estimated for each new overfall (15 in number).

REMODELLING.

Cawnpore Branch.

Alteration in Channel to Keylunpoor Bridge.

61. It is proposed here to depress the bed two feet from the regulating bridge to the Keylunpoor Bridge at the 3rd

Digitized by Google

mile, removing the ogee fall in the flooring of the bridge, and thus obviating the necessity of gratings and lockage. The irrigation will be little if at all affected by this depression, as the depth of water in the channel will be greater with the reduced velocity. All the other modifications to this branch are solely due to the necessities of navigation.

Alterations to Bridges generally.

62. To give a clear headway of ten feet, all the bridges, 56 in number, between the heads and the Dubowlee escape at the 165th mile, must be more or less raised. This it is proposed to effect by substituting girders, as on the main line. At the Aima bridge, 122d mile, the substitution as before mentioned, has been already made. The railway girder bridge at the 163d mile must be raised two feet, and the gradient altered on both sides to correspond. A towpath seven feet in width, close to the left abutment of each bridge, to be fixed similarly to those on the main line.

Retention of present channel below Dubowlee Escape as navigable line recommended, and why.

63. The lower railway bridge being close to the station at Cawnpore, and the surface of the roadways of the bridges in the town, above the terminal lockage, being on the level of the adjoining streets, any raising there is out of the question; there is nothing for it but to depress the bed along this portion of the line. Now, from the Duknapoor Bridge, that situated immediately below the lower railway bridge, there were three methods of completing the navigable communication with the upper portion of the Canal :—1st. By taking off a navigable channel above the upper railway bridge, and rejoining the Canal above Duknapoor; the length of this would be about five miles, requiring one lock and four bridges.

2nd. If deficiency of supply be feared from the wants of the irrigation in a dry season, this channel should be led off from above Runjeetpoor Bridge (the 150th mile), where the last set but one of the rajbuhas leave the Canal; this would add 12 miles to the length, 2 locks and 9 bridges would be required, but it would diminish the number of bridges to be raised on the Canal by six. Both these methods would avoid the railway altogether.

The 3rd was to depress the bed from below Dubowlee bridge to the upper lock at Cawnpore sufficiently to afford the necessary headway under the bridges in the town.

The balance appears to me to be in favor of the latter, and it is the least expensive. The alterations are projected accordingly. The water in the channel below Dubowlee being only for navigation purposes, the declivity and area of section have been determined for a velocity of current just sufficient to prevent the growth of weeds, viz., $1\frac{1}{2}$ feet per second; the width at the water line with a depth of four feet being 36 feet, ample for the passage to and fro of two fully-laden boats. The new section must be carried up close to the Dubowlee bridge, above which the last irrigation channel is taken; as, with only 4 feet of water in the Canal there (the least, I think, which can be allowed for efficient navigation) the discharge will be 225 cubic feet per second, of which the rajbuha will take off fully 80 cubic feet, leaving only 145 cubic feet, the minimum absolutely necessary for the navigation below.

Digitized by Google

64. The drop below the Dubowlee Bridge will thus be 5.61, to overcome which, a double lock, similar to those hereafter described for the separate navigable line, is projected; the head of this will be placed about 150 feet from the bridge on the down stream side.

New lock and alteration at Dubowlee Bridge.

The Dubowlee Bridge itself will be raised to give the full headway; and here it seems preferable to build an arch of larger span so as to give room for towpaths on either side, formed by cutting down the present abutments to a suitable level above the bed, the waterway at this point being reduced to 20 feet, almost too narrow of itself for the purposes of the traffic. The new abutments can be formed without difficulty by filling in the present flank arches, thus giving a clear span of 30 feet, with 5 feet towpaths on either side.

65. The bottom of the foundations of the bridges below Dubowlee being either level with or slightly higher than the remodelled bed, it is proposed to underpin them, as shown in the plan of Duknapoor Bridge (Sheet 21), relaying the floorings at the new level. The span of these bridges, 20 feet, will not allow of the construction of towpaths for cattle *under* the arches ; 18 feet is, I think, the very smallest width which can be allowed for the passage of a laden boat moving with the usual velocity; footpaths 2 feet wide only have therefore been projected close to each left abutment, which will allow of uninterrupted tracking by human labour along these two last miles.

Alterations to works in Cawnpore.

The upper floor of No. 1 lock, the highest of the terminal series, to be lowered 3½ feet, and the gates adjusted to the lower level.

The upper mills will have to be altered to suit the depressed level of the water in the Canal. The cost has not been included in the estimate, as mills in such localities, it is well known, always pay their own expenses, whether of original construction or repairs.

The arch of the "General Gunj" Bridge to be removed, and girders substituted at a higher elevation of 4½ feet. Two feet towpaths added below.

The arches over lock chambers No. 3 to be raised 2 feet.

The quay revetments to be removed wherever the width of channel is thereby narrowed to 20 feet; the ghâts, on account of their great length, aggregating 695 feet on both sides, it is proposed to leave for the present, underpinning their foundations as shown in Sheet 22. If found to interfere materially with the traffic hereafter, they can be removed and rebuilt at a trifling cost; the section on the remaining portion of the earthen channel to be altered as shewn in Sheet 22.

66. This completes the detail of the proposed remodelling on the trunk line. The restricted waterway, 20 feet, through the bridges at and near Cawnpore may hereafter be found inadequate to the wants of a fully developed traffic; this may, however, be obviated at any time by removing the arches and substituting girder bridges of greater span, suitable for an enlarged waterway and cattle towing tracks.

Waterway through Cawnpore may be found insufficient, and remedy possible.

The surface of the springs, even with a dry Canal, being everywhere either at or close below the level of the bed, deep

Digitized by Google

foundations wherever necessary have been projected and estimated for on undersunk wells, except in localities where, as at the Roorkee Fall, the water can be carried off by a cut into adjoining low ground.

Towing, it will be observed, has been provided for only on one bank; with a downward current all along the channel, haulage upwards only will be necessary.

Alterations on Branches.

67. On the Futtehgurh Branch, the only alteration which appears necessary to enable it to carry the full supply safely, is reduction of the declivity of bed in the first 17 miles from the head.

This may be effected by raising the crests of the Churialee and Akbarpoor Falls 2·6 and 1·68 feet respectively, on which might be built masonry weirs (or the bays planked up) to a height sufficient to maintain the surface of the water at its normal level.

The Bolundshuhur Branch seems to act sufficiently well as an irrigating channel; the Koel Branch, it has been stated before, is not yet in existence; and the Etawah Branch is in fair order.

If the Branch Canals also are to be efficient navigable communications, alterations similar to those described for the trunk line will be required to the bridges generally and lockage at the falls; the latter was included in the original designs for the Futtehgurh Branch, but has hitherto been held in abeyance. The detail of such additions and alterations I have not had time to go into; they are therefore not included in the present estimates.

THE ALTERNATIVE LINE.

New line into Futtehgurh Branch not recommended, and why.

68. The maximum supply which can be safely carried by the existing line at various points between Roorkee and Nanoon Regulator, is shewn in the annexed statement in the column of "Actual Capacity."

This is immediately below the—

	Mile.	Cubic feet per second.
Hafiznuggur Falls	23*rd*	1870
Futtehgurh Branch Head	50*th*	1790
Jutpoora Bridge	80*th*	2533
Mussoorie Falls	106*th*	2240
Pulra Falls	149*th*	1967

It has been stated before, in para. 37, that two suggestions have been made regarding the course of an alternative line, one of which is to cross the present channel above Meerut, and take up the line of the Futtehgurh Branch somewhere

Digitized by Google

lower down. If this be adopted, and the maximum supply (2,533 cubic feet) admitted into the old line there (say near Sirdhanna), after taking off the volume of the Bolundshuhur and Koel Branches (1,040 cubic ft.) and the expenditure *en route* (493 cubic feet) only 1,033 cubic feet will pass the head of the Koel Branch, and the Channel there can carry 1,967 with perfect safety. The discharge below the Mussoorie Falls would, on this supposition, be 2,368 cubic ft., while the maximum capacity there is but 2,240 cubic feet; some protection would therefore be necessary to the banks there, and below the Koel Branch head the irrigation would necessarily suffer from the depression of the water surface in the channel. On economical grounds, then, I think this proposition may be considered out of the question, and we may take Sir P. T. Cautley's original suggestion as the only course feasible.

Discharge of alternative line, and redistribution of supply.

69. It is obvious from the statement given above, and that at para. 44, that the existing channel cannot at any point carry the entire supply of water allotted to it in the original projection. It is therefore clear that the alternative line must run the whole distance from Roorkee to the Cawnpore and Etawah Branch heads.

Now, the maximum supply which the channel immediately below Roorkee can carry is about 2,000 cubic feet per second; but between Hafiznuggur and Muhmoodpoor it is only	1,789	cubic feet.
If we add to this the expenditure above Hafiznuggur Falls	82·5	„
The maximum admissible at Roorkee is	1871·5	„

Of this 1,240 cubic feet will be abstracted by the Futtehgurh Branch, leaving 300 cubic feet for the irrigation wants below. The old channel should therefore be supplemented here by a feeder from the alternative line; this, however, is not advisable on economical grounds, as the channel in this sandy tract cannot carry the entire supply required down to Nanoon, and a second feeder would consequently be a necessity.

The first junction has therefore been projected at the highest point, where the soil will admit of a 3 feet velocity of current. Above this, the irrigation must be provided for by holding up the water at each fall.

All irrigation above the junction at Jutpoora Bridge must be supplied from the existing line; below that, the proportion allotted to it (8 cubic feet per mile being taken as the entire expenditure) is 6 cubic feet per mile, the remaining 2 cubic feet being distributed from the alternative line. The volume to be admitted into the old line at the junction is limited by the capacity at the Pulra Falls (with the addition of the expenditure *en route*) to 2,375 cubic feet per second; and as the discharge of the alternative line above, *vide* Tabular

Digitized by Google

Distribution of Water on Alternative Line Project.

Localities.	Position in Miles from Head.		Length in Miles.			Discharge Cubic Feet per Second.				Remarks.
	From.	To.	Total.	Irrigating.	Non-irrigating.	Allowance per Mile.	Expenditure.	Required Capacity.	Actual Capacity.	
Main Line—										
From Hafiznuggur to Futtehgurh Branch Head ...	19	50·5	31·5	23·0	8·5	8	330	1870	1870	d = 4′ V = 2·7
Thence to Jutpoora Bridge ...	50·5	80·0	29·5	29·5	...		165	300	1790	d = 4′ V = 2·7
Thence to Mussoorie Falls ...	80·0	105·5	25·5	25·5	...	6·0	95	2375	2533	d = 5·5 V = 3·07
Thence to Pulra Falls ...	105·5	148·5	43·0	43·0	...		228	2285	2240	d = 5·4 V = 3·07
Thence to Nanoon Regulator ...	148·5	180·9	32·4	32·4	...		192	2057	1967·0	d = 5·4 V = 3·03
Alternative Line—										
From Roorkee to Junction Branch Head ...	0	61	61	...	61	...	...	5000	5087	
Thence to Bolundshuhur Branch Head ...	61	100	39	39	...	2·	78	2760	2808	
Thence to Koel Branch Head ...	100	141	41	41	...	2·	82	2162	2141	
Thence to Nanoon ...	141	166	25	25	...	2·	50	1560	1581	
Branches as in original Project.										

Digitized by Google

Statement, Appendix B) is (6870—1870=) 5,000 cubic feet; and the quantity remaining in the old channel over and above the expenditure below Roorkee is 165 cubic feet; the junction must deliver 2,240 cubic feet into the latter, leaving 2,760 to be carried on by the alternative line. As the abstraction of the supply for the Bolundshuhur and Koel Branch Heads would reduce the volume of water in the existing channel below its actual capacity, besides affecting the irrigation, it will be evident that they must be supplied from the alternative line.

The new depth of water below Jutpoora will be about the same as at present, so that the existing irrigation there will be unaffected by the changes.

Course of Alternative Line.

70. Of the proposed course of the line little explanation is necessary, beyond that afforded by the map (Plan II). Suffice it to say, that it crosses the West Kalee Nuddee above Deobund, passing thence along the watershed (*vide* cross sections, Plan V.) between that river and the Hindun, and recrossing close to its junction with the latter. At the 61st mile the first bifurcation is situated, the easterly branch being the feeder to the old channel. The heads for the Bolundshuhur and Koel Branches have been projected at the actual crossing point of the former, and on the line proposed for the latter.

Sections of channel and declivities.

71. The sections of channel and declivities of bed have been determined for mean velocities of current, similarly to those in the remodelling of the old line, *viz.*, 2·7 for the upper portion down to the junction; 3 feet per second for all below. The soil generally on the upper section is very similar to that on the present line opposite, with the exception of the sand hills at Toghulpoor and elsewhere.

The cross sections of the channels are shown in Plan VII. In natural channels there is, doubtless, a proportion of depth to breadth with which any tendency to abrasion would be equal on bed and banks; there are few observations as yet, however, by which the proportion for different velocities of current could be accurately determined. On the Western Jumna Canal, the proportion, where the stream appeared to have formed a channel for itself, was 1 to 13. On the Ganges Canal in the sandy tracts it varies from $\frac{1}{18}$th to $\frac{1}{20}$th and even less. I have adopted the last proportion for the largest section, as a greater depth than 10 feet is inconvenient in the working of the sluices, lock machinery, &c., &c.

The towpaths are maintained at a uniform height, generally 2 feet above the calculated surface of full supply. A surf berm, 4 feet in width at the level of full supply, as on some Canals in America and elsewhere, is projected for the section where navigation will be carried on, on which the growth of grass, &c., should be encouraged, to form a protection from the wash caused by the passage of boats.

The navigable communication is proposed to be carried along the alternative line from Roorkee to the Jutpoora junction, whence it may pass along the old line, the depth of water being sufficient, and the headway under the bridges ample, except at the branch heads, and the bridges at the Pulra and

Digitized by Google

Simra locks ; the headway at the former should be but $8\frac{1}{2}$ feet with a full supply ; 7 feet at the latter.

No lockage or towing paths in the alternative line are therefore projected below the Junction Branch head. The communication with the Futtehgurh Branch will be kept up along the old line from Roorkee downwards. Escapes are projected from two points :—The first, 1 mile 920 feet in length, from the 51st mile, into the West Kalee Nuddee above the lower crossing ; the second 8 miles long, from the 10th mile, immediately above the bifurcation for the Bolundshuhur Branch, into a nullah leading into the Jumna.

No levels have been taken over the actual course of the latter ; the estimate is based on a parallel line of levels some 2 miles to the Northward.

Overfalls.

72. The overfalls, 25 in number, are designed similarly to those described for the remodelling (*vide* Plan X., Sheets 26 and 27) ; no locks attached below the Junction Branch head.

73. Two aqueducts are required across the Kalee Nuddee, which form a very heavy item in the Estimate. At the lower crossing especially, the width and depth of valley (*vide* longitudinal section, Plan IV.) is very great ; and it is necessary to keep the bed of the Canal at a high elevation to avoid heavy cutting on the down stream side. The designs for these works are given in Sheets 30 and 31. The waterways for the river floods have been determined from that of a bridge on the Shamlee Road, opposite Moozuffurnuggur, which has now been standing for many years, I believe, without injury from the highest known flood.

The width of the Kalee Nuddee catchment basin is tolerably uniform throughout, and the distances from the head of it are as follow :—

Upper crossing, Alternative Line.........	17	miles.
Mozuffurnuggur Bridge........................	36	„
Lower crossing, Alternative Line	56	„

The aggregate area of waterway section at the bridge in the highest known flood was $165 \times 10 = 1{,}650$ S. feet

This gives for the upper crossing a waterway of $\frac{17 \times 1650}{36} = 779$ S. feet nearly.

For the lower $\frac{56 \times 1650}{36} = 2567$ S. feet nearly.

And as the depth of the highest known floods are 13 feet at the former, 12 feet at the latter, the widths of waterway should be 60 feet and 214 feet respectively.

The declivity of the bed of the river, however, at the upper crossing is 1 in 2291, while at the lower, where there is also an ample backwater from the Hindun in time of flood it is 1 in 3748 ; a somewhat greater width has therefore been given to the former ; the waterway (*vide* Tabular Statement) being 2 spans of 40 feet each for the upper, 4 of 50 feet each for the lower crossing. The difference of level between the bed of the river and the Canal channel is, in the former case 22·4 feet, in the latter 34·17 feet.

The width of waterway above for the Canal in both is identical, *viz.* 190 feet (equal to the mean width of the earthen

Digitized by Google

channel) divided into two channels each 95 feet wide by a wall 5 feet thick; roadway on the right bank 12 feet wide, on the left 5 feet.

Abutments, piers and waterwings on well foundations sunk 12 feet below the bed of the river; a flooring of kunkur blocks 3 feet thick under the arches, and on the bed for a width of 20 feet up and down stream; the abutments, backed with puddled clay, and side slopes of the Canal channel, adjoining the wing walls, pitched with kunkur blocks; clay well puddled to be laid over the entire flooring under the brick on edge.

Along the centre of the embankments leading to the aqueducts on both sides, walls to be built of rubble masonry, (as shewn in Plan VII), 2 feet in thickness, level with the surface of full supply in the Canal at top, their foundations being laid one foot below the ground line. The Canal bed here not to be made up uniformly to the true level, a hollow to be left in the centre all the way along 20 feet narrower than the bottom width of the bed, divided at intervals of 100 feet by cross bars 10 feet wide at top; these spaces are left to be silted up after the admission of the water. The walls in the centre of the side banks are intended to prevent all risk of injury from the encroachments of rats or other vermin. A long embankment on the Baree Doab Canal, constructed and protected in this way, has had the water passing over it for some years, without giving the slightest trouble beyond the few repairs necessitated by the settlement of the earth.

74. The Regulator at Roorkee is shewn in Sheet 23. The angle of divergence is projected at 45°. Roorkee Regulator and Branch heads.

The bridge across the alternative line to have an aggregate waterway of 184 feet divided into 8 bays of 23 feet each by piers 3 feet in thickness; on the old channel, 7 similar bays giving a waterway of 161 feet. For regulating purposes each bay to be divided into 3 parts by short pipes 2·5 feet thick, entending up stream to a length of 5 feet from the bridge head wall, across which will be thrown light arches to form a pathway on which the lifting machinery may be worked. The width of the sluice gates will thus be 6 feet. The object of placing the regulating apparatus thus clear of the bridge is to allow the boiling and eddying, which always is found more or less under such circumstances, to be partially deadened in the wide bays under the bridge arches before issuing into the earthen channel below.

The difference of level between the water surface at full supply, up and down stream being, in the old line 8·8 feet, in the alternative 2·8 feet, masonry weirs are projected across the flooring of both Regulators close to the sluice grooves of a height sufficient to maintain the surface of the water up stream at its normal level. Lock chambers are designed, similar to those at the overfalls, on the left and right bank in the old and alternative lines respectively.

The flooring under the bridges to be depressed 2 feet below the bed level, and extended to a length of 100 feet below the down stream head wall, terminating in a curtain ten feet in depth; a talus of boulders 10 feet in width, 2 feet thick, to be added for further protection.

Digitized by Google

A drainage cut leading into the adjoining valley of the Solanee has been estimated for to carry off the spring water when laying the foundations.

At all the bifurcations the Regulating Bridges have been placed as close as possible to the points of divergence, the actual position being determined by the width necessary for the bridge approaches between the branches, and the curve in the channel leading to the entrances of the locks.

The aggregate waterway under the bridge arches, is, in every case, equal, or nearly so, to the mean width of water section at full supply in the channel below.

The sluice arrangements are identical in all.

At the Junction Branch Head, 61st mile, a drop occurs in the bed. Overfalls are designed at the heads of both Branches in lieu of one descent immediately above the point of divergence, for regulating purposes; in the latter case, dam bridges, with numerous piers and narrow openings, would have been necessary in place of the wide arched bridges below the falls as now projected (*vide* Sheet 24.)

The depth of fall would also be restricted to that required for the junction line. 3·26 feet, necessitating an additional fall lower down on the alternative line.

Lockage into the junction branch is provided for on the left bank of the regulating bridge.

The bridges at the extremities of the tail basins are of exactly similar design to those constructed elsewhere on the line for purposes of cross communication only; towpaths 7 feet in width and a clear headway of 10 feet are provided for on the junction. On the other side, the aggregate span of the bridge is equal to the mean width of the water section in the channel below, the arches being sprung from the level of the full supply in the Canal.

At the Bolundshuhur and Koel Branch Heads the fall is placed above the bifurcation, no navigable communication being necessary, and consequently the height of the arches of the dam bridges less. In the former case an escape head is projected on the right bank, between the fall and the regulators, the effects of the rush of the water through which will be in great measure neutralised by the wide basin forming the Canal channel above.

Navigable communication with these branches has not been provided for; if found desirable hereafter, cross channels may be cut at a small expense to connect them with the old trunk line.

Escape Heads.

75. At the 51st mile, the upper escape into the Kalee Nuddee diverges. Here the works (*vide* Sheet 28) consist of a fall, 6 feet in depth, with a dam bridge below, the escape head being placed between the two on the left bank; the position of the overfall in this case being determined by the expediency of diminishing the height of drop at the tail of the escape as much as possible. The escape head itself is designed similarly to the regulator at Roorkee; arches of bridge 23 feet span, sluice openings 6 feet each in width, the aggregate waterway through the latter being 90 feet.

Digitized by Google

The second escape head from above the Bolundshuhur Branch bifurcation has a waterway of 60 feet in openings of similar width.

Overfalls at the extremity of each escape are designed, as shewn in Sheet 29 ; the drop there on the upper escape being 27 feet, on the lower 27·83 feet ; gratings and cisterns below the lower bed as for the Canal overfalls; deep foundations on wells. The height of fall may be thought hazardous; one, however, of somewhat similar design, 17 feet in depth, on one of the Baree Doab Canal Escapes, has now been in existence for some years, and has always acted very satisfactorily. In fact, where the height of drop is considerable, the water falls almost vertically, so that it is only necessary to provide against violent action immediately at the foot of the fall which, with a sufficient depth of backwater, is not a difficult matter.

The drop wall should be carefully backed with puddle, as shewn; and the cistern floor, if stone be not procurable at moderate cost, with brick *on end* of the very best workmanship and material.

Bridges for cross communication are provided on the lower escape; one for the East Indian Railway.

Bridges.

76. The general designs for the bridges on the alternative line are given in Sheets 32, 33, and 34. In the upper section, navigation is provided for by a clear headway of 10 feet above the level of full supply, and towpaths under the arches 7 feet wide on either bank. The aggregate width of waterway is projected equal to that of the water section in the earthen channel; arches below the junction branch head sprung from calculated surface level of full supply.

The widths of roadway between the parapets have been determined as in Sir P. T. Cautley's original design, *viz.*:—

For the main lines of road	25 feet.
District roads regularly lined out and constructed	20 „
Village communications	18 „

Invert arches, to form the floorings between arches, sprung from the level of the bed; foundations of waterwings and curtains laid from 6 to 8 feet below the bed level. With the reduced velocity a boulder or kunkur talus will hardly be necessary. Under the metalling of the bridge above, a layer of brick on edge, or kunkur masonry of similar thickness, to be laid from end to end between the kerbs.

Drainage Culverts.

77. For the passage of the minor country drainages, culverts under the channel are designed as shewn in Sheets 35, 36, 37, and 38.

The admission of drainage water into irrigation channels should never, I think, be allowed unless it be impossible to dispose of it otherwise. Only one instance where this is unavoidable occurs on the alternative line, at the 16th mile, for which an inlet of 10 feet waterway is designed. The waterway for the culvert to carry off the floods of the Seela Nullah, mile 8, has been determined from that of an existing bridge over it, close to the crossing point of the

Digitized by Google

Canal. The proper waterways for the others it is difficult to fix accurately, from the utter impossibility of ascertaining in so limited a time the quantity of water to be provided for at each drainage line. They have been approximated to as nearly as the data procurable would admit; but this, I confess, is the most unsatisfactory part of the entire project.

Rajbuha Inlets and Outlets.

78. Inlets and outlets have been provided for all rajbuhas or main watercourses, at or near their present crossing points; the general design is shewn in Sheet 37.

Chokies.

79. Accommodation for chokeedars, or watchmen, and store room for sluice gear, &c., has been provided at each fall or dam bridge. The general design for these buildings is shewn in Sheet 38. The arched masonry roof, in lieu of a flat one supported by wooden rafters, will, it is considered, be more economical in the end, from its superior durability; and the estimated cost is little greater than that of similar structures on the old plan.

First class Chokies on the standard plan of those on the Ganges Canal have been estimated for, at intervals of 12 miles on the upper section (or first 61 miles) only. Two second class Chokies between each. Below the junction branch head the line will run so close to the present main channel that separate first class accommodation seems unnecessary; second class chokies only have accordingly been estimated for, at intervals of about 5 miles.

Well Foundations.

80. Metalling has been estimated for on all bridges, and for a certain length of the approaches on either side.

The deep foundations of all works from the 123rd mile downwards have been projected on undersunk wells, and estimated accordingly; the longitudinal section shews that the surface of the springs all along this portion of the line stands either at, or close to, the proposed level of the bed.

Sixty-seven bridges, including those at falls and branch heads, have been estimated for, giving crossing points at average intervals of 2½ miles on the entire distance, 165 miles, from Roorkee to Nanoon.

No ghâts, either in connection with, or separated from, the works, have been estimated for.

Here the descriptive detail of the alternative line closes; with the aid of the plans and the tabular statements in appendix B., I trust it will be sufficiently intelligible.

Alterations to main line if alternative line be adopted.

81. If the alternative line be adopted, the following additions and repairs will be necessary to the adjoining portions of the existing line, and have been estimated accordingly.

Bars of earth to be thrown across the present bed at intervals of 500 feet, wherever deep channelling has taken place; the top of each flush with the original level of bed, and 10 feet in width; the spaces between these being left to silt up gradually by the deposit of sediment from the Canal water.

The towpath on the left bank, from Roorkee to the Futtehgurh Branch head, and again from Jutpoora Bridge to the head of the Cawnpore and Etawah branches, 131 miles in all,

Digitized by Google

to be thoroughly repaired; and to be cut down, wherever the height is excessive, to a uniform level above the bed.

At the overfalls, a drop wall to be built, as described for the remodelling, the entire width of the bays, on the present ogees, under the down stream head wall of the bridge; bridge piers to be lengthened, and new piers constructed similarly for the support of gratings of a length suitable to the reduced depth of water. The lower floorings to be removed to a depth of four feet for a length of 40 feet below the new drop walls, thus forming a cistern below the level of the bed; with the reduced volume of water falling into this cistern, it will be sufficient protection to cover the flooring with a layer of brick on end.

At the Futtehgurh Branch head, the bay on the eastern bank of the Futtehgurh Branch to be left free for the passage of boats; iron grooved uprights and wooden sluice gates to be attached to the other arches as designed for the remodelling, the closure when necessary of the cistern bay being effected by an iron drop gate.

To the regulating bridge on the main channel no additions appear necessary. When the Futtehgurh Branch is taking off its full supply, it will be necessary to shut up several of the openings in the main line regulator entirely, for which the present sluice apparatus will answer.

Under the left arches of all the bridges from Roorkee to the Futtehgurh Branch head and from the Jutpoora Bridge to Nanoon, 40 in all, towpaths will be required 7 feet in width. Alterations at the Cawnpore and Etawah Branch heads, the same as for remodelling.

SEPARATE NAVIGABLE LINE.

82. The main lines of artificial irrigation channels in flat countries are, as a rule, and for obvious reasons, carried along the several watersheds, independently of the positions of towns and villages; and this is also the most economical course, both as regards cost of construction and after-maintenance, the interference with the flow of the natural drainage being the least possible. When, however, the object is solely navigable communication, a Canal would, it is manifest, lose much of its value were it not brought close to the large markets. The actual course of the proposed navigable channel from Roorkee to the head of the Cawnpore and Etawah Branches has therefore been determined by the position of the larger towns situated in the general direction, wherever the levels of the ground in their vicinity would allow of carrying the bed either horizontally or on a continually descending slope. This of course raises the cost materially, as they, in common with all towns of any magnitude, are invariably situated close to the drainage outfalls, where water either flows or collects in considerable quantity at some season of the year.

Course of line, and how determined.

The line of levels on which the estimate is based (*vide* Plan IV.) is identical with that of the alternative channel from Roorkee to the watershed between the Hindun and West Kalee Nuddee at the 17th mile, whence it diverges to the westward

Digitized by Google

of Deobund, passing close to the town ; thence it runs in nearly a direct line to Mozuffurnuggur, crossing the West Kalee Nuddee about 3 miles above the town ; it joins the Ganges Canal a little above the Kutowlee Bridge, whence it issues a few hundred feet lower down ; and taking a slightly circuitous route parallel to the Canal for some miles, to avoid the drainage into the Aboo Nullah, reaches the city of Meerut ; from this it passes along a watershed down to Haupper, aud about 5 miles further on crosses the Choya Nullah, a large feeder of the East Kalee Nuddee ; a little in advance of this the line reaches the central watershed of the Doab, and, passing close to the westward of Bolundshuhur, rejoins the Ganges Canal close to the Grand Trunk Road Bridge ; from this it turns off to the town of Khoorja, where it again meets the proposed course of the alternative line, from which it finally diverges at the 138th mile, inclining to the westward to reach the town of Koel, from which it passes in a direct line to its junction with the Canal above the Nanoon Regulator.

Section of channel and declivity.

83. The dimensions of the water section of channel, and the waterways of bridges and locks, have been fixed at the minimum which I believe to be absolutely necessary for boats propelled by cattle haulage, which, I have before stated (para. 41), seems to me best adapted to the habits of the people. It has, however, the advantage, in comparing the cost with that required to give efficient navigable communication along irrigation lines, of showing the smallest outlay at which it is possible to construct a separate channel for the navigation only. On the main lines of the Ganges Canal, the width and depth of water, it must be borne in mind, will admit of the passage of small steamers. In the annexed Statement are embodied certain details of Canals in different countries, from which may be gathered the dimensions considered necessary for various kinds of craft.

Digitized by Google

Tabular Statement showing certain details of various Canals.

Country.	Names.	Channel.		Locks.		Remarks.
		Width at Water Line.	Depth of Water.	Length.	Effective Width.	
America ...	Chesapeake and Ohio ...	48	5	102	14	Recommended by Board of Engineers in 1826.
Ditto ...	Welland ...	58	8	110	22	
Ditto ...	Ditto ...	...	...	130	32	Below St. Catherine's. } From Report of 1839, by Lieut. Col. Philpotts, R. E.
Ditto ...	Ditto ...	...	...	130	24	At Port Colborne on Lake Erie.
Ditto ...	Ditto ...	70	8·5	110	24	For Schooner Traffic. } Recommended in 1837, by C. E. Section.
Ditto ...	Ditto ...	...	...	180	45	„ Steamers.
Ditto ...	Ditto ...	...	9·5	150	26·5	For propellers of from 300 to 500 tons, (from Lieut. Haig's Notes.)
Ditto ...	St. Lawrence ...	...	9	200	45	For Steamers, (ditto.)
Ditto ...	Ditto ...	140	10	200	55	Will pass Steamers 180 feet × 52 feet. } Lieut. Col. Philpotts.
Ditto ...	Ditto ...	48	5	100	20	Not wide enough for large Steamers.
Ditto ...	Erie Canal ...	60	7	...	...	
Ditto ...	Morris Canal, New Jersey...	32	4	...	...	Boats 8·5 feet broad, 60 to 80 feet long, from 25 to 30 tons burthen.
Ditto ...	Pennsylvania ...	...	...	...	...	Boats 12 to 15 feet broad, 80 feet long; when loaded with full number of passengers draw 1 foot of water.
France ...	North-Western Districts ...	...	5 to 7	100	18	Haulage by horses. Boats from 500 to 200 tons.
England ...	General Sections ...	...	...	...	7	Boats 30 to 35 tons.
	Ditto ...	40	...	...	{ 14 18 }	} Ditto 60 to 120 tons.
Scotland ...	Forth and Clyde ...	40	9	68	15	Screw Steamer navigates throughout.
India ...	Madras Coast Canal ...	...	...	...	20	

The section here estimated for is 20 feet wide at bottom with side slopes of 1 in 2, and depth of water of 5 feet, giving a total width at the water line of 40 feet.

The declivity of bed, 1 in 12,000, is calculated to give a mean velocity of current in the channel of 1·5 feet per second (or about 1 mile per hour), the least, as far as can be ascertained at present (*vide* Appendix D) which will prevent the growth of weeds; it appears to be also, from the experience on the Madras Canals, (*vide* Report by Sir A. Cotton dated 16th June 1852, and elsewhere,) the maximum for economical navigation.

The general form of banks is shown in Plan VII. The towpaths 1·5 feet above the surface of full supply, 20 feet in width, to afford space for the passage of wheeled vehicles all along the line.

The depth of water will doubtless, be diminished materially at certain points by absorption and evaporation; no feeders from the main Canal, however, appear necessary; the requisite supply can always be obtained from some of the numerous rajbuhas which intersect the line from Mozuffurnuggur downwards.

Locks.

84. The general design of the locks, 30 in number, is given in Sheet 39 Plan X. They are projected in two chambers, each 16 feet in width, with a clear length of 100 feet; a bridge carried across both chambers below the lower gates with a clear headway under the arches of 10 feet; the width of roadway determined as for ordinary bridges. The gates of iron with sluices in each leaf; opening and closing effected by chains passing under pulleys in the side walls and worked by crabs from above. Inlet and outlet passages of masonry provided round each set of gates on the land side. The detail of the masonry work is almost identical with that of the present Ganges Canal Locks.

The depth of drop is in general 6 feet, but ranges from 281 to 12 feet.

The design for locks at the departure from and junction with the Canal are shewn in Sheet 39.

Aqueducts.

85. Three aqueducts are required; two over the West Kalee Nuddee, the third over the Choya Nullah above Bolundshuhur; the general design is given in Sheet 42. The waterways for the floods of the rivers are determined as for the alternative line; the flood discharge to be provided for at the crossing of the Choya being estimated by a comparison with the actual waterway of the bridge across the East Kalee Nuddee at Bolundshuhur; the waterway of the bridge on the Grand Trunk Road, which crosses close to the line of levels, would have given a more accurate basis for the calculation; the actual dimensions were not, however, procurable at the time.

The width for the Canal channel is 30 feet in the clear with towpaths 5 feet wide on one side, 10 feet on the other, the additional width on the latter being given to admit of the passage of wheeled vehicles.

The foundations of piers, abutments and waterwings to be on wells sunk 12 feet below the beds of the nullahs, kunkur

Digitized by Google

flooring under the arches, and the details of the masonry work similar to those of the alternative line aqueducts.

Masonry walls in the centre of the embankments leading to these aqueducts, to prevent the encroachments of vermin, are not included in the estimate: the risk of injury, with so small a depth of water, does not appear to me sufficiently great to justify the extra expense; cores of sand in a similar position filled in as the banks are made up would, I think, answer every purpose; leakage need not be apprehended except in soils saturated with "reh" or other deliquescent salts.

86. Culverts and syphons for the passage under the Canal of the country drainage will be similar to those on the alternative line, the only difference being in length of archways, which is here invariably 89 feet. The tabular statement shews the several positions and waterways of these works. Drainage Culverts, &c.

Syphons for the passage of the various rajbuhas or main irrigation water-courses under the Canal are estimated for; the general design is shewn in Sheet 43. Cross communication is provided at 87 points along the entire distance—164 miles—giving one passage at an average interval of about 2 miles: on the alternative line the interval was about 2½ miles, the difference being owing to the latter passing at some distance from almost all the more crowded thoroughfares: 28 of these are provided for at locks, the remaining 59 by bridges, the general plan of which is figured on Sheet 41. The headway under the arches is 10 feet; towpaths 6 feet in width on each side, width of waterway 22 feet, thus making the span of the arch 34 feet over all. Depth of curtain and waterwing foundations 6 feet in general. The details of floorings, roadways, &c., identical with those on the alternative line.

87. Store-rooms or chokies as before described are estimated for each lock and point of junction with, or departure from, the Main Canal. Chokies.

88. From the 118th mile downwards the deep foundations of all works in the channel are estimated on wells sunk 8 feet below the bed level, water lying close to the surface everywhere. Well Foundations.

Digitized by Google

RATES FOR ESTIMATES, GANGES CANAL.

N. B.—Rates in Rupees and decimals.
Dimensions in English feet and decimals.

Description.		@	Per	
			Cubic feet.	
Excavation—				
Alter. line, 1st Section	...	2·75	1000	
" Embankment at Kalee Nuddee	...	8·00	"	
" 2nd Section	...	2·50	"	
" 3rd "	...	2·50	"	
" 4th "	...	2·50	"	
Extra excavation	...	2·2	"	
For foundations	...	3·25	"	
Navigable line	...	2·25	"	
Widening present Ganges Canal	...	2·00	"	
Approaches	...	3·0	"	
Brickwork—				
Plain, heavy	...	20	100	
Fine	...	24	"	
Brick on edge	...	25	"	
Arching, heavy (including centrings)	...	32	"	
Do. light (Ditto)	...	28	"	
Inverts	...	26	"	
Kunkur Masonry—				
Plain, heavy		17	"	
Fine	...	20	"	
Arching, heavy (including centrings)	...	28	"	
Ditto, light (Ditto)	...	24	"	
Boulder Masonry	...	14	"	
Rubble (Kunkur) Masonry	...	14	"	
Flooring (dry) kunkur	...	8	"	
Metalling Roadways	...	6	"	
Puddling	...	10	1000	
Agra Stone flooring	...	3	Cubic ft.	
Delhi Do.	...	3	"	
Flooring boulders (dry)	...	7	100	Carried by boats.
Pitching kunkur or boulders	...	10	"	
Undersinking wells, "large"	...	7·0	Rg. ft.	
" " "small"	...	5·0	"	
Well Curbs, "large" (17')	...	90	each.	
Do. "small" (6')	...	20	"	
Thatching slopes	...	0·5	100 Sq. ft.	
Planking 2" over green work	...	0·2	Sq. ft.	
Rubble, filling in wells	...	12	100 cub. ft.	
Staking to support slopes, &c., 10 feet deep	...	2·5	Rg. ft.	
Piles, 18'	...	3·0	each.	Includingdriving.
			Cubic ft.	
Boulder crib work	...	12	100	
Boulder flooring dry (on alternative line)	...	10	"	

Digitized by Google

Description.	@	Per
Stone Grooves ...	1·0	L. ft.
1st Class Chokies, Ganges Canal pattern ...	3200	each.
2nd do. do. ...	800	„
Sal Kurries, 10 feet long ...	1·5	„
		Cubic ft.
Puddled clay backing ...	3·0	100
Removing old boulders or kunkur flooring ...	7·0	1000
Demolition of brickwork ...	1·0	100
Piling, 12 feet long, including driving ...	5·0	L. feet.
Regulating Bridge Gear.		
Cast iron uprights, grooved ...	9·4	L. ft.
do. Grooves (0·5 feet wide) ...	5·0	„
Windlasses, 6·5 feet long ...	22·0	each.
Do. 20 do. ..	66·0	„
Iron drop gates ...	5·0	Sq. ft.
Wooden do. (width, 6 to 7 feet) ...	1·25	„
Lifting Chains, small ...	0·9	L. ft.
Do. large ...	1·0	„
Axle Blocks, large ...	12·0	each.
Do. small ...	5·0	„
Sleepers ...	3·0	Cubic ft.
Hooks for lifting sleepers .	7·0	each.
Lock Gear.		
Lock Gates, Iron ...	6·5	Sq. ft.
Sluices in gates ...	125·	each.
Crabs ...	135·	„
Pulleys ...	5·	„
Chains ..	1·0	L. ft.
Fall Gratings.		
Iron girders (11·5 to 15 ft. long, 7 to 9 feet apart)	4·25	L. ft.
Iron grating bars ...	0·875	„
Wooden do. do., 29·0 × 0·5 × 0·5 ...	21·75	each.
Wall plates, iron, complete ...	6·25	L. ft.

Digitized by Google

RATES, MATERIALS, &c.

Rates how obtained.

89. The annexed table shews the rates on which the estimates generally have been calculated. They have been fixed by a comparison of the actual rates of work now obtaining in the several Canal divisions, or, where the description of work had not been previously executed there, from the most reliable sources.

Stone.

90. Bricks must still be our mainstay in the construction of masonry works, for, notwithstanding all that has been said and written about the sandstone of the Sewalik Hills, in the neighbourhood of Hurdwar, all the information we have hitherto been able to glean both as regards quantity and quality as well as cost, is very unsatisfactory. The officer appointed to search for it, Mr. J. Kelly, was unable to commence operations before the beginning of last April when but three months remained till the setting in of the rains, during which, from the deadly nature of the climate, no European or native can, without risking his life, continue in the neighbourhood. His researches, however, prosecuted vigorously for the time they lasted, have only confirmed the general correctness of Sir P. T. Cautley's views. Sandstone of sufficiently good quality *is* to be found but in small seams here and there at considerable intervals; good stone close to the surface, the quality deteriorating as the quarrying penetrates into the hill side; and as to cost, it was found that blocks of sufficient size and weight for our purposes could not be turned out, hammer dressed, and loaded in boats, for less than 14 annas to one rupee per cubic foot. If to this be added the cost of carriage to the works, 8 annas (or 0·5 rupee) per 100 cubic feet per mile by carts, or 5 annas (0·31 rupee) by boat down the Canal, and setting, I do not think it can be safely rated in the work at less than Rs. 2 per cubic foot. The Delhi sandstone, latterly used for repairs to the fall floorings, does not cost less *laid into the work* than Rs. 3 per cubic foot; and this in cases where the distance of carriage is 70 miles, 18 of which is by carts, the remaining 52 by boats up the Canal. These rates might certainly be improved on were quarrying operations carried out on a large scale; but even were the rates of the Hurdwar stone to come down so low as one rupee per cubic foot *laid into the work*, the cost of the limited extent of stone covering estimated for the Muhmoodpoor Fall flooring would equal that of a grating only; and with the latter protection, and a cistern below the fall, it has been shewn above that good brick covering has been found to last well under similar circumstances elsewhere. Now, as first rate brick on edge (or on end) facing can be executed for Rs. 25 per 100 cubic feet (or ¼ rupee per cubic foot), it appears to me that the substitution for it of stone, except under very peculiar circumstances, to ensure a greater degree of safety, would be an unjustifiable expense. The only positions, therefore, for which it has been estimated in these projects are the tops of cistern walls, &c., and the floorings immediately under the gratings in the present overfalls, where the formation of a cistern below the level of the bed appears impracticable. The cost of such a covering at the Muhmoodpoor and similar falls, upwards of Rs.

Digitized by Google

16,000 for each, forms, it will be seen from the estimate, a very large proportion of the total outlay.

91. All the rates of these estimates are somewhat in excess of those at which work is now executed on the Canal. Plain brickwork costs from Rs. 16 to 18 per 100 cubic feet. The rate for this in the estimate is Rs. 20. On the alternative line, a slight advance on existing prices may be expected on account of the large demand for materials; and if the remodelling of the present Canal be adopted, the excess will be necessary to cover the cost of pumping in laying foundations.

These rates are much in excess of those obtained in the original construction of the Canal (except in the works from Hafiznuggur upwards). Referring to the Ganges Canal Report, Vol. II., pages 179-182, the average rates of building were, at Muhmoodpoor Falls—

		R.	A.	P.		
Masonry	Rs. ...	12	10	6	per 100	c. feet.
Plaster	" ...	4	14	2	"	"
Nirgajnee (or Bailra) Falls—						
Masonry, including plaster	Rs.	13	4	4	"	"
Jaolee Falls—						
Masonry	Rs.	12	7	8	"	"
Plaster	...	4	0	4	"	"

Now, although, as is stated there, old bricks, from some ruins in the vicinity were used to a certain extent in the works, these rates are less than really good brickwork can possibly be constructed at, and the consequence is manifest in the inferiority of materials and workmanship.

At Hafiznuggur Falls, the rate for masonry was Rs. 17-3-11 per 100 cubic feet, and at the Puttree Works, (page 87)—

Masonry (plain)	Rupees	16	13	8	per 100	C. Feet.
Archwork	"	23	15	1	"	"

The rate for arches over 30 feet in span, Rs. 32·0 per 100 cubic feet, including centrings, is based on that for brick on edge, Rs. 25 per 100 cubic feet, the addition for the centrings being obtained from the cost of bridges above Roorkee, where the same wooden centrings were used for several arches. The construction of the Punjab Railway, the route of which is traced on Plans I and II, will not, I think, materially, if at all, affect the rates of labour or materials; there are no masonry works of any magnitude along the line, and the earthwork is nowhere heavy. In the districts affected by the East Indian Railway opposite Delhi, I found by enquiry on the spot that the rate of coolie hire and excavating rose during the construction of the very heavy railway embankments across the vallies of the Hindun and Jumna rivers, but fell again immediately on their completion, and at the date of my enquiries it was at its usual figure. In fact, a permanent rise in the price of labor can only follow a general increase of wealth and prosperity in the country; the construction of the largest public works can only affect it locally and temporarily.

Digitized by Google

Since the Ganges Canal was opened in 1854 wages have undoubtedly risen generally throughout the country; the increase is more apparent in the lower districts. In the [illegible]pore Division of the Canal I was informed by Mr. [illegible] the late Executive Engineer that within his knowledge the pay of common masons had risen from 3 annas to 4 annas per diem, excavation by contract from one-fourth to one-third higher than formerly, and other descriptions of work in proportion.

Bricks 1 foot x ½ foot x [illegible] feet cannot now be manufactured at a less rate than from Rs. [illegible] to Rs. [illegible] per 100,000, owing to the rise in price of all kinds of fuel.

Bricks 10 inches x 4¾ in. x 2¾ in., or 1200 to 100 cubic feet of brickwork, burnt at Delhi in large quantity for the Railway works there, cost from Rs. [illegible] to Rs. [illegible] per 100,000 *at the kiln*. The latter size has been found the most economical in building on the Canal works as well as elsewhere, and is being gradually introduced in place of the old one of larger dimensions.

Boulders.

92. Boulders are delivered at present at the [illegible] works, 6 miles above Roorkee, at the rate of Rs. 4-5 per 100 cubic feet; they have been carried by boats at various times for the repair of works 14 to 20 miles below Roorkee; and from the present rates of carriage, they can be economically used for rubble masonry and [illegible] work as far down as the Muhmoodpoor Falls, 31st mile, or even farther.

Kunkur.

93. Kunkur blocks were used for [illegible] at the Nirgajnee Fall, 42nd mile, brought from a quarry 10 miles distant, close to the West Kalee Nuddee. It is of too open a grain to be of much value for building, where the pressure is great; but it appears to stand the erosive action of water well, and would answer admirably for rubble work. From this downwards the material is procurable with more or less facility; but really good kunkur, of compact texture, which will stand pressure, is not found much above the Bolundshuhur Branch Head at the 110th mile.

In the original construction of the Ganges Canal Works below this point it was extensively used; a large proportion of the masonry on the line of the East Indian Railway is constructed with it; and from the present condition of all the works built of it, it appears preferable to brick, if care be taken in the selection according to the amount of pressure or wear it may have to sustain. The Mahommedan engineers of bygone years used it largely in their works wherever it was to be found; the roadway of one of their bridges, still in good preservation close to the once extensive city of Sirhind on the old line of road between Delhi and Lahore, is paved with kunkur, brought, it is said, from a quarry still in existence in the valley of the Sutlej, some 20 miles distant, which even now is worn through in very few places, though till within the last few years a heavy traffic was, for, we may say, centuries, constantly passing to and fro over it. The largest proportion of the masonry in these projects, except heavy arching, has accordingly been estimated at kunkur rates wherever the material is known to exist; the rates are based on those actually obtaining on the Canal Works, with an addition to cover the price which will probably have to be paid

Digitized by Google

to the owners of the land in which the material may be found, the demand of late years having given it a value it did not formerly possess.

94. Timber of all descriptions has risen greatly in price, owing to the heavy demand for railways and other large public works throughout the country. The rates for iron and framed wood work are those at which the Roorkee Workshops can now supply them. Wood and Iron-work.

95. In Appendix G. will be found a statement of the total outlay on the Ganges Canal from the commencement up to 30th April 1863, divided into two periods, before and after the 1st August 1854, the date of the introduction of the Central Office system of Accounts. The Canal was formally opened three months previously, in April 1854, so that the expenditure shewn for the first period may be taken without much error as that incurred before the commencement of irrigation. The percentage of establishment on the total outlay, including contingencies, during that period was 9·9 (say 10) per cent. On the Baree Doab Canal Works in the Punjab it was 10·6 per cent. In present estimates I have taken it at 7 per cent, as the new works lie either on existing lines or in the Canal districts where the services of the present establishment will be available to a certain extent. The allowance for contingencies, rated on the estimated cost of the works, 5 per cent for remodelling existing lines, is intended to cover all expenditure on such items as conservancy arrangements, Office contingencies, temporary shelter for work-people, tools, &c., and possible excess of cost from unforesen circumstances; with the addition on the alternative and separate navigable lines, of compensation for trees, wells, &c., taken up with the land, and "survey and lining out," where it is increased to 8 per cent. The last item has been taken from results on the Baree Doab Canal Works, (where it was about 10 per cent) allowing for difference in labor rates, as I do not know the exact nature of the charges included in the Ganges Canal Statement under the heads "Sundries" and "Contingencies." Precentage for Contingencies and Establishment.

96. I have stated above in para. 91 that the rate for masonry in remodelling the existing lines has been taken somewhat in excess to cover the cost of pumping in the construction of foundations below the bed where springs will in every case be more or less troublesome. From notes made by Lieutenant Forbes, R. E., Executive Engineer of the Northern Division, Ganges Canal, when repairing the floorings of the present overfalls, where the surface of the springs is above the bed level, the cost of baling averaged Rs. 3 per 100 cubic feet of masonry laid in. The estimated rate for *all* the masonry work in the remodelling project is about Rs. 1½ per 100 cubic feet in excess, which will, I believe, be ample to cover all expenses in this item. Pumping or baling.

Digitized by Google

COMPARISON OF PROJECTS AND TOTAL COST.

Advantages and disadvantages of alternative project.

97. The advantages of a duplicate line below Roorkee are thus summarized in the Memo. of the Committee (Appendix A.) "First, the facility of construction, and of forming a reliable estimate of cost and time of construction; and second, the very great convenience that may be anticipated from the possession of a duplicate line of main channel throughout so great a distance, which would admit of a supply of considerable amount being sent down to the lower parts of the canal, while either of the alternative main lines was closed for repairs." Sir P. T. Cautley in his Memo. *(vide* same Appendix) adds another, *viz.*, " dealing with more manageable masses of water."

The disadvantages are stated to be, that the alternative line "in part, at least, must probably be regarded as not available as an irrigation channel, inasmuch as the supply of water is hardly sufficient for the works already designed and in course of completion in the lower Districts of the Doab; that it involves the passage of the drainage of large areas of the Doab"; and—" further, although the works will be less difficult, they will in absolute quantity be heavier, and require more material, the material again requiring land carriage to a greater extent than would be the case on the open canal." To these are added the waste from absorption and evaporation (which would be nearly double that in a single channel) and the largely increased expense of subsequent repair and maintenance, including establishments.

The absolute necessity of maintaining uninterruptedly the present volume of water to supply existing irrigation, unless there be very cogent reasons to the contrary, is assumed by all.

The present channel can, by careful watching and timely repair, be made to carry this supply until the completion of the duplicate line; but the latter, it must be borne in mind, will only relieve the present line *below* Roorkee. It has been shewn above that extensive alterations are required in the channel above that point, where there is no possibility of making a supplementary line; a regulating bridge must also be constructed across the present channel at Roorkee, at the proposed bifurcation of the duplicate line. Now the alterations to the channel and works above Roorkee must be effected with a dry canal, as it would be economically, if not physically, impracticable to divert the canal supply even temporarily round such works as the superpassages at the Puttree and Ranipoor and the Escape Dam at the Rutmoo: even at Roorkee, this would be no easy matter, hemmed in as the canal is, by buildings, &c., on either side, and in such close proximity to the edge of the high bank of the Ganges valley.

The new works and alterations in remodelling the line below Roorkee, at least so much of them as lie below the full supply level, may, I think, be completed, if materials, &c., be ready on the spot, in very nearly the same time as those in the Ganges valley. In this point of view then there does not appear to be much in favor of the duplicate line. The foundations of the works in the latter however would, with the exception of the aqueducts, be laid on a dry subsoil for the first 121 miles, below which the section shews springs

Digitized by Google

close to the surface, and wells must be undersunk for all deep foundations on the last 44 miles to Nanoon.

The aqueducts and embankments across the Kalee Nuddeed valley are necessarily large and massive, and judging from the experience on other similar works, could hardly be completed under four or possibly five years. The syphons and culverts for the passage of the minor country drainages may hereafter prove insufficient, as it is impossible to foresee how much additional duty may be thrown on them when the subsoil has become fully saturated by constant irrigation.

98. The volume to be dealt with does not appear to me to affect the question much if the velocity in the earthen channel be reduced to a safe limit, and the form and depth of the overfalls be such as to prevent too violent action on the masonry; whilé at the same time confining the irregular action within the limits of the walls or other protective works. If the existing line be remodelled so as to effect this, (and there is no reason against it except difficulty of execution) the trifling repairs which might be necessary could be made by shutting the canal for a few days or a week or two at farthest; nor would this, I believe, be required except at long intervals. **Effects of division of supply.**

The additional loss by absorption and evaporation is, I think, a weighty argument against any division of the supply in the trunk line. Though the total wastage will eventually, when the soil becomes fully saturated, be a fraction of what it appears to be now, absorption there must always be to some extent, and the evaporation is of course constant. Data are not in existence for the exact determination of either, but the proposed division of the supply would at least double it, whatever the amount may be.

99. For the upper 60 miles of its course the alternative line would be useless as an irrigating channel, no water being available for lands not included in the original project, the limits of which it does not reach till opposite Sirdhannah, at the lower passage of the West Kalee Nuddee. **Alternative line non-irrigating for 60 miles.**

100. The reduction of the supply in the present channel to a depth of 4 feet must, to a certain extent, affect the irrigation more or less from Roorkee to Sirdhannah. Above the Futtehgurh Branch head, the depth of full supply at present averages about 6 feet, which would be thus reduced by two feet. For this there is no remedy in the outlets above the Hafiznuggur falls; those lower down may be removed to the fall next above, and so obtain a larger supply by a drop at the head; from the Futtehgurh Branch head to the Sulawur falls the supply must be obtained by planking up the bays of the overfalls Below Sirdhannah, I have elsewhere shewn, the present irrigation will be unaffected by the changes in channels. **Effect on existing irrigation.**

101. "The obvious advantage of remodelling the present canal," as stated in the Memo. above referred to, "is that it will admit of the general design of the works being maintained almost intact, and will interfere very little with the system of minor irrigation channels already in existence." The excavation also would be small, and the quantity of material for masonry works very much less than in an entirely new channel. **Advantages of remodelling.**

Digitized by Google

In the project now submitted it will be seen that every one of the existing masonry works except a few irrigation outlets have been retained; and that it is only necessary to increase the waterways of the 5 bridges between Roorkee and the Futtehgurh Branch head; while on the alternative line project such large works as the regulating bridges at the heads of the Boolundshuhur and Koel branches will be rendered useless, as well as the greater proportion of the works from the Futtehgurh Branch head to the [illegible] bridge below [illegible].

Probable necessity of closing canal temporarily.

102. The argument of greatest weight, in my opinion, which can be urged against the remodelling scheme, is the probable necessity of closing the canal for perhaps a whole year, in order to get in the foundations of the new works. In Appendix F. are given the levels of the surface of the water in wells at different points along the main line and Cawnpore branch of the Ganges canal, with the corresponding levels of the canal bed opposite or nearest to each, from which it appears that the spring level is generally above the bed, and in the more sandy tracts and close to the water's edge, as at the [illegible] bridge, it stands as high as the surface of full supply in the canal. If then even temporary diversions were made to carry the supply round the new works while they were being constructed, it is more than probable that water would stand at some height in the portions of canal channel thus shut off, which it would be next to impossible to keep down to the level of the bed; if the water stood only at the latter level, experience has shewn that the floorings and shallow foundations can be laid in by the aid of pumping or bailing, and for all deeper foundations such as curtain walls, &c., wells can be undersunk. Diversions, however, on the line above Roorkee, for alterations to some of the principal works there, are, as I have shewn in para. 97, clearly out of the question, and these alterations cannot be effected within the period of an ordinary closure. The necessity then of shutting off the canal supply for at least one irrigating season, or half a year, appears inevitable; and to do the work satisfactorily, and give time for the larger masses of masonry to harden sufficiently, an entire year would, in my opinion, not be too large an allowance. This will increase the expense by the loss of a year's water rent, and compensation which must be given to cultivators to enable them to open wells, &c.; but the work will be done better, and after all a year's stoppage is not much in the existence of works destined to last perhaps for centuries.

Nearly the whole of the alterations for remodelling above the present surface of full supply can of course be executed with a running canal.

Cost of each project compared.

103. And, lastly, the comparative expense of the two schemes. The estimated cost of construction is shewn in the abstracts appended to the Report. To this must be added for the alternative line the probable compensation for land occupied (area shewn in Appendix H.) From statements given in the Census Report of 1st January 1853, the average tax on lands, assessed and unassessed, in the Seharunpoor, Mozuffurnuggur, Meerut, Bolundshuhur and Allyghur Districts, appears to be about Rupees 1·2 per acre; if we take double this for the total value, and 10 years' purchase as the selling price, the compensation will be within the mark at Rupees 24 per acre.

Digitized by Google

To arrive at the total probable outlay on the works for re-modelling we must add—first, the probable amount of remission of land revenue solely due to canal irrigation; second, compensation to enable cultivators to re-open new wells or repair old ones for the supply of water to lands in cultivation previous to the receipt of canal irrigation; and thirdly, the loss of a year's water rent in case of the canal being closed for that period.

The increase to the land tax now realized, solely due to irrigation from the Ganges Canal, is, from *rough* statements, kindly furnished to me by the District officers, as follows:—

In Seharunpore	Rs.	4,630	14	0
Mozuffurnuggur	„	91,158	0	0
Meerut	„	20,000	0	0
Total		1,15,788	0	0

or say Rupees 2,00,000 in the aggregate for all the districts down to Cawnpore.

The total area irrigated by the Ganges Canal channels during the last year 1863-64 was 449,788 acres. "Kutcha" wells, *i. e.* without masonry lining, will answer all needful purposes for so short a period, especially as the level of the springs in the irrigated districts is nowhere far below the ground surface. One such well, it is estimated, is sufficient for the irrigation of six acres, and would cost about Rupees 10. We shall be well over the mark, I think, if we take half the present irrigated area as requiring new wells; the amount of compensation will then be—

$$10 \times \frac{449,788}{2 \times 6} = \text{Rupees } 3,74,823.$$

The aggregate canal revenue during the past year 1863-64 was Rupees 7,73,390.

We have then for the alternative line—

Cost of construction as per Estimate, Rs.	70,67,380
Compensation for land occupied—Acres 10,625 @ Rs. 24	2,55,000
Grand Total, Rs. ...	73,22,380

For the remodelling from Roorkee to the head of the Cawnpoor and Etawah Branches—

Construction as per Estimate	Rs.	30,98,372
Compensation and losses if canal be closed for a year—		
Remission of land revenue	„	2,00,000
Compensation for wells	„	3,74,823
Loss of water rents	„	7,73,390
Grand Total	„	44,46,585

shewing an excess of Rupees 18,75,795 against the alternative line; nor does this represent the whole of the difference, the amount of loss by closure of the canal being debitable to the entire remodelling from the head, as well as to the portion below Roorkee.

As to the time which either project would probably take to complete, if men and money be available as required, Time probably occupied in construction.

Digitized by Google

three years will, I think, judging from the time required for the brickmaking, suffice for the remodelling; the alternative line must obviously be a longer business, depending mainly on the time required for the completion of the Kalee Nuddee aqueducts, which could hardly be less than five years.

Probable cost of diversions.

104. Supposing the construction of new falls, the alteration of old ones, and adding arches to the bridges below Roorkee were practicable with a running canal, the cost of diversion may be estimated as follows:—

The estimated rate for a temporary 8 feet fall is, *vide* Estimate 180, Rupees 59 per running foot; for earthen channels above Futtehgurh Branch head, Rupees 4,250; below that point they would average Rupees 3,350 each. If we take 150 feet as the minimum width of water-way above, and 115 feet below the same points, we have—

Cost of temporary fall above Futtegurh Branch head 150 × 59 ...	Rupees	8,850	
Channel ...	„	4,250	
			13,100
Cost of fall below do. 115 × 59	„	6,785	
Channel ...	„	3,350	
			10,135

And total for entire line from Roorkee to Nanoon, above Futtegurh Branch Head—

Round 4 *old* Falls @	13,100 each	Rs.	52,400		
3 new ditto @	4,250 „	„	12,750		
6 Bridges @	4,250 „	„	25,250		
				90,650	
Below ditto	ditto				
Round 6 old Falls @	10,135 each	„	60,801		
12 new ditto @	3,350 each	„	40,200		
				1,01,010	
			Grand Total, Rs.	1,91,660	

Navigation; general considerations.

105. In considering the advisability of forming navigable communications in connection with these irrigation works, either along the irrigating channels themselves, or by separate channels, the question of cost appears to me quite a secondary one. Whatever may be said of Sir Arthur Cotton's under-estimates of outlay and over-estimates of profits, the principle he has so long and ably advocated is undoubtedly true; that in no country,—and especially where the distances from the producing districts to the seaboard are long—can the material resources be fully developed without the aid of water communications. Railways can supply the wants of traffic in passengers and valuable merchandise of small bulk, better than any other known mode of conveyance, but they cannot now, nor ever will be able to carry the heavy and bulky raw materials, which form the staples of commerce in a country like this, at sufficiently low rates to admit of their being sold at the seaboard at remunerative prices. European and American experience prove it—and even in England with its net-

Digitized by Google

work of railways, and not a spot 100 miles distant from the sea—the prices at which canal shares are quoted, shows that there too the water traffic in the interior must be very extensive. It is calculated that Indian cotton, to drive American cotton out of the English market, must be delivered at the seaboard at 4 pence per pound, or Rupees $13\frac{1}{3}$ per maund of 80 pounds. Now the cost by rail from Agra to Calcutta, a distance of about 900 miles, including transit from the interior to the Railway Station, averages from Rupees 6 to Rupees 7 per maund, which would thus leave but $6\frac{1}{3}$ to $7\frac{1}{3}$ Rupees per maund for production, screwing, &c.; while a rate of Rupees 8 per maund is considered as hardly sufficient to remunerate the actual cultivator. Compare this with the carriage of a 400 pound bale for 1,000 miles down the Mississipi for $1\frac{1}{2}$ dollars (£0-6-3), or about $\frac{5}{8}$ths Rupee per maund, and it is easy to perceive that India, unless with the present exceptionally high prices, can never compete successfully with America in this article of trade.

Water communication where required.

106. Below Allahabad the Ganges is navigable at all seasons; boats of considerable size can pass up as high as Futtehgurh, except in a very dry year, when the passage may be closed for a couple of months.

Between Futtehgurh and Gurmuhteesur, navigation is stopped for 8 months in the year, except for small boats of from 50 to 100 maunds.

On the Jumna as far up as Agra, the boat traffic is considerable all the year round. For the districts above these points then, as far as the foot of the Himaylayas, water communication is needed. Whether this should be along the lines of irrigation canals, where they lie in the general direction of the country traffic, or by separate channels constructed expressly for the purpose, is mainly a question of comparative expense. The latter, however, would have so far the advantage in being carried close to the large trading marts, while the irrigation channels, as a rule, pass at some distance. The great drawback to any separate line scheme is the wastage by absorption and evaporation which is a clear loss to the irrigation.

Comparison of cost.

107. The probable expense of separate navigable lines, it will be seen from the estimates, is much in excess of what would be required to make the irrigation channels navigable throughout. The proportion of the cost of the navigable part of the alternative line, due solely to the navigation, is Rupees 5,52,494, while the cost of the separate channel for that distance, taking the average mileage rate of the channel from Roorkee to the Nanoon bifurcation is $\frac{64 \times 25,39,131}{164}$ = Rupees 9,90,848.

The latter sum, however, is considerably less than the actual cost of the separate channel *there*, the estimate for the aqueducts and their embankments at the Kalee Nuddee crossings alone amounting to Rupees 2,56,615, besides the excess in the lockage, thirteen descents out of the total number of thirty occurring in this portion of the line.

If again the total estimated cost due to navigation on the

Digitized by Google

whole distance between Roorkee and Nanoon be compared, we have—

On the alternative line project ...	Rs.	6,06,069
On the remodelled line	,,	11,44,688
while the estimate for the separate channel amounts to	,,	25,39,131

To the probable cost of a separate channel along the general line of the Cawnpore Branch, a close approximation may be made thus—

Total cost of separate channel as per estimate, without establishment and contingencies ...	Rs.	21,97,241	21,97,241
Deduct:			
Aqueducts and their embankments,	Rs.	3,10,154	
Lockage, ...	,,	7,51,505	
Chokies, ...	,,	10,899	
Bridges, ...	,,	3,65,865	14,38,423
Difference, Rupees			7,58,818.

The total length, exclusive of the embanked channels at the crossings of the Kalee Nuddee and Choya, is 160 miles.

We have then a mileage rate for the channel, including the excavation, drainage culverts, irrigation syphons and junctions with the main canal, of $\frac{7,58,818}{160}$ = Rupees 4,742·6. The length of the Cawnpore Branch to the top of the first descent at the terminal lockage is 169 miles, and the total fall in this distance is 190·26 feet, of which $\left(\frac{169 \times 5280}{12000} = \right)$ 74·36 feet would be due to the declivity of bed, leaving 115·90 to be disposed of by locks, say, 19 locks of 6·1 descent each.

From the detailed statement it appears that crossings are required at intervals of 2 miles. The total number of crossings required will therefore be $\left(\frac{169}{2} = \right)$ 84; of these 19 will be supplied at the locks; for the remaining, 65 bridges must be constructed, the aggregate of which will amount to $\left(\frac{65}{59} \times 3,65,865 = \right)$ Rupees 4,03,070. The total cost will then be as follows:—

169 miles excavation, &c., at Rs. 4,740 per mile	Rs.	8,01,060
19 Locks, at Rupees 25,200 each, ...	,,	4,78,800
65 Bridges ...	,,	4,03,070
19 Chokies, at Rupees 364 each ...	,,	6,916
	Rs.	16,89,846
Contingencies @ 8 per cent. ...	,,	1,35,187
		8,25,033
Establishment @ 7 per cent. ...	,,	1,27,752
Grand Total,	Rs.	19,52,785

The estimated cost of the alterations required for navigation on the existing irrigation line being	Rs.	4,26,843

Digitized by Google

The above estimates shew only the probable expense of the *construction* of the separate channels; if to these be added the compensation for land occupied, the total probable outlay will be as follows :—

From Roorkee to Nanoon.

Construction ...	Rs.	25,39,131
Compensation for land, 4,383 acres @ Rs. 24 per acre ...	,,	1,05,192
Grand Total,	Rs.	26,44,323

Nanoon to Cawnpoor.

Construction ...	Rs.	19,52,785
Compensation for land, 4,507 acres @ Rs. 24 per acre ...	,,	1,08,168
Grand Total,	Rs.	20,60,953

108. Considering then, the large additional outlay in first contruction and expense of future maintenance, and above all, the wastage of water involved in the projection of separate channels, the balance appears to me to be largely in favour of adapting all the larger irrigation channels for navigation. If it be found advisable hereafter, short channels from the trunk lines can, without difficulty, be carried into the chief trading towns, the escape water from which would pass off into some of the numerous watercourses, and thus be utilized for irrigation; and at the extremities of the canals, if the navigation be found to be obstructed at certain seasons, by a decrease in the supply of water, owing to the requirements of the irrigation, separate channels can be led off above the points where the obstructions are felt, rejoining the present lines at the junction lockage into the rivers as on the Cawnpore and Etawah Branches. The designs and estimates now submitted for separate channels, it must be recollected, are on a minimum scale ; the main line and branches of the Ganges Canal for 9-10ths of their length, would give a very much wider and deeper waterway.

Adaptation of irrigating channels for navigation preferable.

109. With the water communication thus completed along the centre of the Doab to the Ganges at Cawnpore, it will be quite possible to connect the Districts lying north of Delhie between the Sutlej and Jumna rivers. In a report on a canal projected from the Sutlej, lately submitted to Government, it was shewn that a navigable connection between one of its main channels and the Western Jumna Canal, below Kurnaul, was feasible. From this point, if existing obstructions be removed, the traffic may pass down the Delhie branch of the latter to within a few miles of the city of Delhi, whence a separate channel, provided with suitable lockage, would carry it into the Jumna, which may, I believe, (for there are no levels over the actual course) be connected at no great expense by a navigable channel with the main line of the Ganges Canal.

Connection, with navigable system, on West bank of Jumna, feasible.

This would give an uninterrupted water communication from all the northern districts lying between the Ganges and the town of Sirhind on the left bank of the Sutlej, to the seaboard at Calcutta. To the west of Sirhind, the export traffic would be conveyed by the canals there into the Sutlej; thence down the Indus to Kurrachee.

Digitized by Google

Navigation returns from Ganges Canal.

110. The nett profits from navigation on the canal during the last few years were as follow:—

1859-60	...	...	Rs.	47,220	
1860-61	...	...	„	1,12,757	Including some profits of previous years.
1861-62	..	...	„	55,725	
1862-63	...	...	„	46,834	

Were the existing obstructions to navigation removed, and the branch lines also made navigable throughout, there is little doubt that the returns would be vastly increased, probably seven or eight times greater than the largest amount hitherto realized.

Total probable cost of Ganges Canal.

111. The detailed estimates now submitted, I have elsewhere stated, refer only to the main line and the Cawnpore branch. With their aid however, and the statement of actual expenditure in Appendix G., we may arrive at an approximation to the total outlay required for the completion of the entire system of works. The total expenditure on all accounts up to 31st July 1854, before irrigation had commenced, was Rupees 1,41,83,146. If from this the cost of "Contingencies" and of "Establishment" be deducted, the percentage on the remainder for the former item is 0·7 for establishment; 9·9 on the total of the contingencies and outlay on works. Applying these percentages to the cost of "Original Works," and "Rajbuhas" during the second period, from 1st August 1862 to 30th April 1863, we have—

Cost of Canal Work and Rajbuhas, as per Statement	Rs.	55,86,524
Contingencies at 0·7 per cent...	„	39,105
Total	„	56,25,629
Establishment at 9·9 per cent...	„	5,56,937
Total cost since commencement of irrigation	„	61,82,566
Previous expenditure	„	1,41,83,146
Grand Total up to 30th April 1863	„	2,03,65,712
Of this the expenditure on the Cawnpore Branch was	„	17,87,762
And deducting cost of the terminal works in Cawnpore...	„	1,61,845
The cost of the channel above was	„	16,25,917

The estimated cost of remodelling the Branch amounts to nearly one-fourth of this; for the *Etawah* Branch it may be taken at one-fifth.

The total outlay on the latter will then probably be—		
Expenditure up to 30th April 1863... ...	Rs.	12,09,068
Add Contingencies and Establishment as above	„	1,28,999
Total... ...	„	13,38,067
Add one-fifth for navigation	„	2,67,613
Terminal lockage	„	80,000
Required to complete	„	4,47,613

Digitized by Google

The length of the Etawah Branch completed was somewhat in excess of 169 miles, about the same as the Cawnpore Branch, the discharge at the heads of both being identical. The difference in cost is accounted for by the reduced dimensions of section in the lower half of the Etawah Branch. For arriving at the cost of the other branches, which will only be secondary navigable lines, the lower estimate will, I think, suffice. From the estimates now submitted, one-tenth additional appears to me about the amount required to make these channels navigable when there is no lockage.

Assuming the cost to be proportionate to the several discharges at the head, we have for the Futtegurh Branch—

Cost of channel without overfalls ...		
$\frac{12,09,068 \times 1240}{1640} =$	Rs.	9,14,173
1-10th for navigation	,,	91,417
4 falls already built	,,	1,19,560
6 do. at Rs. 25,000 each	,,	1,50,000
4 locks at ,, 20,000 ,, ...	,,	80,000
6 ,, ,, 15,000 ,, ...	,,	90,000
		14,45,150
Contingencies and Establishment as before...	,,	1,54,187
Total ...	,,	15,99,337

Deduct.

Expended up to date ...	Rs.	6,85,006	
Contingencies and Establishment	,,	73,085	
			7,58,091
Required to complete ...		Rs.	8,41,246

BOLUNDSHUHUR BRANCH.

Cost of works due to irrigation as before		
$\frac{12,09,068 \times 520}{1,640} =$	Rs.	3,83,363
Contingencies and Establishment	,,	40,902
	,,	4,24,265
Add 1-10th for navigation	,,	42,426
Total, Rupees.		4,66,691

Deduct.

Expended up to date ...	Rs.	81,854	
Contingencies and Establishment	,,	8,733	
			90,587
Required to complete		Rs.	3,76,104

FOR THE KOEL BRANCH.

Estimate as for Bolundshuhur Branch Rs. 4,66,691

The aggregate length of the Rajbuhas completed up to 30th April 1863 was 2,266 miles; the total expenditure on this head being Rupees 31,81,259, the rate per mile is found to

Digitized by Google

be Rupees 1,404, which, by the addition of the proportions as above for contingencies and establishment, is increased to Rupees 1,553-8. The lengths of irrigating channels are as follow :—

On the Main Line	......	153 Miles.
Cawnpore Branch	......	168 „
Etawah do.	......	165 „
Futtehghur do.	......	145 „
Bolundshuhur do.	......	55 „
Koel do.	......	55 „
Aggregated length		741 Miles.

The length of Rajbuha channel to each mile of canal on the main line and Cawnpore Branches, where the Rajbuha system may be considered complete, or very nearly so, is about 5 miles ; a like proportion is found to obtain on the Eastern Jumna Canal. This gives an aggregate length of Rajbuha channels for the whole of the irrigation from the Ganges Canals of 3,705 miles ; and deducting 2,266 miles, we find 1,439 miles as the length required to complete the system. The cost at the above rate would then be 1,439 × 1,550 = Rupees 22,30,450. Collecting the several items together, we obtain the following as the total probable outlay on the works of the Ganges Canal and its branches—

Expended up to 30th April 1863	...	Rs.	2,03,65,714
Remodelling as per estimate ...	...	„	39,19,850
Completing Etawah Branch ...	...	„	4,47,613
Do. Futtehgurh do. ...	...	„	8,41,246
Do. Bolundshuhur do. ...	...	„	3,76,104
Constructing Koel do. ...	...	„	4,66,691
Completing Rajbuha system ...	...	„	22,30,450
Permanent head-works on the Ganges, roughly estimated at ...	...	„	10,00,000
Total		„	2,96,47,668
Revenue lost and compensation given if canal be closed for one year	...	Rs.	13,48,213
Grand Total,		Rs.	3,09,95,881

Taking the full supply of water delivered at the head of irrigation to be 6,750 cubic feet per second, the cost per cubic foot per second of discharge is thus, Rupees 4,740.

Discharge of Canal assumed as in original projection and why.

112. The supply of water for irrigation and its distribution have been assumed throughout these projects according to the original projection, as it was based on results obtained from the older canals in Northern India, where irrigation had been long and extensively developed. Though, as I have stated elsewhere, the volume in the Ganges Canal is now much reduced by absorption, there is no reason to suppose that when the surrounding water-bearing strata are fully saturated, the wastage will be greater than in other localities.

Terminus of Futteghur Branch.

113. It was proposed, I understand, some time since to terminate the Futtehgurh Branch at the Escape opposite Anoopshuhur, at the 82nd mile from the head, substituting for the remainder of the projected line two Rajbuhas which would be

Digitized by Google

taken off at that point. If this be determined on, a navigable communication can be made with the trunk line above Nanoon along the line of levels shewn in Plan II., a section of which will be found in Plan IV. The cost of such a channel would, I believe, be fully covered by the estimate for completing the branch as projected.

SUPPLY OF WATER FROM THE JUMNA FOR AUTUMN CROPS.

From Boodhee Jumna at Nyashuhur.

114. The information I have been able to collect on this head is rather of a negative than a positive character. The most economical plan at first sight appeared to be, to take off the supply from the Bhoodhee Jumna above the Nyashuhur Dam, thence carrying it in the present channel of the Eastern Jumna Canal as far as the dam over the Muskarra at Kulseea. from this a new channel would reach the watershed between the Dumola and Hindun Rivers in a length of a few miles, and, passing to the southward, could be carried across the Hindun by an acqueduct, meeting the proposed alternative line above the town of Deobund. The levels Plan IX. show that it is physically feasible, but the outlay must, I think, be greater than the results would justify.

In consequence of the difficult nature of the country, and the small waterways of the Belka and Behut overfalls, on the Eatern Jumna Canal, it would be necessary to construct an entirely new channel from above the Nowgong torrent, which would cross it below the present Dam and rejoin the Canal Channel just above the Muskurra Dam; the overfall or (retaining dam) on the Nowgong, built some years since to stop the retrogression of the bed level, might be utilized for the crosigns of the new canal. Below the Muskurra, however, the declivity of the country is very rapid; numerous overfalls would be required besides an aqueduct over the Hindun, which would involve a large expenditure of time and money.

The irrigation from the Eastern Jumna Canal supplies the country fairly on the right bank of the Hindun; the new channel would, therefore, not commence irrigation above the 30th mile or so from its head. Perhaps the objection of most weight against drawing water from this point, or any where above the present Canal heads, is that it might interfere with the wants of the existing irrigation at the most critical season of the year. To bring the autumn crop to perfection, water would be required from May to September inclusive.

What the increase in the volume of the Jumna may be in the former month, I cannot exactly say, no discharges having been yet measured; but from the experience of the autumn of 1863, when the rains ceased on the 10th of September, and the hot westerly wind parched the lower districts for some weeks subsequently, it is evident that in certain seasons the whole visible supply is needed for the present canals. Though the river bed was then dry below the heads of the Jumna Canals, the cry for more water was incessant.

From Railway crossing opposite Saharunpore.

115. The second locality from which levels were taken was the Railway crossing opposite Saharunpore, where a dam and head-works might be economically combined with the

Digitized by Google

bridge shortly to be erected. The levels however are unfavorable, and the channel would have to be carried across the Eastern Jumna Canal, and the numerous water-courses and drainages, which intersect the district, besides requiring an aqueduct for a passage across the Hindun. The volume of the Jumna also, at so short a distance from the present canal heads, would in all probability be very small at the latter end of the rainy season in a dry year.

From river at confluence of Hindun.

116. The highest point, in my opinion, from which a channel could be taken at a remunerative cost, and with a fair prospect of an unfailing supply throughout the irrigating season of the autumn crops, is at or close to the junction of the Hindun with the Jumna, 16 miles below Delhi. Opposite to this the main watershed of the Doab abuts on the valley of the river, and from a cross section taken from the Bolundshuhur Branch head to the Hindun, close to its junction with the river, it appears that the surface of the stream in the latter, in the dry season, is on the same level as the bed of the main line Ganges Canal at Moonda Khera. A channel threfore led off from this point at a declivity, say, of half a foot per mile (or 1 in 10,560) would connect with the Ganges Canal at about the 160th mile from its head. The length of non-irrigating channel would thus be about 48 miles, and the greatest depth of excavation would not, judging from cross section levels taken over the high land, exceed 32 feet. A dam across the river here could be constructed at a minimum outlay from its proximity to the Delhi quarries, whence stone could be floated down at a small expense in boats.

It would be perhaps advisable to keep this channel quite distinct from the existing Ganges Canal lines reserving all irrigation from it for the districts to the southward, where water can be but scantily supplied at present.

A collateral and very important advantage connected with such a channel is the opportunity it affords of continuing the navigable communication down the Doab, to the junction of the Ganges and Jumna at Allahabad. Though the volume of the Jumna in the dry season at such a distance from the hills cannot be relied on to supply any large extent of irrigation, there will always be sufficient for a navigable channel of considerable size, even with a current running at the velocity assigned to it in this project. In fact, were the river dammed across here, some such provision appears necessary to supply the wants of the traffic which now passes up as high as Delhi for the greater portion of the year. It is superfluous to say more on the matter in this paper, after the unanswerable testimony given to the value of such a communication in the late Colonel Baird Smith's Famine Report.

Of the river below the Hindun.

117. Below the confluence of the Hindun, the valley of the Jumna narrows rapidly; the section at Agra taken for the Railway is given in Plan VIII. A supply might be taken off at a lower point than I have indicated, but I doubt its feasibility at a remunerative cost; the high bank is close to the edge of the stream, about 40 feet above it at Agra, and the declivity of the ground surface to the southward is small, not exceeding a foot per mile on the average.

Digitized by Google

CONCLUDING REMARKS.

118. The question of permanent head works for the canal did not form one of the subjects to which my attention was directed in the present investigation; a few general remarks on it will not, however, be out of place. The site of the present temporary bunds is at a point on the river, where the declivity is great, rapids at short intervals which retrograde more or less every rainy season. The safest position for a permanent weir is obviously at the foot of this excessive slope, where the tendency to deposit on the bed commences; the construction of foundations here also would be a less difficult business than in the heavy boulder strata above. This reduction of declivity appears to occur at a point on the main stream at the bridge of boats about half a mile below the town of Khunkhul; from the levels given in the Ganges Canal Report Atlas, it appears to be just possible that a channel taken off from this point could be connected with the existing line above the Ranipoor superpassage by removing the overfall there, and deepening the bed for a short distance higher up. The cost of this channel and the new head works would not, I think, exceed that of the latter, if constructed at the upper site, added to the outlay on remodelling the line from the present Regulator to below Khunkul Bridge, besides having the advantage of a more effective control over the river above the dam. Permanent Head Works

The bed of the river at the point indicated is of shingle and small boulders; a few rapids occur lower down, but at long intervals, and the descents at each very gradual.

It has been suggested that the bridge for the Rohilcund Railway might be carried across the dam here, thus saving the expense of foundations.

119. One question—affecting not only the Ganges Canal works, but also the whole system of irrigation in Northern India, which is yearly becoming of greater importance—is the necessity for thorough drainage in all the districts under the influence of constant irrigation. The general elevation of the spring level in the adjoining tracts was long since observed to follow the introduction of canal irrigation, but it was not till within the last few years, that the evils resulting from this over saturation of the soil, became so clearly apparent. System of general drainage required.

Swamps are formed over extended areas of low ground, which are further increased by the excessive proportion of the rain-fall, which must now find its way into such hollows, wherever the country drainage outfalls are not sufficient to carry it off, owing to the diminished capacity of the soil for absorption. The condition of the districts bordering the Delhi Branch and other portions of the Western Jumna Canal from this cause has long since attracted the attention of Government. I need not go over the details here; much has been already done in the way of draining these marshes on both the Jumna Canals. A general system of drainage however is required, embracing not only the tracts now constantly flooded, but also all districts where the spring level is so close to the surface as to injure the quality of the crops or generate malaria. When in charge of the Eastern Jumna Canal, for a few months last year, where drainage works have been largely carried out by the able and indefatigable Superintendent, Major Brownlow, R. E., (now

Digitized by Google

on furlough in England) my attention was directed to several extensive marshes which I was informed had only made their appearance a year or two previously; these were due mainly, I believe, to the general elevation of the spring level. It was also evident that some of the drainage works excavated in past years, had become insufficient for their purpose, owing to the increased proportion of rainfall to be carried off in the surface outfalls.

Nor is this to be attributed, or only very partially, to leakage from the canal channels. In an investigation which was carried out last year by the orders of the Punjaub Government into the causes of the diminution of water-supply in the cantonments and city of Umballah, the facts elicited clearly showed that the subsidence of the surface level of the water in the wells was due almost entirely to the shutting off of the floods from certain hill torrents which formerly inundated the country very extensively every rainy season. It is constant flooding over large areas which alone can cause a general elevation of the spring level.

This is only another instance of what may be called a truism, though it requires often to be brought to notice in this age of rapid progress (*vide* Sir John Rennie's letters to the "Times" in December 1863, on "Drainage, Sewage, Water-supply, and Irrigation") that where the course of nature is interfered with by artificial operations, the interference does not stop at the point originally intended; other results supervene, which, if injurious, must also be dealt with artificially.

A general system of subsoil drainage, such as indicated above, would increase rather than diminish the extent of irrigation, as the water thus carried off might be utilized in lands at a lower level.

The "reh" efflorescence, so destructive to all vegetation, is undoubtedly due, in most cases, to excessive moisture at or close to the surface.

Remedial measures why not adopted earlier.

120. The question may be asked why were remedial measures not earlier adopted to remove the acknowledged defects in the Canal. In the beginning of 1857, by the permission of the Punjab Government, I traversed the Canal by boat from Hurdwar to Cawnpore, for the express purpose of seeing how the works had stood, with the view of deriving information which might be useful in the construction of the Baree Doab Canal, then in course of construction. All the evils now so largely developed were then incipient; but it was not considered expedient to enter on any extensive remodelling scheme until the works had had a longer trial. The smothered murmurings of disaffection were then rife, and before two months had passed, the Mutiny with all its horrors was upon us; its echoes had scarce died out ere another, and scarcely less terrible visitation, the famine of 1859-60 and 1860-61, overspread the greater portion of the North West Provinces.

Human lives were then in the balance, and the question no longer was as to the volume which the canal could safely carry, or the best method of rectifying defects, but how the maximum supply of water could at any risk be conveyed to the starving population in the lower districts.

Digitized by Google

Various suggestions have been made and acted on before and since that time, but as the measures hitherto adopted were only directed to the protection of existing works, and did not touch the root of the evils, they have been only partially successful. Engineers were loath to recommend alterations involving a large outlay, until all other minor expedients had been well tried.

121. It has often been put forward as an objection to the large irrigation works in these provinces, that they "do not pay."

Reply to objections that Canals are unremunerative.

Now the Western Jumna Canal has long since returned into the Government Treasury the whole outlay on its construction, and is now yielding a very large profit. The Eastern Jumna Canal has likewise cleared its own expenses, and for the last two years, the balance of revenue over current charges has been clear gain. In the case of the Ganges Canal, it must be borne in mind that the development of the irrigation has been retarded by several causes; the unsettled state of the country and financial pressure for a considerable period since its opening; the defects in its construction, unwillingness of cultivators in certain localities to take water at first (the same objections to any innovation were experienced in the earlier stages of the Jumna Canal irrigation) to which is to be added the change in the first few years after the opening of the canal from the old system of assessing the water-rent by area irrigated, to that of charging by volume discharged; not that the latter is not the very best, if practicable, but it is a novelty, and that, as such, it should be looked on with disfavour will not be surprising to any one acquainted with the natives of this country.

Canal irrigation in a country previously without it can never be very rapidly developed, nor is it at all desirable that it should be; independently of the necessity for the consolidation of the works in the channels before a large supply of water can be allowed to pass over them, the change in climate from extreme drought to constant humidity, which necessarily follows the introduction of irrigation extensively, must have an injurious effect on the health of the inhabitants generally.

Their whole social economy also must undergo alteration, and that such changes should be gradual, no one, I think, will deny. The crops raised by the present canal irrigation are, in general, notoriously inferior in quality to those watered from wells; and one chief reason for their inferiority undoubtedly is, less care in the cultivation as well as deficiency in manure; the greed of gain induces the Zemindars to extend the cultivation further than they have labor to work properly, and until the number of cattle increase, which can only be by degrees, the land is impoverished from constant cultivation without a due allowance of manure.

The credits to these canals in the public accounts, however, shew but a fraction of the real return. Besides the amount realized as water-rent, there is the large increase to the land tax in the irrigated districts which has never yet been allowed to be shewn as profit due to the canals in the balance sheet. Now what are the water-rates? Until within the last two years they were the rates determined by Colonel J. Colvin, Superintendent of Canals in the North West Provinces, and sanctioned

Digitized by Google

by Government in 1827, on which he observes, in his Report of 1831, on the canals generally, "the often-repeated declaration of the Government to the Superintendents, as their main rule of guidance, that the object of Government in collecting a rent through them was not so much to form a productive source of revenue from the actual price paid for the water as to give them an efficient control over its expenditure, by making it of value to prevent its being wantonly wasted, and that they looked alone to the general improvement of the country as the source from which they should derive the return adequate to the outlay. This announcement completely prevented the Superintendent disposing of the water to the best advantage, and led to the settlement of a fixed rate of assessment, so low, that it is not sufficient to prevent carelessness, entailing much waste of water."

Now if the rates were not sufficiently high to shew a remunerative return on the outlay on the comparatively petty canal works executed up to that time, how can a profit be shewn on irrigating canals of the present day, which the experience of years has proved must, for permanent efficiency, be constructed much more expensively. Were the increase to the land revenue due to the irrigation from its commencement up to the present date added to the returns from "water-rent," the balance sheet would shew very differently. In the case of the Ganges Canal, unfinished and defective as it is, if we take the increase to the land tax at the lowest computation as equal to the present total of water-rent, which for the past official year 1863-64 was Rupees 6,93,134, we find as follows :—

2 × 6,93,134 ...	Rs.	13,86,268	
Add miscellaneous receipts	„	80,256	
			14 66,524
Deduct Current expenses...	„		7,00,000
The nett balance is,	Rs.		7,66,524

The total expenditure on the works up to the 30th April 1863, being, as calculated in para. 111, Rupees 2,03,65,712, say Rupees 210,00,000 up to the end of the last official year; this gives a return of 3·65 per cent on the outlay up to date.

The value to the country of these irrigation works is acknowledged on all hands; if it be deemed necessary also to shew their profits as commercial speculations, it will only be necessary to give the aggregate income derived from them, whether it be collected in the shape of land or water taxes.

Insufficiency of Establishment of European Officers.

122. This Report would be incomplete were I not to draw attention to a subject of vital importance to the success of the works both physically and financially. It may be gathered from the above pages, that information on many important points is much needed to admit of a satisfactory decision being arrived at on certain questions of constructive detail.

For investigations of this nature the strength of the present establishment of European Officers is utterly inadequate; hampered as they are, especially the younger officers, with accounts and the preparation of returns, they can scarcely overtake the ordinary current work. This is no exaggeration. I write of what I in common with all acquainted with the working detail of the Department *know* to be the case. Some men there are, of iron frame and large intellectual calibre,

Digitized by Google

whom no amount of toil, physical or mental, seems to affect; such are, it need hardly be said, rare exceptions, and their capabilities can form no basis for a calculation of the working powers of ordinary humanity. Though a portion of the account work has of late years been transferred to Central Offices, the relief to Executive Officers on this score has been little, if any; the office establishments have been so much reduced, that a very large proportion of their and their Assistants time is still taken up with merely mechanical paper work. In these Hydraulic works it must be borne in mind that much closer supervision of every detail is necessary than elsewhere. In a Railway or line of road, errors or defects in construction have only a local influence; here the results may extend themselves almost indefinitely and in a very short space of time.

Every petty distribution channel may be lined out and levelled by a Native subordinate, but numerous proofs are not wanting that the work cannot be relied on without verification by a European Officer. In addition, he has the proper distribution of the irrigation and the revenue details to look after; no trifling matter where irrigation has been fully developed.

It may be deemed travelling out of my province thus to criticise arrangements made by superior authority, but the interests at stake are large, and this Report has to deal, I conceive, with every fact affecting the efficiency of the works, without which the most elaborate system of accounts and best fiscal administration, necessary though they also may be, will be of little value.

While these projects were in course of preparation, another of our number, the late Colonel A. D. Turnbull, one whose loss will be long and deeply felt by all acquainted with him, (Natives as well as Europeans) has passed away, struck down in the prime of life and usefulness by jungle fever, the scourge which has so often ere this carried off our worthiest and best; in his case the deadly influence of malaria was without a doubt intensified by anxiety regarding his work and over exertion.

123. A memorandum by Major General Sir Arthur Cotton, which accompanied a communication dated July 1863, from the Secretary of the East India Irrigation Company, to the Government of India, claims a brief notice here as it contains strictures on the whole projection of the Ganges Canal works, which, if correct, would modify the measures now recommended for their rectification in several important points. Sir Arthur Cotton's Memo.

He states that "there are the greatest fundamental mistakes in its projection," which he classes under five heads:—

1*st.*—The head of the canal is placed too high up, above a tract which has a very great and inconvenient fall, and in which there is a very heavy drainage from the sub-Himalayas across which the canal has to be carried.

2*nd.*—The whole canal has been cut so as to carry the water below the level of the surface, entailing a vast unnecessary excavation, and keeping the water below the level at which it is required for irrigation.

3*rd.*—The whole of the masonry works are of brick, while the most suitable stone for hydraulic works is procurable in the Sub-Himalayas.

Digitized by Google

4th.—The whole of the water is admitted at the head so that some of it is conveyed three hundred and fifty miles to the land it irrigates, while it might have been obtained at a sufficient level at a distance of say 50 or 100 miles.

5th.—There is no permanent dam across the river at the head of the canal, so as to secure the supply of water, but temporary works are thrown up after every monsoon, which are liable to be swept away at the very time when they are most wanted.

Permanent head works.

124. The last cannot be called a "mistake" in the projection, as the work has only been held in abeyance until the necessity for it was fully proved, nor would the addition undo any part of the project already executed. The ultimate necessity for some such work has for years past been a subject much discussed by the Canal Officers; amongst others, the late Colonel R. Baird Smith, in his Famine Report of 1860-61, drew the attention of Government to it as a matter of serious importance, but it was not until every drop of water in the river had become of value to the irrigation, that that necessity could be satisfactorily proved. After thirty years' experience of the efficiency of the cheap temporary bunds across the Jumna in supplying the irrigation on the Western and Eastern Jumna canals, the projector would not, I maintain, have been justified in recommending this costly addition to the Ganges canal works without full proof of its *absolute necessity*. The obstruction of the entire volume of the Ganges for irrigation was required much earlier in the existence of the canal than in the case of the Jumna; in the famine year the total discharge of the former at the Canal heads was at one time so low as 5,600 cubic feet per second, the ordinary minimum when the river is at its lowest being upwards of 7,000 cubic feet. For some time past the necessity for permanent head works has been acknowledged by all, and designs for them are already before the Government.

Water carried "within soil."

125. As to the second point, the excavation of the canal so as to retain the water below the level of the ground surface, it was simply a sanitary precaution, the wisdom of which no one would doubt who had seen the effects of a contrary plan on the older canals in these Provinces. Independent of the risk from certain soils, such as those impregnated with "reh" and other salts, through which water *will* percolate, do what we may, the ravages of vermin have ere this caused sufficient injury to the channels and adjoining lands elsewhere to make the embankment system, on the score of economy, a very questionable mode of construction. In the sandy tracts moreover it would not effect the desired object of preventing percolation, the soil in no portion of it being absolutely watertight; the only difference is that the saturation takes place in coarse sand in a shorter time; and I have shown above, para. 119, that saturation of the soil is sooner or later a certain consequence of extensive irrigation. The statement that the water is *thereby* kept below the level required for irrigation, does not represent the state of matters correctly. It will be seen from the longitudinal section that the level of full supply in the canal for some distance above the overfalls, stands higher than the surface of the ground, and it is from these points only that irrigation cuts are led off between Roorkee and the 110th

Digitized by Google

mile: below this, the full supply level stands almost everywhere (in some places as much as several feet) above the ground line.

Drainage cuts would doubtless carry off leakage water, but could only very partially avert the evils of inundation from breaches in embankments.

Substitution of stone for brick.

126. The third objection that brick was used in the masonry instead of stone is simply a question of comparative expense. The overfalls on the Eastern Jumna Canal by a trial of several years had shewn what violent action *good* brickwork would stand, and the projector did not consider himself justified in substituting stone in the Ganges Canal works at an enormous additional expense merely to ensure a greater degree of safety. Sir Arthur Cotton himself allows that the " absolute impossibility of obtaining it (stone) within a practicable expense, would justify an Engineer in building weirs and sluices without it."

He further states that the brick masonry is " of the very best quality, both materials and workmanship as fair as any" he ever saw. Now I have shewn in paras. 20 and 21, that the materials and workmanship at the overfalls below Roorkee which have been seriously injured are very indifferent indeed, and the only way of accounting for Sir Arthur Cotton's assertion is that he never, as I am informed, *saw these* works, having only inspected minutely the line immediately at and above Roorkee, where, as I have shown above, the worst damage sustained by the works is the stripping of portions of the brick on edge covering from the ogee curves, and the floorings immediately below, at the overfalls.

Boulders were used extensively in the construction of the more massive parts of the works above Roorkee wherever they could be transported at a reasonable cost, but they were covered wherever fine work was required with brick facing, as building with hammer-dressed boulders is quite out of the question on account of the excessive expense.

The "Hurdwar Stone," I have shewn in para. 90, is only procurable in small quantity and at great cost.

The researches even up to the present date* only confirm the soundness of Sir P. T. Cautley's views, that the stone of the Sewalliks *generally* is unfit for building with; strata of good materials *are* to be found, but at wide intervals, and the quantity in any one locality is very insignificant.

It would be less expensive to construct overfalls of the form I have detailed elsewhere which we know can stand with even brick, or a very small amount of stone facing, than to adopt works of Sir Arthur Cotton's simpler design covered throughout with stone.

It is further recommended in the Memo. that the locks should be " lined with stones most carefully fitted." Brick has answered its purpose hitherto ; I see no good reason for the additional expense at present. A statement is made that " monstrous fines" are inflicted for any injury done by boats to the plastering. I have failed in discovering that fines were imposed on this account anywhere except at Cawnpore ; there is no doubt that plaster is useless under such circumstances,

* November 1864.

Digitized by Google

and the infliction of fines for injuries to it from boats or rafts is, to say the least, an oppressive exercise of authority.

Position of head of Canal.

127. The 1st and 4th objections may be best considered together, as they involve one, if not *the* main point at issue.

NOTE TO PARA. 127.

Since this para. was written, a review of Sir A. Cotton's and other pamphlets bearing on this discussion has appeared in the columns of the "Times" Newspaper of November 2nd, in which the writer states his opinion that when the difference of level between the bed of the river and the top of the adjoining bank was so great, "an Engineer, who had to take a channel down to some point in the valley beyond it, would not be likely to turn into the bank at such an angle as to involve "deep digging for many miles, unless he went mad on purpose; he would probably take it in flank for some distance with no more excavation than was just sufficient to make his embankment on each side, perhaps sometimes not above a yard deep, until he found a favourable opportunity for getting through with a short cutting of 20 or 25 feet, after which he would reach a flat country with only one trifling stream to cross." Sir A. Cotton (in a pamphlet which has only lately come to hand) suggests the possibility of utilizing an old branch of the Ganges shown in the map at the foot of the high bank between Sookertal and Gurmukhtesur for a portion at least of the proposed line, but it will be evident from the sections, that so shallow a depth of excavation at the entry into the high land as 20 to 25 feet could not be obtained without carrying the channel for a long distance at a considerable elevation above that old bed or the surface of the adjacent low land, keeping close to the face of the high bank, the slope of which all along is excessively steep (in places almost perpendicular) and cut into by innumerable deep ravines which carry the drainage from the table land above into the valley of the Ganges. The belt of land from which these are the out-falls varies in width from 3 to 4½ miles, and the drainage thus brought down must either be discharged into the canal, or passed under or over it by masonry works.

Of the evils consequent on the adoption of the former method of disposing of the drainage, we have proof in the case of the canal on the western bank of the Jumna above Kurnaul, where the old native channel taken up and improved by British

Sir Arthur Cotton is of opinion that the head of the canal is placed too high up on the river; now this is also a question chiefly of cost. No one doubts the practicability of building a weir across the river anywhere and leading off a channel thence for irrigation, but the *cost* of this will vary much with the circumstances of the locality. In Plan VIII., Sheets 1 and 2, are given sections of the Ganges at the points indicated in the General Map (Plan No. 1). If we take the section at Sookertal, below the confluence of the Solanee, the point suggested by Sir A. Cotton as the best site for the upper head, we find that the top of the high bank forming the boundary of the valley is 95 feet above the surface of the dry weather stream in the river, or 101 feet above the bed. Sir A. Cotton proposes to construct a weir to raise the surface of the water to a level 15 feet above the bed, and to carry the canal channel thence at a declivity of 1-4th foot per mile, or 1 in 21,120. With this slope the bed would meet that of the present main line of the Ganges canal about Moradnuggur Bridge (the 100th mile from the head), and this distance on the most direct course is not less than 57 miles. If we suppose the bed of the new channel to commence at a level 3 feet above the present bed of the river at Sookertal, the depth of water at its entrance will be 12 feet. With this depth of water and declivity a channel 260 feet wide at bottom, side slopes 1 in 2, would discharge about 7,000 cubic feet per second, at a mean velocity slightly exceeding 2 feet per second. The maximum depth of excavation, supposing the edge of the high land to be reached at a distance of 2 miles from the weir, is 96 feet, the minimum at Moradnuggur bridge, 10 feet, giving a mean of 53 feet. The side slopes of this cutting, where nothing but pure sand will be met with below the upper 10 or 12 feet, cannot be made less than 1 in 2; the berms 15 feet wide on either side at a level of 14 feet above the bed. This gives a mean area of 26,186 superficial feet, or contents of excavation on 1 mile=138,262,080 cubic feet; say that the rate of excavation for the first 27 miles of deep cutting is 4 Rupees per 1,000 cubic feet, for the last 28, Rupees 3; (the work could not possibly be done for less) and we have an aggregate of Rupees 265,46,304 for earthwork alone, without a single masonry work of any description! The total cost of the first 23 miles of the present Ganges Canal from the head to the Hafiznuggur falls (4 miles below Roorkee) including all the heavy works in the Ganges valley was Rupees 81,17,114; even as far as the 100th mile the aggregate was under a crore of Rupees. Sir A. Cotton has compared the cost of a channel from Sookertal with that of the entire existing line down to their junction; this is obviously unfair; the comparison should have been with the *non-irrigating* length below the present head, which terminates at Hafiznuggur Falls, with the addition only of the extra outlay for overfalls on the remainder of the distance.

At Bysoomah, 20 miles to the south of Sookertal, the difference of level between the dry weather surface of the

Digitized by Google

Ganges and the top of the adjoining high bank is reduced to 77·8 feet, and at Gurmuktesur, 30 miles further down, it is 56 feet.

The latter must have been one of the points alluded to in Sir Arthur's Memo. as being 40 feet below the bed of the canal, the bed of the Futtehgurh branch opposite being at very nearly that elevation above the river surface (*vide* Longitudinal Section 45th mile). A channel led off here would not connect with the main line of the Ganges Canal on the watershed under a length of 40 miles, besides having to cross all the drainage brought down by the East Kalee Nuddee and its feeders ; a sketch of an existing bridge over this drainage at Bolundshuhur is given in Plan VI.

Now Gurmuktesur is about 80 miles below the debouche of the river into the plains at Hurdwar, which is stated in the Memo. to be so far an advantage that a larger supply would be obtainable, water draining out of the sands below the shingle tracts besides additions from the small affluents above ; and this is apparently confirmed by the statement of discharges, given in the Ganges Canal Report (Vol 1, page 24) observed simultaneously at Hurdwar and Gurmuktesur, the excess at the latter point being accounted for there by accessions from the drainage of the Khadir and the different smaller lines both on the right and left banks of the river. Such affluents however, it is obvious, cannot be relied on as a permanent source of supply, for in a dry season they would yield little or nothing; and facts are opposed to the theory of the volume being increased by water draining from the sands of the river below the shingle tract. Observations were taken to ascertain this in the Ravee some years since at the instance of Captain J. H. Dyas, then Superintendent of Irrigation in the Punjaub, the results of which were that the volume of water in the river at the season of minimum discharge was found to *decrease* steadily, as the distance from the foot of the hills, where the bed is in shingle, increased, and at a point 60 miles above Mooltan, or about 280 miles in a direct line from the hills, the reduction amounted to half the discharge measured at the highest point.

The affluents along this portion of the river are too insignificant, except during the rainy season, to affect the discharges materially. Now, as all the rivers from the Ganges to the Chenab traverse the plains under precisely analogous circumstances of soil, &c., there is, I think, good reason for supposing that their discharges, excluding additions from affluents, are similarly affected. By abstracting then the whole visible supply in the shingle tracts, and if practicable, taking off channels from points lower down in the sandy beds, we obtain the *largest supply possible* from these rivers.

From all the information I have been able to gather, the maximum volume, when the rivers are at the lowest, will, I believe, be found at the junction of the shingle and sandy beds.

One advantage of no mean importance connected with the heads from the shingle beds is the fact of the water in the river there flowing for ⅔rds of the year clear as crystal, while in the sandy tracts lower down, silt is *always* more or less held in suspension. It must also be borne in mind that the navigable communication from the foot of the hills would not be complete if the Canal head be placed lower down. For the

officers some 40 years ago, is carried in this way for 45 miles along the foot of the high bank of the valley. Spite of its large capacity, about 2,500 cubic feet per second, and the relief afforded by escapes, it cannot at times carry off the drainage entering on the right bank. I have known it to run full for days when the head sluices were closed. The amount of silt thus deposited in the canal was, as might be supposed, enormous. With this example before them, no one would, I think, be justified in adopting a similar course in a *permanent* canal elsewhere.

If a channel be taken off as proposed, and the drainage carried under or over it, as the depth of excavation will be comparatively trifling, the width may be greater than if cut directly into the high bank. Assuming the depth of water entering at the head to be 8 feet, a channel 496 feet in mean width, on a declivity of ½ foot per mile would discharge 6,800 cubic feet per second, with a mean velocity of a little over 1·7 feet per second, and might enter the high land 30 miles from its head with a depth of excavation of about 23 feet; 6½ miles below this the water would reach the surface of the country. The outlay on these 36 miles for excavation, culverts, bridges, &c., could not possibly be less than 50 lakhs, and at its entry into the high land the bed would have reached an elevation above the surface of the valley immediately adjoining of not less than 25 *feet*; this for a permanent supply channel, and with so large a volume of water cannot, in my opinion, be considered safe.

If a greater depth of water be admitted into the channel, or the declivity of bed increased, or both, the width of section would of course be less for the same discharge, but the length of non-irrigating channel would be thus extended.

The course of a supply channel in fact must obviously depend on circumstances peculiar to the locality in each case, and in this of the Ganges from Sookertal to some distance at least below Gurmukhtesur, a line along the face of the high bank is, I think, clearly unadvisable.

J. Crofton, *Capt.*

Digitized by Google

traffic from the interior of the hills, it would therefore be necessary to "break bulk" twice, first—at the foot of the hills, where the mode of conveyance now changes, and always must do so, and again, into the boats at the head of the Canal.

The above appear to me to be sufficiently conclusive reasons for the determination of the heads of the canals in these Provinces from the shingle tracts. Additional quantities may be drawn from points lower down, but the main supply must be taken as at present.

With regard to deep cuttings through pure sand, I have not touched on the difficulties and consequent expense of working many feet below the level of the surface of the springs, and the consequent desiccation of the lands for perhaps miles on either side; the water would of course drain into the canal, and thus pass off to benefit the lower districts, but at the expense of those higher up. Bridges and aqueducts over excavations such as these would raise the outlay to something very large. A weir if constructed so high up as even Gurmuktesur must still be chiefly of brick; laden boats cannot ascend the river in the shingle tracts, and even if that were possible, or they could be brought within 5 or 6 miles of the works by the present canal channels, the cost of stone thus transported would be enormous. Sir Arthur Cotton apparently has little idea of what the rates for materials and carriage in these Provinces really are, for in one place he estimates the cost of pitching the slopes of the canal with loose stones, carried by boat 200 miles on an average, at Rupees 4·63 per 100 cubic feet, whereas the rate of small boulders delivered 6 miles *above* Roorkee is now 4½ Rupees per 100 cubic feet.

In the case of the Jumna a point has been indicated elsewhere where it *may* be possible to construct a weir and head works at a practicable cost.

Enumeration of alleged "minor" mistakes.

128. Fourteen "minor" mistakes are enumerated as follow :—

1st. All the weirs are made of a length corresponding with the full breadth of the canal, &c.

2nd. These weirs are placed in the direct line of the canal, &c, thus compelling the whole of the traffic to go round instead of the irrigation water.

3rd. The whole canal has too great a fall in its bed, &c.

4th. The canal has been terminated at Cawnpore instead of being carried on to Allahabad, &c.

5th. The slope of the canal is continued to the end at Cawnpore, so that to keep the navigation open there must be a large body of water constantly flowing to waste into the river.

6th. The bridges are so low as to prevent a fully loaded boat passing under them.

7th. The towing paths are not carried through the arches of the bridges so that the lines have to be thrown off at every bridge, that is, at every three miles.

8th. The lock channels have such sharp curves that boats of the length of the locks cannot pass through them.

Digitized by Google

9*th*. No arrangement has been made for the disposal of the silt.

10*th*. There are no connecting navigation lines between the different branches so that boats can only get across the tract by going all the way up to the point where the branch and main line divide.

11*th*. The Solanee aqueduct is made of the full breadth of the canal above, and of the full length of the breadth of the river below, &c.

12*th*. The breadth of the canal at the lower end is much too small for a large traffic, such as there would be if the navigation were in an effective state.

13*th*. The slopes of the sides of the canal are much too steep.

14*th*. There is no communication between the canal and the river at Cawnpore; for although there are double locks the gates of the lower one are not in repair.

129. Regarding the first of these minor defects, Sir Arthur subsequently explains his design for preventing undue depression of the water surface at the falls, by contracting the width of the passage over the creek ; this passage being, as I gather from the description, in one or more large bays. In para. 39 I have given my reasons for preferring a different form of overfall. Weirs and velocity of current.

The second alteration suggested, that the falls should be placed out of the direct line of canal, is unnecessary with the form of fall designed in these projects. It would besides lead to greater expense in construction of fall and locks and protection to the sides of the curved channel below the fall, as well as in clearance of silt hereafter, which would undoubtedly be lodged in large quantities at the head of the locks, unless the gates or sluices were kept constantly open so as to cause a scour.

The third objection, that the declivity of the canal bed is too great, should have been placed at the head of the list of defects. To any unprejudiced mind, acquainted with the real facts of the case, it will be evident, I think, that this has been the main, if not the sole cause of the evils which now impair the efficiency of the canal as an irrigating machine.

130. The ninth objection is, that there is no arrangement for the disposal of the silt. From his subsequent explanations, and design for a large basin near the canal head, which would act as a silt trap, Sir Arthur evidently supposed that the silt in the canal water is mainly brought in from the river ; while the fact is, as I have shewn in para. 36, that by far the largest proportion is due to the erosion from the bed and banks along its course ; were it otherwise, we should find silt deposits to a considerable extent in the upper reaches of the canal where the velocity of the current is much below that of the river in floods. Silt.

131. The eleventh objection is that the waterway of the Solanee aqueduct, both for the passage of the torrent below and the canal above, is much too great. Now it is an instructive fact, that of the four torrents crossed by the canal in the Ganges valley, only one, the Rutmoo, has suffered from dan- Solanee Aqueduct.

Digitized by Google

gerous erosive action below the masonry works at the crossing, and *in this instance alone* the waterway for the passage of floods is *contracted.* From the diagram given at para. 6 it will be seen that the bed of the torrent below the Rutmoo Dam has been channelled out to an average depth of about 9 feet, the bottom of the hole scooped out some 700 feet from the masonry having been at one time upwards of 15 feet below the level of the dam flooring. In August last year, there was a hole 12 feet in depth below the flooring at a distance of only 300 feet from the dam. The boulder talus is here 53 feet in length; but undermining has been hitherto only prevented by the construction of expensive temporary weirs of boulders and piling carried right across the earthen channel. The width of the natural channel is here about 800 feet; the highest known flood has never risen over the top of the piers, or 10 feet above the flooring of the escape dam, through which the aggregate width of waterway is 470 feet up to a height of 6 feet, or 570 feet above that level.

The declivities of the beds of these torrents are as follow, *vide* Ganges Canal Report :—

Ranipoor	...	...	14·11 foot per mile.
Puttree	...	...	24·43 do.
Rutmoo	...	...	8·23 do.
Solanee	...	...	5·08 do.

The length of the temporary weir nearest to the dam was 500 feet, which was in the spring of the present year increased to 680 feet ; the result of this enlargement of the passage for floods is now seen in extensive silting up of the bed for a considerable distance below.

Sir Arthur Cotton alludes to the Gunnarum aqueduct, constructed across one of the minor branches of the Godavery, as an instance of the possibility of passing river floods with perfect safety through a very contracted waterway ; this work I had heard of years ago and was at a loss to account for the difference of results there, and in the torrents with which we have to deal in Northern India, until I was informed by an Officer of the Irrigation Department in Madras that the Gunnarum aqueduct was constructed over a *tidal* river at a point where, as well as he could recollect, the rise of the tide was from 3 to 4 feet (the distance in a direct line from the sea is, by the plan given in the late Colonel Baird Smith's " Madras Irrigation," about 18 miles) ; there must therefore be a certain depth of backwater constantly standing on, or close up to the flooring which would fully account for the absence of the dangerous channelling out in the bed lower down, which is invariably found to be the case under similar circumstances with us.

That the present waterway under the Solanee aqueduct is just sufficient and no more is evident from the absence of silting under the arches, and the perfect condition of the channel below.

As to the proposed contraction of the width of the channel for the canal above, supposing the velocity of current through it to be increased to three times that in the earthen channel, or 9 feet per second, the up traffic would be entirely stopped, as Sir A. Cotton himself subsequently observes, without the addi-

Digitized by Google

tion of a separate lock chamber at the side and machinery for heaving the boats, &c., up the rapid. To work either of these an establishment must be permanently maintained. Besides this a large basin, protected at the sides by masonry revetments or otherwise, would be necessary in the heavy embankment at the lower end of the aqueduct, similar to those below the overfalls, to counteract the effects of the accelerated velocity and eddying action there. The expense of all this would be scarcely less than that of the work as it stands, and the wear and tear on the masonry would be infinitely greater than at present.

132. The remaining nine objections refer to points connected with the navigable capabilities of the canal and water communication in general. One or two points only require notice here.

Hindrances to navigation.

With reference to No. 5, it is stated that to combine navigation satisfactorily with irrigation, the lines of canal should be reduced below where the irrigation ceases, to levels by locks, and an opinion is given that the last 30 or 40 miles of the Cawnpore Branch should have been thus dealt with. This would restrict the extent of the present irrigation materially, as I have shewn elsewhere that the lowest outlet is at the Dubowlee Bridge within three miles of the terminus. It is further stated (in No. 14) "that there is no communication between the canal and river at Cawnpore." I can only say that when I saw the works in March last, the communication was perfectly free ; not a hindrance existed to the passage of boats or rafts through the terminal lockage. Great difficulty had been experienced more than a year previously in working hinged gates at the lowest lock, owing to the quantity of silt continually deposited by the river water. Since the substitution of iron drop-gates, noticed elsewhere in this report, no interruption to the traffic has occurred.

133. None of the defects enumerated above (some of them have been long known, and acknowledged by the projector and the canal officers to be so) except the original projection of the bed on too great a declivity and the absence of means for contracting the waterway at the falls, have, I maintain, affected the irrigation revenue to any appreciable degree; however large the navigation returns may ultimately be, they can never amount to more than a fraction of the former.

Irrigation returns affected by only two of the alleged defects.

The temporary nature of the works on the Ganges at the heads has not hitherto, as far as I have been able to discover, been the cause of any failure of irrigation from short supply except in one single season.

134. In conclusion, I protest in the name of my brother officers of the Canal Department in these Provinces against the claim set up by the Secretary to the East Indian Irrigation and Canal Company in a letter to Sir A. Cotton, published at the end of his pamphlet, that the professional opinions and suggestions regarding the Ganges Canal works put forth by him "belong absolutely to the East India Irrigation and Canal Company." Sir Arthur Cotton, it is true, came here in the interest of the Company; he was afforded every facility for obtaining information by the canal officers; in fact, the very defects of the works, were, as he himself states, in some instances pointed out to him. On this he wrote the Memorandum above

Claim set up by Secretary to Irrigation Company.

Digitized by Google

alluded to, solely as he states for the information of the Company, and without any view to its publication. The paper, however, somehow or other, found its way into print, and has given rise to a public discussion of the professional opinions contained therein. The subjects treated of have been discussed by those concerned in and out of India for years past, and reports and suggestions have been at different times made on every point mooted in the above pages; especially a Memo. drawn out in considerable detail last year at the request of the Superintendent General of Irrigation, long before Sir Arthur Cotton's pamphlet was heard of in this country, on the rectification of the works from the heads of the Ganges Canal to Cawnpore.

Some of these views and suggestions are necessarily identical with those put forth by Sir Arthur; in others, opinions disagree ; but that in the instances, and there are several in these projects, where our views do coincide with his, they are therefore to be considered the private property of the Company is about as preposterous a claim as could be put forward.

With the personal feelings which have unfortunately become linked with this discussion I have no concern. It is a matter of great regret to us all, that two such men as Sir Proby Cautley and Sir Arthur Cotton, who have done more in their respective spheres of action for the material development of this country than any others either in the past or the present generation, should have thus come into unpleasant collision.

My task is done, as far as time and the information at hand would permit. Unpleasant and invidious as it ever must be to be obliged to criticise and point out defects in a brother Engineer's work, it has been specially so in the present instance, where the projector of those works was for many years our loved and honored chief. If the views here advocated appear to his and other minds to be legitimate conclusions from the facts, and otherwise reasonable, though they differ in some important points from the ideas which guided the original projection, let it be borne in mind that they are those of men trained in his school, who have had the advantage of the accumulation of experience in subsequent years. To detect errors is an easier task than to produce faultless designs.

J. CROFTON, *Capt.*, R. E.,
On Special Duty, Ganges Canal.

ROORKEE,
23rd November 1864.

Digitized by Google

APPENDIX A.

Memorandum of the Measures recommended to be taken for Remodelling the Ganges Canal.

It is admitted by every one that the Ganges canal was originally designed with too strong a slope for its bed. The primary result of this error is the erosion of the earthen channel. From this follow two secondary results. First, the formation of rapids on the masonry works which occur along the canal, by which the foundations are undermined. Second, a direct dangerous action takes place on the masonry of the falls, at which the level of the tail water has been in many cases very greatly depressed by the erosion of the earthen channel; and a condition of things is brought about which these works were not designed to meet, and which, in fact, must eventually almost certainly destroy them if some complete restoration of the original water levels is not accomplished.

It will plainly be impossible to deal with the secondary results of the erosion of the bed until this erosion is arrested; and the only way of effecting this is to reduce the velocity of the water, which can be effected either by diminishing the slope of the bed, or the volume of water in the canal, or by a combination of these two things.

Obviously, the reduction of the volume of water alone in the existing canal cannot be entertained as a remedy, as the first condition of the problem to be solved is, that the whole supply of the Ganges, capable of being passed over the Solani aqueduct, shall be made available for irrigation. Hence the slope must be reduced by the introduction of additional falls, or a new channel to carry some of the water must be formed, or these two remedies might be applied in conjunction.

In proceeding to consider further which plan shall be adopted, it is at once apparent that irrigation from the canal having been already largely developed, it becomes almost essential that the present supply of water shall be maintained in the canal, while the measures requisite for the permanent restoration of the works are in progress. To stop the canal for a lengthened period would cause most serious complications with the cultivators now using the water, independently of the actual injury done to the country by the withdrawal of the means of irrigation. Such a step as the closure of the canal, for longer periods than are now customary, that is, a month or two in the year, should not be taken unless as a last resort, after all other means have failed.

It is calculated that the canal, as now constructed, could safely carry a depth of about four feet of water and no more. To reduce the discharge from its present amount, the depth being about seven feet, to a depth of four feet would, Colonel Turnbull considers, lead to a reduction of about half of the existing irrigation, and a money loss of about four lakhs of rupees a year. It would, therefore, seem to follow that any expenditure short of four lakhs a year that was necessary to maintain the 7-foot supply in the canal till the restoration is completed, will not be attended with greater loss to the Government than would be involved by the reduction of the supply, and the consequent falling off of revenue. At the same time, there can be no question that the community will be much better off if the supply is maintained; and on the whole, so far as it is found practicable to do this, it should be done.

Immediate steps, therefore, should be taken to secure the works that have been injuriously affected by the action of the water. The most practicable means of protecting the foundations of the falls and bridges will probably be found in theuse of loose stone to be brought down the canal from Hurdwar by boats, and the necessary steps should be taken at once for providing an ample fleet for this purpose. The canal bed should be very carefully watched henceforth, and a periodical review of the state of the bottom should be made, say every three months, so as to place beyond doubt what is the result of the remedial measures adopted. Of course the Canal Officers will use their discretion in the use of piles, or any other appliances, besides throwing in loose stones below the masonry works, that may, from time to time, be necessaay to secure the end in view.

It may here be remarked that the history of the Ganges canal seems to indicate the importance of the systematic watching of the bed of all irrigation canals of any magnitude, with a view to the Engineers being kept thoroughly acquainted with this most essential element of their works. The Irrigation Officers should be desired to consider this point,

Digitized by Google

and to frame rules under which yearly or half-yearly reports on the canal bed should be brought under the review of the heads of that department.

In proceeding further to consider the more precise form that should be given to any remedial measures, it may first be remarked that the bed of the canal above the Solani aqueduct must plainly be dealt with as it stands, and any excess of slope must be got rid of by additional falls in the present channel. There is here no possibility of a supplementary channel.

Below the Solani aqueduct greater freedom is possible, and the proposal of Sir Proby Cautley to form a supplementary or alternative channel from Roorkee, passing round by Deobund, and re-uniting with the original line at the suitable point lower down its course, calls for careful attention. If this plan were adopted, the old canal would either be re-modelled so as to carry with security an enlarged body of water, or would be made use of without material change to carry the largest possible volume that it could do with safety, which, as before observed, would give a depth of about four feet. This depth, it may be added, would be equivalent to about one-fourth of the full canal supply of 6,750 cubic feet per second.

Captain Crofton has satisfied us that it is not likely to be worth while to undertake any operations on the existing canal bed, in the way of re-modelling the slope, short of fitting it to carry the whole supply. It seems probable that at least one additional fall between each pair of existing falls would be requisite to admit of half the full supply being carried on the present line. Such falls would, of course, be less in height than falls suitable for the full supply, but the difficulty of construction would be very nearly as great in the one case as in the other, the important thing in both being the foundations, and the work to be done below the water level of the country.

In making comparison between the plan of a simple re-modelling of the present canal, and the plan of adopting a supplementary canal, the question is simplified, therefore, by the consideration that such a supplementary line would have to carry about ¾ths of the whole supply, while the old canal would carry, without important change, the remaining fourth. We have in fact to compare a properly re-modelled system of works on the existing canal, and a supplementary line to carry ¾ths of the full supply.

The two primary considerations that should influence a decision in favour of one or other of these plans will be their expense, and the time that they will require for completion. An important, but still a secondary point, will be the relative convenience of the two arrangements hereafter.

The comparative cost of these two plans it is quite impossible to conjecture, without real designs and estimates, but their probable difficulties, advantages, and disadvantages may usefully be touched upon, with a view to forming a judgment whether there may be any *a priori* ground for giving a preference to either at once—immediate action being most important.

The obvious advantage of the first plan of re-modelling the present canal, (which for brevity will be referred to in the sequel as Plan A, while the alternative will be termed Plan B) is that it will admit of the original general design of the works being maintained almost intact, and will interfere very little with the system of minor irrigation channels already in existence. It is supposed that all, or at all events most of the existing bridges will be utilized, and possibly the existing falls might be used with safety with certain precautions and modifications, when the excessive slope has been removed by the erection of the new intermediate falls. On this plan the excavation to be undertaken would be small, and the quantity of materials for masonry works very much less than in Plan B. The water being all in one channel, the waste from absorption and evaporation would be less than if it were in two, and also the ultimate expense for repairs and maintenance, including establishment, would be sensibly less in Plan A.

On the other hand, the disadvantages of Plan A. would be the difficulties of constructing the necessary falls on the existing channel, while a constant supply of water was maintained in it. These difficulties will be of such a nature as to make it very difficult to form a trustworthy estimate, either of the true cost of the works, or of the time that they will require for their completion. They will also add to the risk of the works themselves being constructed in a less complete and thoroughly durable manner than might be anticipated if Plan B. were adopted. These objections have very great weight with some of us.

The advantages of Plan B. will be—first, the facility of construction, and of forming a reliable estimate of cost and time of construction,—and second, the very great convenience that may be anticipated from the possession of a duplicate line of main channel throughout so great a distance, which would admit of a supply of considerable amount being sent down to the lower parts of the canal, while either of the alternative main lines was closed for repairs.

Digitized by Google

Although the existing canal cannot, with safety, carry more than one-fourth of the supply for a permanence, it might on an occasion of pressure, without serious risk, be made to take down probably one-half of the full supply for a limited period. Should it appear on the preparation of proper estimates that Plan B is likely to be more costly than Plan A, it will be a matter for consideration, whether these advantages are fairly commensurate with the increased cost.

The advantages of Plan B. will be that in part, at least, it must probably be regarded as not available as an irrigation channel, inasmuch as the supply of water is hardly sufficient for the works already designed and in course of completion in the lower districts of the Doab. It will involve the passage of the canal over the drainage of large areas of the Doab, requiring aqueducts in probably three parts of its course, thus introducing a fresh element of cost in addition to the requirements for bridges and falls. Further, although the works will be less difficult, they will, in absolute quantity, be heavier, and require more material ; the material again requiring land carriage to a greater extent than will be the case on the open canal.

On the whole, we do not feel ourselves to be in a position to give an absolute preference to either plan with the information now before us. But this difficulty is of less importance than might at first sight seem likely. Whichever plan were adopted—supposing that we could absolutely have preferred one to the other—a complete design and estimate would be quite essential before attempting to put any work in hand. The time that will suffice to prepare the designs and estimates for one set of works will, if suitable arrangements be made, suffice for the preparation of the like documents for the other set. Therefore we advise that immediate steps should be taken to draw out projects for both plans of operations, on the completion of which, the Government might probably think fit to cause them to be put before us, and to call for our further opinions as to the final decision to be come to.

We therefore advise that Captain Crofton, R. E., should at once be entrusted with the duty of drawing out projects and estimates under the two suppositions above referred to, and that he should have placed under him as Assistants, Mr. Hair, and another officer, to be selected by the Government, North Western Provinces. Mr. Mossop (Punjab Irrigation Department,) should also be placed under Captain Crofton's orders as soon as his present season's work is over.

It may best be left to Captain Crofton to consider, in his own manner, in communication with the Government of the North Western Provinces, through Colonel Turnbull, the precise form to give to both projects. The question whether navigation should be provided for in the new supplementary canal, or whether a separate navigation canal would not be preferable, is one that may be left for Captain Crofton's consideration. Also he might be asked to bear in mind the possibility of reinforcing the Ganges canal during the rainy months with the waters of the Jumna, which are in excess of the requirements of the Eastern and Western Jumna canals, and which now flow off to waste. The capacity of the Solani aqueduct is an absolute limit to the supply of water that can be brought into the Doab from the Ganges at Hurdwar, but this supply is notoriously insufficient for the irrigation of the whole available area that lies between the Ganges and Jumna, and the present occasion seems one on which this general question might usefully be looked into.

Having in view the length of time that would be required to provide bricks in sufficient quantity for the works that will, under all circumstances, be required for the objects that have here been discussed, and remembering that the Punjab Railway Company is just about to commence operations on the country through which the alternative line of canal will pass ; also having regard to the value of stone as a material for the construction of the falls, it seems specially requisite to take measures for examining properly the hills near Hurdwar, with the intention of finding a suitable stone for building purposes, if possible. There is reason to suppose that a fair description of sand-stone may be got, and the water carriage by the canal will now admit of such a material being brought down at a reasonable rate, if a stone of sufficiently good quality can be found.

For this purpose it is proposed that Mr. Kelly (lately returned from leave to England be specially nominated to examine and work the Hurdwar quarries, and to take charge o the provision of this description of material should our anticipations be realised. In the event of good stone being found, the needful staff of quarry-men will readily be obtained by the Government, North Western Provinces.

To meet the charge that will be incurred it carrying out the proposals above made, the Government of the North Western Provinces might make a transfer of credit to the extent of one lakh of rupees from such head of service as is most convenient.

Inasmuch as it will be important to restrict irrigation from the Ganges Canal, at all events to its existing limits, until the works are placed in a thoroughly secure position, it should be at once ordered that no new engagements should be entered into for the supply of

Digitized by Google

water. So far as is practicable, the work on rajbuhas under construction may be suspended. Should the officers of the Irrigation Department see their way to any reduction of the extent of irrigation without involving breach of engagements, or pressure on the country, it might be advisable to effect it, and a strict limit should, without loss of time, be placed on the maximum quantity of water to be admitted into the canal.

R. STRACHEY, *Colonel*, R. E.,
Secy. to the Govt. of India.

W. E. MORTON, *Lieut. Col.*, R. E.,
Secy. to Govt., N. W. P., P. W. D.

A. D. TURNBULL, R. E.,
Supdt. Genl. of Irrigation, N. W. P

J. H. DYAS, *Captain*, R. E.,
Director of Canals, Punjab.

J. CROFTON, *Captain*, R. E.,
Offg. Supt., E. J. Canal.

[*COPY.*]

MEMORANDUM.

The Committee of the Engineer Officers, with the fullest data before them, have, so far as I can understand, come to the conclusion, that it is not likely to be worthwhile to undertake operations on the existing canal in the way of re-modelling slope, short of fitting it to carry the whole supply.

The canal as now constructed, it would appear, can safely carry a depth of 4 feet of water, and no more. To re-model the bed, so as to carry a greater depth, say one-half of the full supply whilst the remaining half is carried by a separate channel, would, the Committee observes, be very nearly as difficult as to re-model the existing channel, so as to carry the full supply, the important item in both being the foundations, and the work to be done below the water level of the country.

The Committee, therefore, starts with the idea, that the existing channel, which can, without injury, carry a supply of 1,700 cubic feet per second, may be required so as to carry that volume *only*, the separate channel being projected to carry the remainder, *viz.*, 5,050 cubic feet per second.

The objection to this appears to be—

1*st.* The supply provided for the irrigation of the lands under the existing channel (or what in the new scheme would become the Eastern Branch,) *viz.*, 1,700 cubic feet per second *would be insufficient for their irrigation*, their wants being as follow :—

For the line from Roorkee to the Futtehgurh Branch Head, including the supply for the Futtehgurh Branch	1,420
For the line south from the Futtehgurh Branch Head to the Bolundshuhur Branch Head, including the supply of the Bolundshuhur Branch ...	1,000
Total required for Irrigation on existing channel, cubic feet per second ...	2,420

2*nd.* That to make a separate or alternative line to carry 5,050 cubic feet per second, would be a very large and a very expensive work, very nearly as large, in fact, as the existing canal, whilst the existing canal would be left with a body of water in it, so small as to bear no comparison with its capacity and the extent of its works.

Now my original views on this division of the water were based on the following :—

1*st.* The absolute necessity of maintaining in all its integrity the supply passing the Bolundshuhur Head, *viz.*, 4,330 cubic feet per second, for the irrigation of the Southern Districts, as originally projected.

2*nd.* The absolute necessity of securing to the existing channel from Roorkee to the Bolundshuhur Branch Head (6750—4330) 2,420 cubic feet per second.

I was not, of course, aware at the time of the actual quantity that the existing channel could with safety carry, but I estimated this at the full amount required for the irrigation, *viz.*,

Digitized by Google

2,420 cubic feet per second. It appears that I over-estimated its value, and that it will carry 1,700 cubic feet per second only, or 720 cubic feet less than what is required for irrigation.

A channel that will carry 1,700 would, with a very little improvement I imagine, carry 2,420; at any rate, I consider it to be indispensable that this supply should be secured to the existing line.

In addition to this, 2,420 cubic feet per second to be carried on the existing line, I proposed an additional quantity, making up the volume to 3,750 cubic feet per second, leaving the remainder to be carried in the separate or alternative line.

From Roorkee to the Futtehgurh Branch Head, the eastern or existing channel would have to bear		3,750
From the Futtehgurh Head to the Bolundshuhur Head	3750—1420=	2,330

whilst the remaing 3,000 cubic feet per second would be carried in the Western Channel.

I considered that the present supply, in defiance of the difficulties which encompassed it, might be maintained, *until the Western Channel was completed.* I looked upon the completion of this Western Channel, in the first instance, as a necessary part of the scheme, so that 3,000 cubic feet per second might be at once securely available.

The Eastern or existing channel, which now can only carry 1,700 cubic feet per second, would then be re-modelled so as to carry 3,750. This would, of course, necessitate additional falls of masonry which, although requiring deep and well protected foundations, would not (as calculated to carry 3,750 cubic feet per second) require to be of so large a size as those now in existence for the carriage of 6,750.

In fact, the size of the falls is an element not to overlooked. Should the whole body of water be retained in the present or existing channel, the extent, and consequently the cost of constructing additional falls, will be very much more than if built for the reduced volume of water. I leave out of the question the advantage of dealing with more manage able masses of water, and the very valuable resources of having an alternative line for the security of the irrigation of the Southern Districts.

My object in writing this memorandum is, simply to point out the grounds upon which I originally suggested, the division of the water. I had much rather see the whole matter left in the hands of Captain Crofton (an Officer in whose skill and judgment I have great faith) and the Committee of Engineer Officers, who, as being on the spot, are provided with details, with which I am imperfectly acquainted, than that my views, as here submitted, should be officially dealt with.

(Signed) P. T. CAUTLEY.

8th April 1864.

Digitized by Google

Digitized by Google

APPENDIX B.

TABULAR STATEMENT showing positions of Masonry Works, changes in declivity and dimensions of Channel, on the present line of the Ganges Canal, with the alterations and additions, projected for re-modelling.

N. B.—Proposed alterations in **Antique Type.**

Distance from Head.		NAME OF WORK.	Bottom width of Channel.	Depth of Water at full supply.	Side slopes, 1 in	Declivity of bed, 1 in	Mean velocity, feet per second.	Discharge calculated c. feet per second.	Discharge required c. feet per second.	Depth of foundations below bed.	Height from bed to crown of Arch.	Bridges.			Reduced Levels of Bed.		Projected alterations and additions.
												No. of Arches.	Span.	Width of Road-way.	At present.	If re-model-led.	
Miles.	Feet.							MAIN LINE.									
0	0	Ganges Dam, 15 days of 10' each, 517' over all. Myapore Regulating Bridge	...	...	...	......	......	......	......	6	16·5	10	20	37·75	200·00	**200·00**	**New regulating apparatus.**
			140	9	1·5	2630	5·132	7091	6750								
			140	**9**	**1·5**	**2630**	**5·132**	**7091**	**7180**								
0	2757	Lounda Leniwala Drainage Inlet R. B. 50' wide	...	...	...	......	......	......	......	6·3							
1	1959	Kunkhul Drainage Inlet R. B. 3 bays of 10' ... Outlet, L. B. 2 arches of 10'	...	...	...	......	......	......	......	6 & 7							
1	4347	Kunkul Bridge	...	...	...	......	......	......	......	10	20	3	55	18	203·66	**203·66** 206·73	**With lock bed below lowered 3·07. Grating attached and lock channel.**
			140	9·75	1·5	3403	4·526	6824	6750								
			145	**13**	**2**	**8500**	**3·229**	**7179**	**7180**								
3	1215	Jowalapoor Drainage Inlet, R. B. 100' wide	...	...	...	......	......	......	......	6·3							
3	3222	Jowalapoor Bridge and lock channel head, L. B.	...	...	...	......	......	......	......	10	**21·13** 20	3	55	18	206·48	**207·61**	**Floor to be lowered 1·13. Towpath.**
5	648	Ranipoor Superpassage and lock attached, Fall 9·05.	...	...	...	......	......	......	......	20	16	8	25	200	208·78 217·76	**208·78** **218·62**	**Grating to be attached, direct entrance made into lock, bed below fall lowered 0·86.**
			143	11	1·5	5221	3·86	6773	6750								
			145	**11**	**2**	**9000**	**3·138**	**6976**	**7100**								

Digitized by Google

APPENDIX B.—(Continued.)

N. B.—Proposed alterations in **Antique Type.**

Distance from Head.		NAME OF WORK.	Bottom width of Channel.	Depth of Water at full supply.	Side slopes, 1 in	Declivity of bed 1 in	Mean velocity, feet per second.	Discharge calculated c. feet per second.	Discharge required, c. feet per second.	Depth of foundations low bed.	Height from bed to crown of Arch.	Bridges. No. of Arches.	Bridges. Span.	Bridges. Width of Road-way.	Reduced Levels of bed. At present.	Reduced Levels of bed. If remodelled.	Projected alterations and additions.
	Feet.																
6	5111	Bahadoorabad Fall 8·93 lock on separate channel	... 170	... 9	... 1·5	 4024	...... 4·052	 6692	 6750	20	Lk. br. 19·5	8	25	28	219·70 228·63	**219·70** **228·63**	**Bridge to be raised. Grating to be attached; new entrance to lock channel; walls of lock to be raised.**
7	2527	Bahadoorabad Fall 8·89 lock on seperate channel	...	...	...	......	......	......	......	20	Lk. br. 19·5	8	25	18	229·30 238·19	**229·30** **239·59**	**Bridge to be raised. Grating; new exit from lock channel; Bridge of lock to be raised; Bed lowered 1·4 below Fall.**
			160 **145**	9·75 **13**	1·5 **2**	4382 **9000**	4·001 **3·138**	6750 **6976**	6750 **7100**								
8	1151	Sulempoor Drainage Inlet R. B. 150′ wide ...	...	...	...	......	......	......	......	6·3							
9	3930	Puttree Superpassage and lock attached, Fall 9·22.	...	...	...	......	......	......	......	20	15·34	8	25	300	240·92 250·14	**240·92** **256·20**	**Grating: direct entrance made into lock. Bed lowered 6·06 below Fall. New lock down stream.**
			133 **145**	1·05 **13**	1·5 **2**	4221 **9000**	4·188 **3·138**	6541 **6976**	6750 **6900**								
11	4173	Badshapoor Drainage Inlet R. B. 50 wide ...	...	...	...	......	......	......	......	10							
12	4179	Dhunowrie Bridge ...	...	...	...	......	......	......	......	20	20	3	55	18	253·83	**253·83**	**Towpath.**
		Rutmoo Inlet and Outlet Dams, 57 bays of 10′ 800′ waterway above ...	...	...	...	......	......	......	......	...	...	...	...	...	253·93		
13	328	Ditto Regulating Bridge	...	...	...	......	......	......	......	20	15	10	20	18	254·29	**254·29** **257·93**	**Regulating apparatus; Side arches to be raised. Bed below lowered 3·64.**
			150 **150**	10 **12·8**	1·5 **1·5**	4293 **9000**	4·09 **3·152**	6750 **6826·7**	6750 **6750**								
14	1721	Peeran Kulliar Bridge ...	...	...	...	......	......	......	......	10	33	3	55	18	255·53	**258·67**	**Floor lowered 3·14.—Towpath.**
15	5070	Muhewar ditto at North end of aqueduct ...	...	...	...	......	......	......	......	10	22	3	55	18	257·84	**259·63**	**Ditto 1·79. ditto.**
18	404	Solanee Aqueduct (Centre).	...	...	...	......	......	......	......	...	...	15	50	170	261·42	**261·42**	

18	3808	Roorkee Bridge ...	...	...	...	......	......	......	......	10&19	22	3	55	18	261·25	**261·25**	Towpath.
			140	11	1·5	4819	4·013	6908	6750								
19	**2028**	**Ditto Fall 4·07** ...	...	...	...	......	......	......	......	...	...	**10**	**15**	...	......	**261·65** **265·72**	
			197	**11·3**	**2**	**11000**	**2·717**	**6742**				**4**					
20	74	Guneshpoor Bridge ...	...	...	...	......	......	......	......	10	22	3	55	18	262·66	**266·34**	One arch of 55 feet added. Floor lowered 3·68. Towpath.
22	390	Rajbuha Outlet, R. & L. B. Lock Channel head.	...	...	...	......	......	......	......	...	...	...	...	...	Sills on level of bed.	......	Lock channel head to be removed.
22	3890	Hafiznuggur or Asoffnuggur Fall 7·98. Locks on separate channel ...	...	...	...	......	......	......	......	20	Lk. br. 18	8	25	18	265·65 273·63	**267·65** **275·28**	Floor to be lowered 1·65. Gratings. New exit for lock channel.
			140	10	1·5	4196	4·123	6391	6667·5								
24	4451	Munglour Bridge ...	...	...	...	......	......		......	12	22	4 3	55	18	276·29	**276·29**	One arch of 55 feet added. Towpath.
26	1409	Liburheree **Fall 6·87**	...	...	...	......	......	......	......	...	...	**12**	**15**	...	......	**276·97** **283·84**	
		Ditto Bridge ...	...	...	...	......	.....	......	......	11·7	22	4 3	55	18	278·19	......	Floor lowered 5·65. One arch of 55 feet added. Towpath.
28	3672	Do. Mundowlee Bridge ...	...	...	...	......	......	......	......	15	20	4 3	55	21	281·15	**284·87**	Floor lowered 3·86. One arch of 55 feet added. Towpath.
30	2374	Rajbuha Outlet, R. & L. B. Lock Channel head ...	...	...	...	......	......	......	......	...	...	...	...	...	Sills on level of bed.	.....	Lock channel head to be removed.
31	594	Muhmoodpoor Fall 7·83. Locks on separate channel ...	...	...	...	......	......	......	......	32	Lk. br. 18	8	25	18	284·17 292·00	**286·17** **294·56**	Gratings. Floor lowered 2·56. New exit for lock channel.
			140 **196**	10 **12**	1·5 **2**	4081 **13000**	4·18 **2·566**	6480 **6776**	6585								
33	3730	Dimat Bridge ...	...	...	...	......	......	......	......	15	22	4 3	55	18	295·61	**295·61**	One arch of 55 feet added. Towpath.
38	714	**Fall 8·54** ...	...	...	...	.....	......	......	......	...	...	**12**	**15**				
		Toghulpoor Bridge ...	...	...	...	......	......	......	......	10&16	20	4 3	55	18	300·88	**297·49** **306·03**	One arch of 55 feet added. Towpath. Floor lowered 5·15.
41	4116	Rajbuha Outlet R. and L. B. Lock Channel head	...	...	...	......	......	......	......	...	...	...	...	...	Sills 1' above bed.	......	Lock channel head removed.
42	2336	Nirgajnee or Bailra Fall 8·19. Lock on separate Channel ...	...	...	...	......	......	......	......	20	Lk. br. 18	8	25	18	306·78 314·97	**307·78** **319·36**	Gratings. Floor lowered 4·39. New exit for lock channel.
			140 **197**	10 **11·3**	1·5 **2**	4238 **11000**	4·111 **2·717**	6373 **6742**	6502·5								
44	1099	Bailra Bridge ...	...	...	...	......	......	......	......	15·5	20	4 3	55	18	316·53	320·21	One arch of 55 feet added. Towpath. Floor lowered 3·68.

Digitized by Google

APPENDIX B.—(Continued.)

N B.—Proposed alterations in **Antique Type.**

Distance from Head.		NAME OF WORK.	Bottom width of Channel.	Depth of Water at full supply.	Side slopes, 1 in	Declivity of bed, 1 in	Mean velocity, feet per second.	Discharge calculated, c. feet per second.	Discharge required, c. feet per second.	Depth of foundations below bed.	Height from bed to crown of Arch.	Bridges. No. of Arches.	Bridges. Span.	Bridges. Width of Road-way.	Reduced Levels of Bed. At present.	Reduced Levels of Bed. If re-modelled.	Projected alterations and additions.
Miles.	Feet.																
46	3101	Bhopa Bridge ...	...	...	...	......	......	......	......	15	20	**4** 3	55	18	319·89	**321·35**	**One arch of 55 feet added. Towpath. Floor lowered 1·46.**
47	3493	Rajbuha Outlet, R. & L. B. Lock Channel head ...	...	...	...	......	......	......	......	...	...	...	...	...	Sills 1' above bed.	......	Lock channel head to be removed.
48	1713	Jaolee Fall 8·03. Lock on separate Channel ...	...	...	...	......	......	......	......	20	Lk. br. 18	8	25	18	322·18 330·21	**322·18** **332·63**	**Gratings. Floor lowered 2·42; new exit for lock channel.**
			140	10	1·5	4168	4·136	6411	6420								
50	2530	Futtehgurh Branch Regulating Head.															
		Main Channel ...	...	...	...	......	......	......	......	8	16	9	20	18	333·67	**333·67**	**Regulating Apparatus. Side arches raised.**
		Futtehghur Branch ...	...	...	...	......	......	......	......	...	...	4	20	18	333·59	**333·59**	**Lock and Grating into Futtehgurh Branch.**
			130	9	1·5	4168	3·93	5076	5180								
			158	**11**	**2**	**11000**	**2·653**	**5252**									
53	2347	Dukheree **Fall 3·53** ...	...	...	...	......	......	......	......	...	...	**9**	**15**	...	......	**335·01** **338·54**	
		Dukheree Bridge ...	...	...	...	......	......	......	......	10·3	20	3	55	18	335·75	......	**Floor lowered 2·79. Towpath.**
			143	**11**	**2**	**10000**	**27·66**	**5020**									
54	3981	Nugla Bridge ...	...	...	...	......	......	......	......	10	20	3	55	20	337·44	**339·17**	**Ditto 1·73; ditto.**
55	1476	Rajbuha Outlet, R. & L. B. Lock Channel head ...	...	...	...	......	......	......	......	...	...	...	...	...	Sills 1' above bed.	......	Lock channel head removed.
55	4976	Chitowra Fall 8·05. Lock on separate Channel ...	...	...	...	......	......	......	......	8·75	Lk. bk. 18	8	25	18	339·86 347·91	**339·86** **352·26**	**Gratings. Floor lowered 4·35; new exit for lock channel.**
			130	9	1·5	4307	3·867	5000	5097·5								
58	3935	Suraee Bridge ...	...	...	...	......	......	......	......	10	20	3	55	18	350·46	**353·73**	**Floor lowered 3·27. Towpath.**
62	1262	Khutowlee Bridge ...	...	...	...	... ...	......	......	......	12	22	3	55	24	355·58	**355·58**	**Towpath.**
62	1892	Khutowlee Escape L. B. to West Kalee Nuddee...	...	...	...	......	......	......	......	6&8	...	10	6	8·5	354·01	......	**Floor in 4 bays lowered 1·5 feet.**

Digitized by Google

62	**1950**	**Khutowlee Fall 3·68** ...	...	...	...	......	......	......	......	...	...	**9**	**15**	...	......	355·58 359·26	
			120	9·5	1·5	4307	3·943	5030	5097·5								
64	3281	Sutheree Bridge ...	...	...	...	......	......	......	......	11·25	20	3	55	18	358·62	**360·52**	**Floor lowered 1·90. Towpath.**
66	4130	Rajbuha Outlet R. and L. B. Lock Channel head ...	...	...	...	......	......	......	......	...	...	...	...	...	Sills on level of bed.	......	Lock Channel head to be removed.
67	2350	Sulawar Fall 8·09. Lock on separate Channel ...	...	...	...	......	......	......	......	12·5	Lockbr 18	6	25	18	362·01 370·10	**362·01** **374·61**	**Gratings. Floor lowered 4·51 feet. New exit for lock channel.**
			120	9·5	1·5	4450	3·88	4950	5015								
69	5106	Aboo Nulla Escape L. B. to West Kalee Nuddee...	...	...	....	......	......	......	......	6·5	......	10	6	8·5	371·59	**Bed.** **375·94**	**Floor in 4 bays lowered 2 feet.**
71	2888	Aternah Bridge ...	...	...	...	......	......	......	......	7·5	20	3	55	18	374·90	**376·79**	**Floor lowered 1·87. Towpath.**
74	3990	Sirdhannah ditto ...	...	...	...	......	......	......	......	6·7	22	3	55	25	378·47	**378·47**	**Towpath.**
76	......	**Sirdhannah Fall, 5·76**...	...	...	...	......	......	......	......	...	...	**9**	**15**	...	......	**379·13** **384·61**	
			128	**11**	**2**	**8000**	**3·07**	**5067**	5015								
77	3776	Nanoon Bridge ...	...	...	...	......	......	......	......	9	16	3	50	25	382·18	**385·75**	**Floor lowered 3·57. Towpath. Arch raised.**
79	5124	Jutpoora ditto ...	...	...	...	......	......	......	......	13	16	3	50	18	385·28	**387·15**	**Floor lowered 1·57. Towpath. Arch raised.**
82	2145	Pooth ditto ...	...	...	...	......	......	......	......	15·75	16	3	50	20	388·02	**388·84**	**Floor lowered 0·82. Towpath. Arch raised.**
83	3281	Rajbuha Outlet R. and & L. B. Lock Channel head ...	...	...	...	......	......	......	......	...	...	...	...	...	Sills on level of bed.	......	Lock Channel head removed.
84	1501	Bhola Falls 7·84. Lock on separate Channel ...	...	...	...	......	......	......	......	21·5	Lockbr 18	6	25	18	390·08 398·17	**390·60** **398·17**	**Grating. New exit for lock channel.**
			120	9·5	1·5	4340	3·928	5010	4932·5								
87	402	Jannee Khoord Escape R. B. to Hindun River ...	...	...	...	......	......	......	......	12	...	10	6	8·5	398·70	**Bed.** **400·01**	**Floor in 4 bays lowered 1·5 feet.**
87	1594	Ditto Bridge ...	...	...	...	......	......	......	......	11·25	16	3	50	20	401·86	**399·86**	**Towpath. Arch raised.**
89	3790	Nugla **Fall, 6·78** ...	...	...	...	......	......	......	......	...	...	**8**	**15**	...	......	**401·75**	
		Ditto Bridge ...	...	...	...	......	......	......	......	10·75	16	3	50	20	404·88	**408·53**	**Floor lowered 3·65. Towpath. Arch raised**
93	2012	Newarree Bridge ...	...	...	...	......	......	......	......	10·75	16	3	50	18	409·44	**410·95**	**Floor lowered 1·51. Towpath. Arch raised.**
96	1145	Sounda Ditto ...	...	...	...	......	......	......	......	10	16	3	50	18	412·82	**412·82**	**Towpath. Arch raised.**
		Aboopoor **Fall 5·11** ...	...	...	...	......	......	......	......	...	...	**8**	**15**	...	......	**414·30**	
98	2430	Ditto Bridge ...	...	...	...	......	......	......	......	11	16	3	50	18	415·41	**419·41**	**Floor lowered 4·0. Towpath. Arch raised.**
100	1282	Moradnuggur Ditto ...	...	...	...	......	......	......	......	10	16	3	50	25	417·65	**420·59**	**Floor lowered 2·94. Towpath. Arch raised.**
103	238	Noorpoor Ditto ...	...	...	...	......	......	......	......	11	16	3	50	18	42135	**422·44**	**Floor lowered 1·09. Towpath. Arch raised.**
104	4892	Rajbuha Outlet, R. and L. B. Lock Channel head ...	...	...	...	......	......	......	......	...	...	...	...	...	Sills level with bed.	......	Lock Channel head to be removed.
105	3112	Musoorie or Dasna Fall 7·9. Lock on separate Channel ...	...	...	...	......	......	......	......	12	Lockbr 18	6	25	18	424·12 432·17	**424·12** **436·36**	**Gratings. Floor lowered 4·19; new exit for lock channel.**

Digitized by Google

APPENDIX *B.*—(Continued.)

N. B.—Proposed alterations in **Antique Type.**

Distance from Head. Miles.	Feet.	NAME OF WORK.	Bottom width of Channel.	Depth of Water at full supply.	Side slopes, 1 in	Declivity of bed, 1 in	Mean velocity, feet per second.	Discharge calculated, c. feet per second.	Discharge required, c. feet per second.	Depth of foundations below bed.	Height from bed to crown of Arch.	Bridges. No. of Arches.	Span.	Width of Road-way.	Reduced Levels of Bed. At present.	If remodel-led.	Projected alterations and additions.
			110	9·5	1·5	4275	3·938	4648	4850								
			111	**12**	**2**	**9000**	**2·965**	**4767**									
106	4094	Peepulheree Bridge ...	...	...	...	......	......	......	......	16	16	3	45	20	433·68	**437·05**	**Floor lowered 3·37. Towpath. Arch raised.**
108	3889	Raolee Ditto ...	...	...	...	......	......	......	......	17	16	3	45	18	436·04	**438·20**	**Floor lowered 2·16. Towpath. Arch raised.**
110	1746	Boolundshuhur Branch Regulating Head ...	...	...	...	......	......	......	......	...	...	...	...	...	......	**439·14**	**Regulating Apparatus. Side arches raised and lock Chamber added in Bolundshuhur Branch.**
		Main Channel ...	...	...	...	......	......	......	......	5 to 15	14	8	20	18	437·64	**437·64**	
		Boolundshuhur Branch ...	...	...	...	......	......	......	......	...	14	2 1	15 20	18	437·64	437·64	
			110	9	1·5	4275	3·845	4274	4330								
			114	**10·5**	**2**	**7500**	**3·084**	**4372**									
113	3801	Nidhaolee Bridge ...	...	...	...	......	......	......	......	5·5 to 7·5	16	3	45	18	441·87	**440·02**	**Towpath. Arch raised.**
		Jarcha **Fall 5·20** ...	...	...	...	......	......	......	......	...	...	**8**	**15**	...	......	**422·08**	
116	3338	Jarcha Bridge and Rajbuha Outlet Sills 2' above bed ...	...	...	...	......	......	......	......	5·3 to 7	16	3	45	18	445·55	**447·28**	**Floor lowered 1·73. Towpath. Arch raised.**
119	4335	Geesoopoor Bridge and Rajbuha Outlets. Sills 2 ft. above bed ...	...	...	...	......	......	......	......	5·5 to 6·3	16	3	45	18	449·52	**449·52**	**Towpath. Arch raised.**
122	3290	Sunowta ditto ditto ...	...	...	...	......	......	......	......	8 to 9	16	3	45	18	453·16	**451·49**	**Ditto Ditto.**
		Pukhana **Fall 4·67** ...	...	...	...	......	......	......	......	...	...	**8**	**15**	...	......	**453·59**	
125	3227	Pukhana Bridge ditto ...	...	...	...	......	......	......	......	5·5 to 6	16	3	45	18	457·09	**458·26**	**Floor lowered 1·17. Towpath. Arch raised.**
128	2909	Dumkoura Bridge, no Rajbuha Outlets ...	...	...	...	......	......	......	......	5·3 to 6·3	16	3	45	18	460·33	**460·33**	**Towpath. Arch raised.**
131	1175	Urowlee Bridge and Rajbuha Outlets, Sills 2 ft. above bed ...	...	...	...	......	......	......	......	5 to 8	16	3	45	25	463·81	**462·22**	**Ditto. Ditto.**

Digitized by Google

133	4072	Wullipoora **Fall 6'25**...	...	...	...	......	......	......	......	...	...	**5**	**18**	...	....	**462'22**	
		Wullipoora Bridge ditto	...	...	...	......	......	......	......	8 to 8·5	16	3	45	25	467·34	**464'00** **470'25**	**Floor lowered 2'91. Towpath; Arch raised.**
137	420	Mamun Bridge ditto ...	...	...	...	......	......	......	......	6 to 6·2	16	3	45	18	471·31	**472'59**	**Floor lowered 1'28. Towpath; Arch raised.**
139	3642	Uchuhja Bridge, no Rajbuha Outlets ...	...	...	...	......	......	......	......	7·5 to 8·5	16	3	45	18	474·42	**474'42**	**Towpath; Arch raised.**
		Moonda Khera Escape L. B. to East Kalee Nuddee	...	...	...	......	......	......	......	6·0	...	10	6	17			
142	512	Ditto Bridge and Rajbuha Outlets Sills 2 feet above bed ...	...	...	...	......	......	......	......	0·6 to 8·6	16	3	45	18	477·26	**476'12**	
		Ditto. **Fall 5'51** ...	...	...	...	......	......	......	......	...	...	**8**	**15**			**481'63**	
144	3408	Suhenda Bridge and Rajbuha Outlets, Sills as before ...	...	...	...	......	......	......	......	6·6	16	3	45	18	480·09	**483'42**	**Floor lowered 3'33. Towpath; Arch raised.**
148	361	Rajbuha Outlets R & L. B. Lock Channel head...	...	...	...	......	......	......	......	...	...	...	...	...	Sills 2 feet above bed.		Lock Channel head removed.
148	3861	Pulra Fall 4·94. Lock on separate Channel ...	...	...	...	......	......	......	......	13	Lk. br. 12·5	5	20	18	485·30 490·24	**486'30** **493'04**	**Gratings; Floor lowered 2'80. New exit for lock channel.**
			107	8·8	1·5	4,337	3·774	3,992	4002							**495'31**	**Regulating Apparatus; Side Arches raised.**
151	5024	Koel Branch Regulating Head Main Channel ...	...	...	...	......	......	......	......	5	14	6	20	18	49·431	**494'31**	
		Koel Branch ...	...	...	...	......	......	......	......	5	14	2 1	15 20	18	494·25	**494'25**	**Lock and gratings into Koel branch.**
			96 **101**	8·5 **9'5**	1·5 **2**	4337 **7000**	3·692 **3'032**	3413 **3457**	3482								
155	2501	Daopoor Bridge and Rajbuha Outlets, Sills 2 feet above bed ...	...	...	...	......	......	......	......	6	15·33	3	40	18	498 66	**496'96**	**Towpath; Arch raised.**
		Burowlee **Fall 5'14** ...	...	...	...	......	......	......	......	...	...	**7**	**15**			**498 97**	**Floor lowered 1'98; Towpath. Arch raised.**
158	663	Ditto Bridge and Rajbuha Outlets, Sills 2 feet above bed ...	...	...	...	......	......	......	......	6	15·33	3	40	18	502·13	**504'11**	
161	941	Dubthulla, ditto ditto ...	...	...	...	......	......	......	......	7	15·33	3	40	18	505·89	**506'40**	**Floor lowered 0'51. Ditto. Ditto.**
162	3737	Rajbuha Outlets, R. & L. B. Lock Channel head...	...	...	...	......	......	......	......	...	...	...	...	...	Sills 2 feet above bed.		Lock channel head removed.
163	1957	Simra fall 4·93 Lock on separate Channel ...	...	...	...	......	......	......	......	15·5	Lk. br. 12·5	5	20	22	508·06 512·99	**508'06** **512'99**	**Gratings. New exit for lock channel.**
			90 **99**	8·5 **9'5**	1·5 **2**	4282 **7000**	3·7 **3'028**	3232 **3394**	3394								

Digitized by Google

APPENDIX B.—(Continued.)

N. B.—Proposed alterations in **Antique Type.**

Distance from Head. Miles.	Feet.	NAMES OF WORK.	Bottom width of Channel.	Depth of Water at full supply.	Side slopes, 1 in	Declivity of bed 1 in	Mean velocity, feet per second.	Discharge calculated, c. feet per second.	Discharge required, c. feet per second.	Depth of foundations below bed.	Height from bed to crown of Arch.	Bridges. No. of Arches.	Span.	Width of Roadway.	Reduced levels of bed. At present.	If remodelled.	Projected alterations and additions.
		Kasimpoor Escape LB to East Kalee Nuddee ...	...	...	...	......	......	......	......	6	...	10	6	17			
166	2353	Ditto Bridge and Rajbuha Outlets, sills 2 feet above bed ...	...	...	...	......	......	......	......	7	15·33	3	40	18	516·93	**515·31**	**Arch raised; Towpath.**
		Kassimpore **Fall 4·83**...	...	...	...	......	......	......	......	...	...	**7**	**15**			**515·31** **520·14**	
170	370	Burotha Bridge and Rajbuha Outlets ...	...	...	...	......	......	......	......	7	15·33	3	40	22	521·65	**522·87**	**Floor lowered 1·22; Towpath; Arch raised.**
173	99	Machooa Bridge and ditto	...	...	...	......	......	......	......	5 & 6	15·33	3	40	18	525·09	**525·09**	**Towpath; Arch raised.**
		Chungeyree **Fall 3·56** ...	...	...	...	......	......	......	......	...	...	**7**	**15**			**526·92**	
175	2358	Chungeyree Bridge & do.	...	...	...	......	......	......	......	6·3	15·33	3	40	18	527·99	**530·48**	**Floor lowered 2·49; Towpath; Arch raised.**
177	4446	Shekha Bridge and ditto...	... 80 **96**	... 9 **9·5**	... 1·5 **2**	...... 4282 **7000**	...... 3·762 **3·024**	...... 3166 **3301**	 3250	5 to 6	15·33	3	40	22	530·97	**532·29**	**Floor lowered 1·32. Ditto Ditto.**
180	4657	Nanoon Regulating Head Cawnpoor Branch ...	...	...	...	......	......	......	......	6	14	5	20	25	534·58	**534·58**	**Regulating apparatus; Lockage into both branches, Gratings and tail revetments.**
		Ditto Etawah ditto ...	...	...	...	......	......	......	......	6	14	5	20	25	534·62	**534·62**	
		CAWNPORE BRANCH.															
0	0	Nanoon Regulating Bridge	... 80	... 6·0	... 1·5	 4131	...... 3·209	 1714	 1610	6·0	14	5	20	25	534·58	**534·58** **536·58**	**Bed lowered 2 feet below Bridge.**
2	4064	Keylunpoor Bridge and Rajbuha Outlets 10 feet, Sills 2 feet above bed, Fall 2·0 in flooring ...	... 79	... 6·0	... 1·5	 4275	...... 3·153	...... 1·665	......	6·0	13·5	3	33	20	538·12 510·00	**540·00**	**Fall in floor removed; Arches raised; Towpath added.**

Digitized by Google

6	1800	Rudain Bridge and Rajbuha Outlets, Sills as before ...	...	...	...	......	......	......	......	5·25	13·5	3	33	18	543·24 544·51	544·51	Fall in floor removed; Arches raised; Towpath added.
9	1332	Ginnowlee Escape into East Kalee Nuddee ...	...	...	...	......	......	......	......	...	...	3	6				
9	1760	Ditto Bridge, Rajbuha Outlets, Sills as before	...	...	...	......	......	......	......	...	13·5	3	33	18	547·27 548·20	548·20	Fall in floor removed; Arches raised; Towpath added.
11	1880	Buramye ditto, no Rajbuha Outlets ...	...	...	...	......	......	......	......	...	13·5	3	33	20	550·28 550·68	550·68	Ditto Ditto.
12	5265	Poordillnuggur ditto, Rajbuha Outlets, Sills as before ...	...	...	...	......	......	......	......	...	13·5	3	33	20	552·78	....	Arches raised; Towpaths added.
15	4970	Jirrowlee ditto ditto ...	...	...	...	......	......	......	......	...	13·5	3	33	18	556·58	....	Ditto ditto.
19	1960	Junsooee ditto ditto ...	...	...	...	......	......	......	......	...	13·5	3	33	18	560·53	....	Ditto ditto.
			72	...	1·5	4275											
22	3975	Tuttarpoor Bridge, Rajbuha Outlets, Sills as before	...	...	...	......	......	......	......	...	13·5	3	32	18	564·96	....	Ditto ditto.
			71	...	1·5	4275											
26	3800	Bundee Bridge Rajbuha Outlets, Sills as before	...	...	...	......	......	......	......	...	13·5	3	31	18	569·85	....	Ditto ditto.
			70	...	1·5	4275											
29	2150	Guddunpoor Bridge, Rajbuha Outlets, Sills as before ...	...	...	...	......	......	......	......	...	13·5	3	30	20	573·40	....	Ditto ditto.
32	4840	Gopalpoor ditto ditto 6 ft. Sills 1·3 above bed ...	...	...	...	......	......	......	......	...	13 5	3	30	18	577·06	....	Ditto ditto.
			67	...	1·5	4275											
35	3255	Dharoo Bridge and Rajbuha Outlets, Sills as before ...	...	...	...	......	......	......	......	...	13·5	3	29	18	580·92	....	Ditto ditto.
38	3810	Keylaee ditto ditto ditto...	...	...	...	......	......	......	......	...	13·5	3	29	20	585·00	....	Ditto ditto.
			65	...	1·5	4275											
41	3530	Khoreet Bridge and Rajbuha Outlets, as before...	...	...	...	......	......	......	......	...	13·5	3	28	18	588·61	....	Ditto ditto.
44	5000	Mokumpoor ditto ditto ...	...	...	...	......	......	......	......	...	13·5	3	28	20	592·65	....	Ditto ditto.
47	5130	Nuggureea Escape into Eesun Nullah ...	...	...	...	......	......	......	......	...	...	5	6				
48	400	Nuggureea Bridge and Rajbuha Outlets, as before	...	...	...	......	......	......	......	...	13·5	3	28	18	596·73	....	Ditto ditto.
			61	...	1·5	4275											
50	3550	Puchowar Bridge & Rajbuha Outlets, as before	...	...	...	......	......	......	......	...	13·5	3	27	20	599·64	....	Ditto ditto.
54	615	Kuraolee ditto ditto ...	...	...	...	......	......	......	......	...	13·5	3	27	18	600·97	....	Ditto ditto.
			58	...	1·5	4275											

Digitized by Google

APPENDIX B.—(Continued.)

N. B.—Proposed alterations in **Antique Type.**

Distance from Head. Miles.	Feet.	NAME OF WORK.	Bottom width of Channel.	Depth of Water at full supply.	Side slopes, 1 in	Declivity of bed 1 in	Mean velocity, feet per second.	Discharge calculated, c. feet per second.	Discharged required, c. feet per second.	Depth of foundations below bed.	Height from bed to crown of Arch.	Bridges. No of Arches.	Bridges. Span.	Bridges. Width of Road-way.	Reduced levels of bed. At present.	Reduced levels of bed. If remodelled.	Projected alterations and additions.
57	3285	Dunahar Bridge, no Rajbuha Outlets ...	...	...	...	......	......	......	......	...	13·5	3	26	25	608·25	......	**Arches raised, Towpaths added.**
60	5266	Roostnmpoor ditto and Rajbuha Outlets, as before ...	...	...	...	......	......	......	......	...	13·5	3	26	20	612·59	......	**Ditto ditto.**
64	4150	Singhpoor ditto ditto ...	...	...	...	......	......	......	......	...	13·5	3	26	20	616·90	......	**Ditto ditto.**
			54	...	1·5	4275											
67	3325	Putturhar Bridge and Rajbuha Outlets 6 feet, Sills 1·3 above bed ...	...	...	...	......	......	......	......	5·25	13·5	2	35	18	620·46	......	**Ditto ditto.**
70	2610	Bhawunt ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	35	20	623·64	......	**Ditto ditto.**
			52	6	1·5	5145	2·798	1024									
74	1327	Sagaon Bridge and Rajbuha Outlets as above ...	...	...	...	......	......	......	......	...	13·5	2	33	18	627·70	......	**Ditto ditto.**
77	1345	Kussudh ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	33	18	630·79	......	**Ditto ditto.**
80	3281	Ryharr ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	33	18	634·16	......	**Ditto ditto.**
			48	...	1·5	5145											
82	4652	Dhundos Bridge and Rajbuha Outlets as before ...	...	...	...	......	......	......	......	...	13·5	2	32	18	636·46	......	**Ditto ditto.**
87	556	Tireea Escape into Eesun Nuddee ...	...	...	...	......	......	......	......	...	......	5	6				
87	922	Ditto Bridge and Rajbuha Outlet as before ...	...	...	...	......	......	......	......	...	13·5	2	32	20	640·76	......	**Ditto ditto.**
90	2151	Futtehpoor ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	32	18	644·25	......	**Ditto ditto.**
			44	6	1·5	4741	2·878	915									
93	872	Mirzapoor Bridge and Rajbuha Outlets 6 feet, Sills 0·7 above bed ...	...	...	...	......	......	......	......	...	13·5	2	30	20	647·70	......	**Ditto ditto.**
96	2516	Dingree ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	30	18	650·79	......	**Ditto ditto.**
98	2986	Sureya ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	30	20	663·31	......	**Ditto ditto.**
102	1556	Kunsowad ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	30	18	657·30	......	**Ditto ditto.**
			40	6	1·5	5204	2·725	801									

Digitized by Google

104	4048	Husseyrun Bridge and Rajbuha Outlets as before	...	...	...	......	......	......	......	...	13·5	2	30	20	660·29	......	Ditto	ditto.
108	3678	Bahosee ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	30	18	663·87	......	Ditto	ditto.
111	218	Gohna ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	30	18	666·20	......	Ditto	ditto.
113	4670	Oomurda ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	30	18	669·11	......	Ditto	ditto.
			36	...	1·5	5204												
115	4700	Sookhee Bridge and Rajbuha Outlet as before ...	...	...	...	......	......	......	......	...	13·5	2	25	15	671·50	......	Ditto	ditto.
119	200	Khyrnuggur Bridge and Rajbuha Outlets as before	...	...	...	......	......	......	......	...	13·5	2	25	15	674·80	......	Ditto	ditto.
122	600	Aima ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	25	15	678·02	......	Girders raised.	Towpaths added.
124	4460	Barrapoor ditto, no Rajbuha Outlets.. ...	...	...	...	......	......	......	......	...	13·5	2	25	15	680·15	......	Arches raised.	ditto.
127	960	Bidheen ditto and Rajbuha Outlet as before ...	...	...	...	......	......	......	......	...	13·5	2	25	18	681·85	......	Ditto	ditto.
130	630	Ootha ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	25	18	685·23	......	Ditto	ditto.
132	4625	Munowa, ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	·25	18	687·71	......	Ditto	ditto.
134	5141	Kukwan Escape into Pandoo Nuddee	...	...	...	......	......	......	......	...	...	5	6					
135	330	Ditto Bridge and Rajbuha Outlets as before ...	...	...	...	......	......	......	......	...	13·5	2	25	20	690·71	......	Ditto	ditto.
138	480	Mudoopoor Bridge and Rajbuha Outlets as before	...	...	...	......	......	......	......	...	13·5	2	25	18	692·91	......	Ditto	ditto.
140	2105	Koondun ditto, no Rajbuja Outlets	...	...	...	......	......	......	......	...	13·5	2	25	15	695·35	......	Ditto	ditto.
142	2330	Tukroulee ditto and Rajbuha Outlets as before...	...	...	...	......	......	......	......	...	13·5	2	25	18	697·40	......	Ditto	ditto.
		... ...	27	...	1·5	5204												
145	1135	Bhosan Bridge and Rajbuha Outlets as before	...	...	...	......	......	......	......	5·0	13	1	30	20	699·96	......	Ditto	ditto.
147	625	Juggutpoor ditto ditto ...	...	...	...	......	......	......	......	...	13	1	30	18	701·80	......	Ditto	ditto.
150	1330	Runjeetpoor ditto ditto ...	...	...	...	......	......	......	......	...	13	1	30	18	705·02	......	Ditto	ditto.
153	1715	Hoorkapoor ditto ditto, sills level with bed ...	...	...	...	......	......	......	......	...	13	1	30	18	708·64	......	Ditto	ditto.
156	630	Koorsoulee ditto ditto ...	..	...	...	......	......	......	......	...	13	1	30	18	711·46	......	Ditto	ditto.
158	2200	Barra ditto ditto ...	...	...	...	......	......	......	......	...	13	1	30	18	713·48	......	Ditto	ditto.
			20	5	1·5	5204	2·373	326	296					...				
161	306	Muswanpoor Bridge and Rajbuha Outlets as before	...	...	...	......	......	......	......	...	13	1	25	15	716·19	......	Ditto	ditto.
162	2870	Khujooree ditto skew 37°	...	...	...	......	......	......	......	...	13	1	25	20	718·05			
162	4170	E. I. Railway, ...	...	...	...	......	......	......	......	...	12·75	1	25	out-side. 33	717·27	......	Girders raised.	ditto.
164	3019	Dabowlee escapes right and left bank into Pandoo Nuddee	...	...	...	......	......	......	......	...	...	3	6	...	720·08	......		

APPENDIX B.—(Continued.)

N. B.—Proposed alterations in **Antique Type.**

Distance from Head. Miles.	Distance from Head. Feet.	NAME OF WORK.	Bottom width of Channel.	Depth of Water at full supply.	Side slopes, 1 in	Declivity of bed 1 in	Mean velocity, feet per second.	Discharge calculated c. feet per second.	Discharge required, c. feet per second.	Depth of foundations below bed.	Height from bed to crown of Arches.	Bridges. No. of Arches.	Bridges. Span.	Bridges. Width of Road-way.	Reduced Levels of Bed. At present.	Reduced Levels of Bed. If remodel-ed.	Projected alterations and additions.
65	4174	Gangsee Bridge and Rajbuha Outlets, 6 ft., Sills as before ...	... **50**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·5	2	33	18	614·10		
68	2524	Hawellia ditto ditto ...	... **48**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·3	2	33	18	616·81		
70	3504	Boojea ditto ditto ...	... **46**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·3	2	33	25	619·63		
73	1671	Bansookh ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	33	18	622·35		
76	1374	Tukrao Bridge and Rajbuha Outlets, 6 ft., Sills 1·33 above bed	... **44**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·5	2	33	18	626·06		
79	415	Bulinda ditto ditto	...	...	...	......	......	......	......	...	13·5	2	33	18	628·68		
81	4664	Rookya Bridge and Rajbuha Outlets as before...	... **42**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·5	2	30	18	631·37		
84	1474	Raheem ditto ditto 10 ft., Sills 0·66 above bed	...	...	...	......	......	......	......	...	11·5	2	30	18	634·47		
87	3734	Lohya ditto ditto 6 ft., Sills as before ...	... **40**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·5	2	30	25	636·81		
90	4994	Budamye ditto ditto ...	...	...	...	......	......	......	......	...	11·5	2	30	18	640·53		
93	3964	Toreyeea ditto ditto ...	... **38**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·5	2	30	18	642·69		
96	3584	Oomurseyra Bridge and Rajbuha Outlets as before	... **36**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·5	2	26	18	646·06		
100	374	Bahurpoora ditto ditto ...	... **34**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·3	2	26	18	649·62		
103	474	Mulhosee Escape R. B. into Seyngoor Nullah	...	...	...	......	......	......	......	...	...	5	6				
		Ditto Bridge and Rajbuha Outlets, 10 ft., Sills as before ...	...	...	...	......	......	......	......	...	11·3	2	26	18	651·84		

Digitized by Google

104	4048	Husseyrun Bridge and Rajbuha Outlets as before	...	...	...	......	......	......	......	...	13·5	2	30	20	660·29	......	Ditto	ditto.
108	3678	Bahosee ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	30	18	663·87	......	Ditto	ditto.
111	218	Gohna ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	30	18	666·20	......	Ditto	ditto.
113	4670	Oomurda ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	30	18	669·11	......	Ditto	ditto.
			36	...	1·5	5204												
115	4700	Sookhee Bridge and Rajbuha Outlet as before ...	...	...	...	......	......	......	......	...	13·5	2	25	15	671·50	......	Ditto	ditto.
119	200	Khyrnuggur Bridge and Rajbuha Outlets as before	...	...	...	......	......	......	......	...	13·5	2	25	15	674·80	......	Ditto	ditto.
122	600	Aima ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	25	15	678·02	......	Girders raised.	Towpaths added.
124	4460	Barrapoor ditto, no Rajbuha Outlets.. ...	...	...	...	......	......	......	......	...	13·5	2	25	15	680·15	......	Arches raised.	ditto.
127	960	Bidheen ditto and Rajbuha Outlet as before ...	...	...	...	......	......	......	......	...	13·5	2	25	18	681·85	......	Ditto	ditto.
130	630	Ootha ditto ditto	...	...	...	......	......	......	......	...	13·5	2	25	18	685·23	......	Ditto	ditto.
132	4625	Munowa, ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	25	18	687·71	......	Ditto	ditto.
134	5141	Kukwan Escape into Pandoo Nuddee ...	...	...	...	......	......	......	......	...	...	5	6					
135	330	Ditto Bridge and Rajbuha Outlets as before ...	...	...	...	......	......	......	......	...	13·5	2	25	20	690·71	......	Ditto	ditto.
138	480	Mudoopoor Bridge and Rajbuha Outlets as before	...	...	...	......	......	......	......	...	13·5	2	25	18	692·91	......	Ditto	ditto.
140	2105	Koondun ditto, no Rajbuja Outlets	...	...	...	......	......	......	......	...	13·5	2	25	15	695·35	......	Ditto	ditto.
142	2330	Tu'kroulee ditto and Rajbuha Outlets as before...	...	...	...	......	......	......	......	...	13·5	2	25	18	697·40	......	Ditto	ditto.
		... ...	27	...	1·5	5204												
145	1135	Bhosan Bridge and Rajbuha Outlets as before	...	...	...	......	......	......	......	5·0	13	1	30	20	699·96	......	Ditto	ditto.
147	625	Juggutpoor ditto ditto ...	...	...	...	......	......	......	......	...	13	1	30	18	701·80	......	Ditto	ditto.
150	1330	Runjeetpoor ditto ditto ...	...	...	...	......	......	......	......	...	13	1	30	18	705·02	......	Ditto	ditto.
153	1715	Hoorkapoor ditto ditto, sills level with bed ...	...	...	...	......	......	......	......	...	13	1	30	18	708·64	......	Ditto	ditto.
156	630	Koorsoulee ditto ditto ...	..	...	...	......	......	......	......	...	13	1	30	18	711·46	......	Ditto	ditto.
158	2200	Barra ditto ditto ...	...	...	...	......	......	......	......	...	13	1	30	18	713·48	......	Ditto	ditto.
			20	5	1·5	5204	2·373	326	296					...				
161	306	Muswanpoor Bridge and Rajbuha Outlets as before	...	...	...	......	......	......	......	...	13	1	25	15	716·19	......	Ditto	ditto.
162	2870	Khujooree ditto skew 37°	...	...	...	......	......	......	......	...	13	1	25	20	718·05			
162	4170	E. I. Railway, ...	...	...	...	......	......	......	......	...	12·75	1	25	out-side. 33	717·27	......	Girders raised.	ditto.
164	3019	Dabowlee escapes right and left bank into Pandoo Nuddee	...	...	...	......	......	......	......	...	...	3	6	...	720·08	......		

APPENDIX B.—(Continued.)

N. B.—Proposed alterations in **Antique Type.**

Distance from Head. Miles.	Distance from Head. Feet.	NAME OF WORK.	Bottom width of Channel.	Depth of Water at full supply.	Side slopes, 1 in	Declivity of bed 1 in	Mean velocity, feet per second.	Discharge calculated c. feet per second.	Discharge required, c. feet per second.	Depth of foundations below bed.	Height from bed to crown of Arches.	Bridges. No. of Arches.	Bridges. Span.	Bridges. Width of Road-way.	Reduced Levels of Bed. At present.	Reduced Levels of Bed. If remodeled.	Projected alterations and additions
65	4174	Gangsee Bridge and Rajbuha Outlets, 6 ft., Sills as before ...	... **50**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·5	2	33	18	614·10		
68	2524	Hawellia ditto ditto ...	... **48**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·3	2	33	18	616·81		
70	3504	Boojea ditto ditto ...	... **46**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·3	2	33	25	619·63		
73	1671	Bansookh ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	33	18	622·35		
76	1374	Tukrao Bridge and Rajbuha Outlets, 6 ft., Sills 1·33 above bed	... **44**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·5	2	33	18	626·06		
79	415	Bulinda ditto ditto	...	...	...	......	......	......	......	...	13·5	2	33	18	628·68		
81	4664	Rookya Bridge and Rajbuha Outlets as before...	... **42**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·5	2	30	18	631·37		
84	1474	Raheem ditto ditto 10 ft., Sills 0·66 above bed	...	...	...	......	......	......	......	...	11·5	2	30	18	634·47		
87	3734	Lohya ditto ditto 6 ft., Sills as before ...	... **40**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·5	2	30	25	636·81		
90	4994	Budamye ditto ditto ...	...	...	...	......	......	......	......	...	11·5	2	30	18	640·53		
93	3964	Toreyeea ditto ditto ...	... **38**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·5	2	30	18	642·69		
96	3584	Oomurseyra Bridge and Rajbuha Outlets as before	... **36**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·5	2	26	18	646·06		
100	374	Bahurpoora ditto ditto ...	... **34**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·3	2	26	18	649·62		
103	474	Mulhosee Escape R. B. into Seyngoor Nullah	...	...	...	......	......	......	......	...	...	5	6				
		Ditto Bridge and Rajbuha Outlets, 10 ft., Sills as before ...	...	...	...	......	......	......	......	...	11·3	2	26	18	651·84		

105	3374	Munohurpoor Bridge and Rajbuha Outlet 6 ft. Sills as before	...	...	...	......	......	......	......	...	11·5	2	26	18	654·84
			32	6	1·5	5038									
109	1224	Uchuldee ditto ditto ...	...	...	...	......	......	......	......	...	11·5	2	26	18	658·70
			30	6	1·5	5038									
113	1374	Koomhara Bridge and Rajbuha Outlet 6 ft. Sills as before ...	...	...	...	......	......	......	......	...	11·5	2	26	18	662·52
			28	6	1·5	5038									
116	3674	Kundhon ditto ditto ...	...	...	...	......	......	......	......	...	11·5	2	26	18	666·42
			26	6	1·5	5038									
119	3374	Devipoora ditto ditto ...	...	...	...	......	......	......	......	...	11·5	2	26	18	669·23
			24	6	1·5	5038									
122	2074	Bijhye ditto ditto ...	...	...	...	......	......	......	......	...	11·75	1	33	18	672·58
			22	6	1·5	5038									
125	2074	Nogaon ditto ditto ...	...	...	...	......	......	......	......	...	11·75	1	33	18	675·44
128	2474	Gopalpoor ditto ditto ...	...	...	...	......	......	......	......	...	11·5	1	33	18	679·04
			20	6	1·5	5038									
131	5114	Jheenjuck Bridge and Rajbuha Outlet 10 ft. Sills as before ...	...	...	...	......	......	......	......	...	11·25	1	33	17	682·80
135	1874	Jooria ditto ditto 6 ft. do.	...	...	...	......	......	......	......	...	11·25	1	33	16	686·10
138	4014	Sithmurra ditto ditto ...	...	...	...	......	......	......	......	...	11·25	1	31	17	
140	3414	Jundamow ditto ditto ...	...	...	...	......	......	......	......	...	11·25	1	27	17	
143	574	Roora Escape L. B. into Rinde River ...	...	...	...	......	......	......	......	...	...	3	6		
		Do. Bridge, &c. as before	...	...	...	......	......	......	......	...	11·5	1	28	25	694·24
145	4564	Tignen ditto and Rajbuha Outlet 10 ft. Sills on level of bed ...	...	...	...	......	......	......	......	...	11·5	1	22	18	696·52
149	2274	Nurheea ditto ditto 6 ft. Sills as before ...	...	...	...	......	......	......	......	...	11·5	1	22	18	700·24
152	474	Akburpore ditto ditto ...	...	...	...	......	......	......	......	...	11·5	1	22	18	703·86
154	1674	Nubbeepoor ditto ditto ...	...	...	...	......	......	......	......	...	11·5	1	28	25	707·72
			20	6	1·5	3769									
157	3314	Naholee ditto ditto ...	...	...	...	......	......	......	......	...	11·5	1	21	18	712·77
			15	6	1·5	3769									
161	724	Girsee Bridge and Rajbuha Outlets as before ...	...	...	...	......	......	......	......	...	11·8	1	21	18	718·21
163	874	Rutgaon ditto ditto ...	...	...	...	......	......	......	......	...	11·5	1	21	18	
165	2814	Reona ditto ditto ...	...	...	...	......	......	......	......	...	12·05	1	21	18	724·91
168	5174	Googooa ditto ditto ...	...	...	...	......	......	......	......	...	11·8	1	28	...	728·14
170	734	Kerown Escape L. B. into Jumna River ...	...	...	...	......	......	......	......	...	...	1	10		
		Ditto Bridge ...	...	...	...	......	......	......	......	...	...	...	...	...	728·73

N. B.—Distances from head as far as Gihror Bridge taken from Appendix J. Ganges Canal Report; below that from the Executive Engineer's (Mr. Forrest's) statements. Reduced levels of flooring from head to Burraguon bridge taken from the Executive Engineer's (Lieut Jeffrey's) section. Below that from Mr. Forrest's section.

Digitized by Google

APPENDIX B.—(Continued.)

N. B.—Proposed alterations in **Antique Type.**

Distance from Head. Miles.	Feet.	NAME OF WORK.	Bottom width of Channel.	Depth of Water at full supply.	Side slopes, 1 in	Declivity of bed 1 in	Mean velocity, feet per second.	Discharge calculated c. feet per second.	Discharge required, c. feet per second.	Depth of foundations below bed.	Height from bed to crown of Arches.	Bridges. No. of Arches.	Bridges. Span.	Bridges. Width of Road-way.	Reduced Levels of Bed. At present.	Reduced Levels of Bed. If remodeled.	Projected alterations and additions
65	4174	Gangsee Bridge and Rajbuha Outlets, 6 ft., Sills as before ...	... **50**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·5	2	33	18	614·10		
68	2524	Hawellia ditto ditto ...	... **48**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·3	2	33	18	616·81		
70	3504	Boojea ditto ditto ...	... **46**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·3	2	33	25	619·63		
73	1671	Bansookh ditto ditto ...	...	...	...	......	......	......	......	...	13·5	2	33	18	622·35		
76	1374	Tukrao Bridge and Rajbuha Outlets, 6 ft., Sills 1·33 above bed	... **44**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·5	2	33	18	626·06		
79	415	Bulinda ditto ditto	...	...	...	......	......	......	......	...	13·5	2	33	18	628·68		
81	4664	Rookya Bridge and Rajbuha Outlets as before...	... **42**	... **6**	... **1·5**	...... **5038**	......	......	......	...	13·5	2	30	18	631·37		
84	1474	Raheem ditto ditto 10 ft., Sills 0·66 above bed	...	...	...	......	......	......	......	...	11·5	2	30	18	634·47		
87	3734	Lohya ditto ditto 6 ft., Sills as before ...	... **40**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·5	2	30	25	636·81		
90	4994	Budamye ditto ditto ...	...	...	...	......	......	......	......	...	11·5	2	30	18	640·53		
93	3964	Toreyeea ditto ditto ...	... **38**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·5	2	30	18	642·69		
96	3584	Oomurseyra Bridge and Rajbuha Outlets as before	... **36**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·5	2	26	18	646·06		
100	374	Bahurpoora ditto ditto ...	... **34**	... **6**	... **1·5**	...... **5038**	......	......	......	...	11·3	2	26	18	649·62		
103	474	Mulhosee Escape R. B. into Seyngoor Nullah	...	...	...	......	......	......	......	...	...	5	6				
		Ditto Bridge and Rajbuha Outlets, 10 ft., Sills as before ...	...	...	...	......	......	......	......	...	11·3	2	26	18	651·84		

105	3374	Munohurpoor Bridge and Rajbuha Outlet 6 ft. Sills as before	...	...	...	......	......	......	......	...	11·5	2	26	18	654·84		
			32	6	1·5	5038											
109	1224	Uchuldee ditto ditto ...	...	...	...	......	......	......	......	...	11·5	2	26	18	658·70		
			30	6	1·5	5038											
113	1374	Koomharn Bridge and Rajbuha Outlet 6 ft. Sills as before ...	...	...	...	......	......	......	......	...	11·5	2	26	18	662·52		
			28	6	1·5	5038											
116	3674	Kundhon ditto ditto ...	...	...	...	......	......	......	......	...	11·5	2	26	18	666 42		
			26	6	1 5	5038											
119	3374	Devipoora ditto ditto ...	...	...	...	......	......	......	......	...	11·5	2	26	18	669·23		
			24	6	1 5	5038											
122	2074	Bijhye ditto ditto ...	...	...	...	......	......	......	......	...	11·75	1	33	18	672 58		
			22	6	1·5	5038											
125	2074	Nogaon ditto ditto ...	...	...	...	......	......	......	......	...	11·75	1	33	18	675 44		
128	2474	Gopalpoor ditto ditto ...	...	...	...	......	......	......	......	...	11·5	1	33	18	679·04		
			20	6	1·5	5038											
131	5114	Jheenjuck Bridge and Rajbuha Outlet 10 ft. Sills as before ...	...	...	...	......	......	......	......	...	11 25	1	33	17	682·80		
135	1874	Jooria ditto ditto 6 ft. do.	...	...	...	......	......	......	......	...	11·25	1	33	16	686·10		
138	4014	Sithmurra ditto ditto ...	...	...	...	......	......	......	......	...	11·25	1	31	17			
140	3414	Jundamow ditto ditto ...	...	...	...	......	......	......	......	...	11·25	1	27	17			
143	574	Roora Escape L. B. into Rinde River ...	...	...	...	......	......	......	......	...	...	3	6				
		Do. Bridge, &c. as before	...	...	...	......	......	......	......	...	11·5	1	28	25	694 24		
145	4564	Tigaen ditto and Rajbuha Outlet 10 ft. Sills on level of bed ...	...	...	...	......	......	......	......	...	11·5	1	22	18	696·52		
149	2274	Nurheea ditto ditto 6 ft. Sills as before ...	...	...	...	......	......	......	......	...	11·5	1	22	18	700 24		
152	474	Akburpore ditto ditto ...	...	...	...	......	......	......	......	...	11·5	1	22	18	703 86		
154	1674	Nubbeepoor ditto ditto ...	...	...	...	......	......	......	......	...	11 5	1	28	25	707·72		
			20	6	1·5	3769											
157	3314	Nuholee ditto ditto ...	...	...	...	......	......	......	......	...	11·5	1	21	18	712·77		
			15	6	1·5	3769											
161	724	Girsee Bridge and Rajbuha Outlets as before ...	...	...	...	......	......	......	......	...	11 8	1	21	18	718·21		
163	874	Rutgaon ditto ditto ...	...	...	...	......	......	......	......	...	11·5	1	21	18			
165	2814	Reona ditto ditto ...	...	...	...	......	......	......	......	...	12 05	1	21	18	724·91		
168	5174	Googooa ditto ditto ...	...	...	...	......	......	......	......	...	11·8	1	23	...	728 14		
170	734	Kerown Escape L. B. into Jumna River ...	...	...	...	......	......	......	......	...	...	1	10				
		Ditto Bridge ...	...	...	...	......	......	......	......	...	...	...	...	...	728·73		

N. B.—Distances from head as far as Gihror Bridge taken from Appendix J. Ganges Canal Report; below that from the Executive Engineer's (Mr. Forrest's) statements. Reduced levels of flooring from head to Burragaon bridge taken from the Executive Engineer's (Lieut Jeffrey's) section. Below that from Mr. Forrest's section.

Digitized by Google

APPENDIX B.—(Continued.)

N. B.—Proposed alterations in **Antique Type.**

Distance from Head.		NAME OF WORK.	Bottom width of Channel.	Depth of Water at full supply.	Side slopes, 1 in	Declivity of bed, 1 in	Mean velocity, feet per second.	Discharge calculated c. feet per second.	Discharge required c. feet per second.	Depth of foundations below bed.	Height from bed to crown of Arch.	Bridges. No. of Arches.	Bridges. Span.	Bridges. Width of Road-way.	Reduced Levels of Bed. At present.	Reduced Levels of Bed. If remodelled.	Projected alterations and additions.
		FUTTEHGURH BRANCH.															
0	0	Jaolee, Regulating Head	...	...	...	......	......	......	......	...	...	4	20	18	333·59		
			70	5·5	1·5	4233	2·976	1281	1240								
			63	**6**	**2**	**5500**	**2·721**	**1225**	**1240**								
2	4884	Koomhera, Rajbuha Outlet LB ...	...	...	...	......	......	......	......	...	...	1	10				
3	660	Ditto, Bridge ...	...	...	...	......	......	......	......	...	13	3	25	18	337·48		
6	3206	Jutwara, Rajbuha Outlet RB ...	...	...	...	......	......	......	......	...	...	1	10				
6	3300	Ditto Bridge ...	...	...	...	......	......	......	......	...	13	3	25	18	341·88		
8	3960	Sumbulhera Ditto ...	...	...	...	......	......	......	......	...	13	3	25	20	344 49		
10	3300	Churiala fall 7·94 ...	...	...	...	......	......	......	......	...	...	3	20	18	346·89	**343·81**	
															354 83	**354·35**	
			69·5	...	1·5	4190											
			63	**6**	**2**	**5500**											
12	3300	Bhoomah Bridge ...	...	...	...	......	......	......	......	...	13	3	25	18	357·33		
			68·5	...	1 5	4333											
14	4620	Meerpoor Bridge ...	...	...	...	......	......	......	......	...	13	3	25	18	360·14		
			67·5	...	1·5	4333											
16	720	Akbarpoor, Rajbuha Outlets R & LB ...	...	...	...	......	......	......	......	...	...	1	10	...	358·90		
17	660	Ditto Falls ...	...	...	...	......	......	......	......	...	...	3	20	18	363·02	**360·59**	
															370·96	**370·21**	
			66	...	1·5	4175											
18	4620	Kol Bridge ...	...	...	...	......	......	......	......	...	...	3	25	20	373·15		
			65·5	...	1·5	4310											
21	4620	Mowana Bridge ...	...	...	...	......	......	......	......	...	...	3	20	18	376·90		
			64	...	1·5	4310											
24	1023	Dhakaulee, Rajbuha Outlet, RB ...	...	...	...	......	......	......	......	...	...	1	6				
24	1320	Ditto Falls ...	...	...	...	......	......	......	......	...	...	3	20	18	379·97		
															387 87		
			62·5	...	1·5	4407											

Digitized by Google

27	1980	Bahadurpoor Bridge ...	...	...	...	......	......	......	......	...	...	3	20	18	391·78	
			61	...	1·5	4407										
30	3180	Pareechetghur, Rajbuha Outlet, R. B. ...	...	...	...	......	......	......	......	...	...	1	15	...	392·97	
31	1320	Ditto Falls ...	...	...	...	......	......	......	......	...	...	3	20	18	396·71	
															404·62	
			59	...	1·5	4261										
33	3960	Burla Bridge ...	...	...	...	......	......	......	......	...	...	3	20	18	407·74	
			58	...	1·5	4261										
36	1320	Raidhuna Bridge ...	...	...	...	......	......	......	......	...	...	3	20	18	410·87	
			56·5	...	1·5	4261										
39	2090	Keihor, Rajbuha Outlet, L. B. ...	...	...	...	......	......	......	......	...	...	2	9·75			
		Shahjehanpoor Escape L. B. into Ganges river...	...	...	...	......	......	......	......	...	...	6	6	...	413·33	
39	4290	Ditto Bridge (Skew 60°)	...	...	...	......	......	......	......	...	...	3	20	24	415·31	
			55	...	1·5	4261										
41	5016	Doobae Falls ...	...	...	...	......	......	......	......	...	...	...	...	...	417·98	
															425·98	
			54	...	1·5	4206										
44	3300	Nowada Bridge ...	...	...	...	......	......	......	......	...	...	3	20	18	429·33	
			52·5	...	1·5	4206										
46	4620	Bagsar Bridge ...	...	...	...	......	......	......	......	...	...	3	20	24	432·20	
			51·5	...	1·5	4206										
50	2640	Huroura Bridge ...	...	...	...	......	......	......	......	...	...	2	29	18	436·67	
			49·5	...	1·5	4206										
53	495	Jukhera Falls	...	...	...	......	......	......	......	...	...	...	...	...	439·96	
			48	...	1·5	4224									443·96	
56	1500	Siana Bridge ...	...	...	...	......	......	......	......	...	...	2	29	20	447·90	
			46·5	...	1·5											
60	195·36	Mankree Falls ...	...	...	...	......	......	......	......	...	...	...	...	...	452·64	
															460·64	
			44·5	...	1·5	4224										
63	990	Bhurkon Bridge ...	...	...	...	......	......	......	......	...	...	2	24	18	464·57	
			43	...	1·5	4224										
66	...	Nursina Bridge ...	...	...	...	......	......	......	......	...	...	2	24	18	468·19	
			41·5	...	1·5	4224										
70	1320	Moos Khera Falls ...	...	...	...	......	......	......	......	...	...	...	...	...	473·40	
															477·40	
			39·5	...	1·5	4378										
72	1650	Churoura Bridge ...	...	...	...	......	......	......	......	...	...	2	24	20	480·06	
			39	...	1·5	4378										
74	4752	Dhuroura Bridge ...	...	...	...	......	......	......	......	...	...	2	24	20	483·30	
			38·5	...	1·5	4378										
77	2310	Anibas Falls ...	...	...	...	......	......	......	......	...	...	...	...	...	487·05	
															491·05	
			38	...	1·5	4222										

APPENDIX B.—(Continued.)

N. B.—Proposed alterations in **Antique Type.**

Distance from Head.		NAME OF WORK.	Bottom width of Channel.	Depth of Water at full supply.	Side slopes, in 1	Declivity of bed, 1 in	Mean velocity, feet per second.	Discharge calculated, c. feet per second.	Discharge required, c. feet per second.	Depth of foundations below bed.	Height from bed to crown of Arch.	Bridges.			Reduced levels of bed.		Projected alterations and additions.
												No. of Arches.	Span.	Width of Road-way.	At present.	If remodel-led.	
Miles.	Feet.																
80	660	Anchoura Bridge ...	... 37·5	... ...	... 1·5	 4222	......	......	......	...	...	2	22	20			
		Makhena Escape into Ganges River															
82	2970	Ditto Bridge ...	...	...	...	......	......	......	......	...	...	2	22	24			

ALTERNATIVE LINE, GANGES CANAL.

N. B.—Datum line 200 feet above flooring of Myapore Regulating Bridge.

Distance from Head. Miles.	Feet.	Bottom width	Depth of Water.	Side slopes 1 in	Declivity of bed 1 in	Mean velocity ft. per sec.	Discharge calculated c. ft. per sec.	Discharge required c. ft. per sec.	Reduced level bed.	Remarks.
0	0	Branch Head, Old line, 21 openings of 6 feet each, Road 15 feet					...	...	261·25	Lock on right bank into new line.
		New line, 24 do. of 6 feet each, do.					...	...	....	Ditto from left bank old line into old channel.
		170	10	2	10,000	2·676	5,086·7	5,000		
2	2500	Bridge, 4 arches of 51 feet each, towpaths 7 feet, Road 18 feet					...	...	262·55	
6	3000	Ditto					...	...	264·71	
7	4000	Culvert for Seela N. 2 arches of 20 feet					...	...	265·34	
8	0	Fall 6 feet, 11 bays of 15 feet, Bridge as before, Road 18 feet					...	...	265·47 271·47	Fall No. 1.
10	2640	Do.	do.	do.	do.	...	...	...	272·79 278·79	" No. 2.
11	2000	Culvert for Drainage one arch of 10 feet			...	...	...	...	279·25	
13	0	Fall 6 feet, 11 bays of 15 feet, Bridge as before, Road 18 feet					...	...	280·11 286·11	" No. 3.
14	2640	Aqueduct, 2 arches of 40 feet, Canal waterway 190 feet				...	...	...	286·89	Over Kalee Nuddee.
15	0	Bridge, 4 arches of 51 feet each, towpaths 7 feet, Roadway 18 feet					...	...	287·16	
16	0	Inlet for drainage, 10 feet arch		...	...	...	...	...	280·22 287·69	
17	2000	Bridge as before, Roadway 25 feet		...	...	...	...	...	288·42	Road from Mozuffernuggur to Seharunpore.
19	2000	Do.	do.	20 feet ...	...	...	...	...	289·47	" " Deobund to Bahlah.
20	0	Culvert for drainage, one arch of 10 feet		...	...	...	...	...	289·80	
22	0	Fall 6 feet, 11 bays of 15 feet, Bridges as before, Roadway 18 feet					...	...	290·86 296·86	No. 4.
24	0	Do.	do.	do.	...	...	...	...	297·91 303·91	No. 5.
26	0	Do.	do.	do.	...	...	...	...	304·97 310·97	No. 6.
29	0	Bridge as before, Roadway 18 feet		...	...	...	...	...	312·55	
31	0	Fall 6 feet, 11 bays of 15 feet, Bridge as before, Roadway 20 feet					...	...	313·61 319·61	No. 7 Road from Mozuffernuggur to Thanah Bhowun.
35	0	Do.	do	do.	...	...	...	...	321·73 327·73	No. 8 Road from Mozuffurnuggur to Shamlee.

Digitized by Google

APPENDIX B.—(*Continued.*)

N. B.—Datum line 200 feet above flooring of Myapoor Regulating Bridge.

Distance from Head. Miles.	Feet.	Bottom Width.	Depth of Water.	Side slopes 1 in	Declivity of bed 1 in	Mean velocity. ft. per sec.	Discharge calculated c. ft. per sec.	Discharge required c. ft. per sec.	Reduced level bed.	Remarks.
38	0	Fall 6 feet, 11 bays of 15 feet, Bridge as before, Roadway 18 feet					...	...	... 329·31 335·31	No. 9.
41	0	Do.		do.	do.	...	...	...	... 336·89 342·89	No. 10.
43	2000	Bridge as before, Roadway 18 feet	...	...		...	...	...	... 344·14	
46	0	Fall 6 feet, 11 bays of 15 feet, Bridge as before, Roadway 20 feet					...	...	... 345·53 351·53	No. 11 Road from Mozuffurnuggur to Boorhaneh. " " "
49	0	Do.		do.	do.	18 feet	...	...	... 353·12 359·12	No. 12.
51	0	Do. Dam bridge 11 arches of 23 feet				...	...	...	... 360·17 366·17	No. 13.
53	0	Escape Head, 15 arches of 6 feet	...	...		...	...	...	... .	Fall 0·5 in flooring.
		Aqueduct, 4 arches of 50 feet, Canal Waterway, 190 feet				...	...	...	... 367·23	Over Kalee Nuddee.
55	2640	Bridge as before, Roadway 18 feet	...	...		...	...	...	... 368·55	
58	2000	Do.	do.	...	...	...	...	...	... 370·07	
59	0	Rajbuha Inlet and Outlet, 1 arch of 6 feet		...		...	...	...	... 370·40	
61	0	Branch Head, Main, Fall 6 feet, 10 bays of 10 feet, Bridge 3 arches of 40 feet, Roadway 18 feet							371·45 377·45	No. 14.
		Junction, Fall 3·26, 9 bays of 10 feet, Bridge 3 arches of 40 feet, Roadway 18 feet							371·45 374·71	
		JUNCTION TO OLD LINE.								
		90	7	2	5400	3·000	2184	2240		
1	2000	Bridge 3 arches of 40 feet, Towpath 7 feet, Roadway 18 feet					...	...	... 376·05	
4	0	Fall 6 feet, 6 bays of 14 feet, Light 10 feet Bridge				...	...	...	... 378·63 384·63	
4	3510	Junction above Jutpoora Bridge	...	...		...	...	...	... 385·28	
		NEW LINE CONTINUED.								
61	0	104	8	2	6500	2·925	2808	2760	377·45	Below Branch Head.
63	0	Bridge 3 arches of 40 feet, Roadway 18 feet		...		...	...	...	... 379·07	

65	0	Fall 6 feet, 7 bays of 15 feet, Bridge 3 arches of 40, Roadway 18 feet	380·69 386·69	No. 15.
67	2000	Bridge, 3 arches of 40 feet, Roadway 18 feet	388·62	
69	0	Rajbuha Inlet, 1 arch of 6 feet	389·94	
69	4000	Bridge, 3 arches of 40 feet, Roadway 18 feet	390·54	
70	2000	Culvert for drainage 1 arch of 15 feet...	391·06	For Jannee Khoord Escape.
71	3000	Bridge, 3 arches of 40 feet, Roadway 20 feet	392·03	Road from Meerut to Baghput.
72	1000	Rajbuha Outlet, 1 arch of 6 feet	392·53	
74	0	Fall 5 feet, 7 bays of 15 feet, Bridge as above, Roadway 18 feet	394·00 399·00	No. 16.
76	4000	Rajbuha Inlet and Outlet 1 arch of 6 feet	401·23	
77	0	Bridge as before, Roadway 18 feet	401·44	
78	4000	Rajbuha Outlet, 1 arch of 6 feet	402·85	
80	0	Fall 6 feet, 7 bays of 15 feet, Bridge as above, Roadway 18 feet	403·88 409·88	No. 17.
82	5000	Rajbuha Outlet, 1 arch of 6 feet	412·26	
83	0	Fall 6 feet, 7 bays of 15 feet, Bridge as above, ditto 18 feet	412·32 418·32	No. 18.
85	0	2 Rajbuha Outlets, 1 arch of 6 feet	419·94	
85	2640	Bridge as before, Roadway 18 feet	420·34	
87	2640	Ditto ditto 25 feet	421·96	Grand Trunk Road.
89	0	Fall 5 feet, 7 bays of 15 feet, Bridge as before, Roadway 18 feet	423·19 428·19	No. 19.
91	3000	Bridge as before, Roadway 20 feet	430·27	Road from Delhi to Haupper.
94	0	Bridge as before, ditto 18 feet	432·25	
94	500	Syphon for drainage, 2 arches of 10 feet	432·32	
95	2640	Rajbuha Outlet, 1 arch of 6 feet	433·46	
96	0	Bridge as before, Roadway 18 feet	433·87	
98	0	Ditto ditto	435·50	
98	1000	2 Rajbuha Outlets, 1 arch of 6 feet	435·65	
99	5000	Fall, 4·72, 7 bays of 15 feet each	437·07 441·79	No. 20.
		Escape head 10 bays of 6 feet each	......	Into Jumna River, fall 0·5 in flooring.
		Branch head, Bolundshuhur Branch, 6 bays of 6 feet each ; Main, 15 bays of 6 feet each.		
		89 | 7 | 2 | 5500 | 2·97 | 2141 | 2162		
102	2000	Bridge 3 arches of 35 feet, Roadway 18 feet	444·12	
102	4000	Syphon for drainage 1 bay of 10 feet	444·48	
103	0	Rajbuha Outlet, 1 arch of 6 feet	444·72	
105	0	Bridged as before, Roadway 18 feet	446·64	
107	0	Ditto Ditto	448·56	
109	0	Rajbuha Outlet, 1 arch of 6 feet	450·48	
110	0	Fall 5 feet, 6 bays of 15 feet, Bridge 3 arches of 35 feet, Roadway 18 feet	451·44 456·44	No. 21:
111	0	Rajbuha Outlet, 1 arch of 6 feet	457·40	

Digitized by Google

APPENDIX B.—(Continued.)

N. B.—Datum line 200 feet above flooring of Myapore Regulating Bridge.

Distance from Head. Miles.	Feet.	Bottom Width.	Depth of Water.	Side slopes, 1 in	Declivity of bed, 1 in	Mean velocity.	Discharge calculated.	Discharge required.	Reduced level bed.	REMARKS.
112	0	Bridge 3 arches of 35 feet each, Roadway 18 feet...				...	...	...	458·36	
113	4000	Syphon for drainage 2 arches of 10 feet			...	...	...	...	460·04	
115	0	Bridge as before, Roadway 20 feet ...			...	...	...	...	461·24	Road from Sikundrabad to Boolundshuhur.
110	4000	Inlet and Outlet (Rajbuha) 1 arch of 6 feet			...	...	...	...	461·96	
118	0	Fall 4 feet, 6 bays of 15 feet, Bridge as before, Roadway 18 feet				...	...	...	464·12 468·12	No. 22.
119	2640	Syphon for drainage, 1 arch of 10 feet...			...	...	...	...	469·56	
120	5000	Bridge as before, Roadway 20 feet ...			...	...	...	...	470·94	Road from Jhujjur to Boolundshuhur.
123	4000	Bridge as before, Roadway 18 feet ...			...	...	...	...	473·64	Deep foundations below this on wells.
0	0	Two Rajbuha Outlets, 1 arch of 6 feet.								
126	2640	Bridge as before, Roadway 18 feet ...			...	...	...	...	476·28	
127	2640	Rajbuha Inlet and Outlet, 1 arch of 6 feet			...	...	...	...	477·24	
128	2000	Bridge as before, Roadway 25 feet ...			...	...	...	...	478·08	Grand Trunk Road.
129	0	Fall 5 feet, 6 bays of 15 feet each, Bridge as before, Roadway 20 feet				...	...	...	478·68 483·68	No. 23.
129	0	Bridge as before, Roadway 25 feet ...			...	...	..	...	481·40	Grand Trunk Road.
0	0	Rajbuha Inlet and Outlet, 1 arch of 6 feet			...	...	...	...	481·40	
131	4000	Bridge as before, Roadway 20 feet ...			...	...	...	...	486·32	
133	2000	Rajbuha Outlet, 1 arch of 6 feet ...			...	...	...	...	487·88	
134	0	Bridge as before, Roadway 20 feet ...			...	...	...	...	488·48	
135	3000	Syphon for drainage, 1 arch 10 feet ...			...	...	...	...	489·98	
136	2000	Bridge as before, Roadway 18 feet ...			...	...	...	...	490·76	
138	3000	Ditto ditto ...			...	...	...	...	492·84	
139	0	Rajbuha Outlet, 1 arch of 6 feet ...			...	...	...	...	493·28	
140	2640	Fall 4·59, 6 bays of 15 feet ...			...	...	...	...	494·72 499·31	No. 24.
		Branch Head, *Coel Branch*, 2 *arches of* 23 *feet each, Roadway* 18 *feet. Main Line,* 4 *arches of* 23 *feet each, Roadway* 18 *feet.*								
		75	6	2	4500	3·03	1581	1560		
142	2640	Bridge 3 arches of 30 feet each, Roadway 18 feet...				...	...	...	501·64	
143	0	Syphon or drainage, 1 arch of 3 feet ...			...	...	...	...	502·24	
144	4000	Rajbuha Outlet, 1 arch of 6 feet ...			...	...	...	...	504·29	
145	2000	Bridge as before, Roadway 20 feet ...			...	...	...	...	505·02	
147	2500	Syphon for drainage, 1 arch of 3 feet ...			...	...	...	...	507·48	
148	2640	Bridge as before, Roadway 20 feet ...			...	...	...	...	508·68	Road, Allygurh to Puhasoo.
151	0	Ditto Ditto 18 feet ...			...	...	...	...	511·62	

Digitized by Google

151	2000	Rajbuha Outlet, 1 arch of 6 feet						512·06	
152	1000	Syphon for drainage, 1 arch of 3 feet						513·01	
153	1000	Bridge 3 arches of 30 feet each, Roadway 20 feet						514·19	Road Allyghur to Anoopshuhur.
154	0	Fall 4 feet, 5 bays of 15 feet, Bridge as before, Roadway 18 feet						{ 515·14 { 519·14	No. 25.
157	0	Bridge as before, Roadway 20 feet						522·66	Road from Allyghur to Ramghat.
157	2640	Syphon for drainage, 1 arch of 3 feet...						523·24	
159	0	Bridge as before, Roadway 18 feet						525·01	For Seyngoor Nullah.
160	0	Syphon for drainage, 2 arches of 10 feet						526·18	
161	0	Bridge as before, Roadway 18 feet						527·35	
163	2000	Ditto, ditto 20 feet						530·14	Road from Allyghur to Khasgunge.
165	0	Syphon for drainage, 1 arch of 3 feet						532·04	
166	3510	Junction with Ganges Canal							
		ESCAPE NO. 1, INTO WEST KALLEE NUDDEE.							
0	0	75	10	1·5	7000	3·069	2762		
1	920	Fall 27·0,6 Bays of 15 feet						{ 367·56 { 399·00	
		ESCAPE NO. 2 INTO HINDUN FROM 100TH MILE.							
0	0	48	8	1·5	5000	3·181	1527		
4	0	Bridge 2 arches of 30 feet, Roadway 25 feet							Grand Trunk Road.
4	4000	Ditto ditto ditto 33 feet							For East Indian Railway.
8	0	Fall 27·83, 4 bays of 15 feet						{ 246·02 { 273·85	

Digitized by Google

APPENDIX B.—(Continued.)

SEPARATE NAVIGABLE LINE.

Distance from Head.		Bottom Width.	Depth of Water.	Side slopes, 1 in	Declivity of bed, 1 in	Mean velocity.	Discharge calculated.	Reduced level bed.	Depth of foundation.	REMARKS.
Miles.	Feet.									
0	0	Double lock chamber, each 16 feet wide			...	...	... ...	261·25	8·0	Below Roorkee Bridge, Right Bank.
		20	5	2	12,000	1·546	232			
2	2500	Bridge 1 arch of 34 feet, Roadway 18 feet.								
6	3000	Ditto ditto ditto.								
7	4000	Culvert, 2 arches of 20 feet ...			...	...	... ...	......	......	For Seela Nullah.
8	0	Double lock, 7 feet, Bridge as before, Roadway 18 feet				...	... ...	264·77	......	No. 1.
								271·77	......	,, ,,
10	2640	Ditto 6 feet Bridge, Roadway 18 feet			...	...	... ...	272·87	......	No. 2.
11	2000	Culvert for drainage, 1 arch of 10 feet.						278·87	......	,, ,,
13	0	Double lock, 6·51, Bridge Roadway 18 feet ...				...	... ...	279·97	......	No. 3.
14	2640	Aqueduct, 2 arches of 40 feet, Channel Waterway above, 30 feet						286·48	......	,, ,,
15	0	Bridge as before, Roadway 18 feet.					... ...	......	......	Over Kalee Nuddee, on wells.
16	0	Syphon for drainage, 1 arch of 6 feet.								
17	2000	Bridge as before, Roadway 20 feet ...			...	...	... ...	......	......	Road from Mozuffurnuggur to Saharunpore.
18	0	Double lock, 6 feet Bridge Roadway 18 feet ...				..	... ...	288·84	......	No. 4.
18	4000	Syphon for dainage, 1 arch of 10 feet.						294·84	......	,, ,,
19	0	Bridge as before, Roadway 20 feet.								
20	2640	Do. do. 25 ,, ...			...	...	... ...	......		
22	0	Double lock, 8 feet do. 18 ,, ...			...	...	... ...	296·60	......	No. 5.
24	0	Bridge as before, do. 18 ,,						304·60	......	,, ,,
25	2000	Do. do.								
27	0	Do. do.								
29	0	Double lock, 12 feet, Bridge, Roadway 18 feet				...	... ...	307·68	......	No. 6.
30	4500	Aqueduct, 3 arches of 40 feet Channel Waterway above, 30 feet					... ...	317·68	......	,, ,,
31	3000	Bridge as before, Roadway 18 feet.						320·50	......	Over West Kallee Nuddee.
31	4000	Syphon for Rajbuha 6 feet.								
33	0	Double lock, 6 feet Bridge, Roadway 25 feet ...				...	... ...	321·44	......	No 7. Road from Mozuffurnuggur to Saharunpore.
33	3000	Syphon for Rajbuha, 6 feet.						327·44	......	,, ,,
34	0	Bridge as before, Roadway 20 feet.								
34	4000	Ditto ditto.								

Digitized by Google

35	3000	Ditto ditto.			
36	4000	Syphon for Rajbuha, 6 feet.			
37	1000	Bridge as before, Roadway 18 feet.			
37	5000	Culvert, 2 arches of 20 feet	......	......	For feeder of West Kalee Nuddee.
39	4500	Double lock, 6 feet Bridge, Roadway 18 feet	330·38 336·38	....	No. 8. " "
43	0	Ditto Ditto	337·84 343·84	....	No. 9. " "
43	1000	2 Syphons for Rajbuha, 6 feet each.			
45	0	Bridge as before, Roadway 18 feet.			
47	0	Double lock, 9·73, Bridge, Roadway 10 feet	345·60 355·33	....	No. 10. At junction with Ganges Canal. " "
47	2000	Double lock chamber, bed level, Roadway 10 feet	......	......	At exit from Ganges Canal.
48	4000	Bridge as before, Roadway 20 feet.			
50	0	Ditto Ditto 18 feet.			
50	1000	Syphon for drainage 3 feet.			
52	2000	Bridge as before, Roadway 18 feet.			
53	0	Syphon for Rajbuha 6 feet.			
54	0	Double lock, 6 feet, with Bridge, Roadway 18 feet	358·41 364·41	....	No. 11. " "
55	3000	Syphon, 2 arches of 6 feet	......	......	For Aboo Ka Nullah.
56	3000	Bridge as before, Roadway 18 feet.			
56	5000	Syphon for Rajbuha 6 feet.			
58	0	Double lock, 6 feet Bridge, Roadway 18 feet	366·17 372·17	....	No. 12. " "
58	4000	Syphon for Rajbuha 6 feet.			
60	2000	Bridge as before, Roadway 18 feet.			
62	0	Double lock, 8 feet, Bridge, Roadway 20 feet	373·93 381·93	....	No. 13. " "
62	4500	Syphon for drainage, 10 feet wide.			
65	0	Bridge as before, Roadway 20 feet.			
66	4000	Syphon for Rajbuha, 6 feet wide.			
"	"	Bridge as before, Roadway 18 feet.			
68	0	Double lock, 6 feet Bridge, Roadway 18 feet	384·57 390·57	....	No. 14. " "
68	4500	Syphon for drainage, 1 arch of 6 feet.			
70	2000	Bridge as before, Roadway 18 feet.			
71	0	Double lock, 6 feet Bridge, Roadway 20 feet	391·89 397·89	....	No. 15. " "
71	2000	Culvert for drainage, 1 arch of 10 feet.			
71	3000	Bridge as before, Roadway 25 feet	......	......	Grand Trunk Road. Meerut to Delhie.
73	0	Ditto Ditto 18 feet.			
74	4500	Ditto Ditto			
76	4500	Syphon for Rajbuha 6 feet.			
77	0	Double lock, 6 feet with Bridge, Roadway 18 feet	406·53 412·53	....	No. 16. " "
78	4500	Bridge as before, Roadway 18 feet.			

APPENDIX B.—(Continued.)

Distance from Head. Miles.	Feet.	Bottom width	Depth of Water.	Side Slopes 1 in	Declivity of bed 1 in	Mean velocity.	Discharge calculated.	Reduced level bed.	Depth of foundations.	Remarks.
81	1000	Bridge as before, Roadway 25 feet ...			...	...	...	......	......	Grand Trunk Road, Meerut to Allyghur.
82	0	Double lock, 8 feet, with Bridge, Roadway 18 feet			...	...	...	414·73 / 422·73	......	No. 17
84	2000	Bridge as before, Roadway 18 feet							......	,, ,,
86	2000	Ditto Ditto								
88	0	Double lock, 6 feet, with Bridge, Roadway 18 feet			...	...	...	425·37 / 431 37	......	No. 18.
89	2000	Bridge as before, Roadway 25 feet ...			...	...	...	......	....	,, ,, Road Delhi to Gurmukteesur.
92	0	Double lock, 6 feet, with Bridge, Roadway 18 feet			...	...	...	433·13 / 439·13	....	No. 19.
94	0	Ditto Ditto Ditto ...			...	...	...	440·01 / 446 01	....	,, ,, No. 20.
96	2000	Aqueduct, 3 arches of 30 feet			...	...	...	447·00	......	,, ,, Over Choya, feeder of East Kalee Nuddee.
97	0	Bridge as before, Roadway 18 feet								
98	2000	Syphon for Rajbuha, 6 feet								
99	0	Bridge as before. Roadway 20 feet								
101	1000	Ditto Ditto 25 feet			...	...	...	......	......	G. T. Road Meerut to Allyghur.
102	2000	Syphon, 3 feet, for watercourse								
102	3000	Bridge as before, Roadway 18 feet								
104	0	Double lock, 6 feet, with Bridge, Roadway 18 feet			...	...	...	450·41 / 456·41	....	No. 21.
106	0	Bridge as before, Roadway 18 feet								,,
107	0	Double lock, 6 feet, with Bridge, Roadway 18 feet			...	...	...	457·73 / 463 73	....	No. 22.
108	2000	Syphon, 6 feet, for Rajbuha escape								,,
108	3000	Bridge as before, Roadway 18 feet								
110	1000	Ditto Ditto 18 feet								
112	4500	Ditto Ditto 25 feet			...	...	...	......	......	G. T. Road, Meerut to Bolundshuhur.
113	30 0	Ditto Ditto ditto			...	...	...	......	......	Ditto Bolundshuhur to Allyghur.
113	3500	Culvert, 6 feet, for Rajbuha escape								
116	2500	Syphon 6 feet for Rajbuha								
118	0	Double lock 2 81, with Bridge, Roadway 18 feet			...	...	...	468·48 / 471·31	....	No. 23. Deep foundations below this on wells.
118	500	Bridge as before, Roadway 10 feet ...			...	...	...	......	......	At Junction with Ganges Canal. At exit from ditto.
119	0	Double lock, 6 feet, with Bridge, Roadway 25 feet			...	...	...	471·84 / 477·84	....	No. 24. Grand Trunk Road.
119	2000	Syphon, 6 feet, for Rajbuha								,, ,,
121	2000	Bridge as before, Roadway 18 feet								
121	3000	Syphon for Drainage, 6 feet								
123	0	Syphon, 6 feet, for Rajbuha								

Digitized by Google

124	0	Bridge as before, Roadway 25 feet	......	......	G. T. Road, Khoorja to Delhie.
124	2000	Syphon, 6 feet, for Rajbuha escape			
124	4000	Ditto for Rajbuha			
125	0	Double lock, 6 feet, with Bridge, Roadway 25 feet	480·48 486·48	....	No. 25. G. T. Road. „ „
126	4500	Bridge as before, Roadway 25 feet	......	......	G. T. Road, Khoorja to Allyghur.
127	1000	Syphon, 6 feet, for Rajbuha			
129	3000	Bridge as before, Roadway 20 feet			
130	4000	Syphon for drainage, 1 arch of 10 feet			
131	2000	Bridge as before, Roadway 18 feet			
133	4500	Ditto Ditto			
133	4500	Syphon, 6 feet, for Rajbuha			
135	0	Double lock, 6 feet, with Bridge, Roadway 18 feet	490·88 496·88	....	No. 26. „ „
136	4500	Bridge as before, Roadway 18 feet			
137	3000	Ditto Ditto			
137	4000	Syphon, 6 feet, for Rajbuha			
141	0	Double lock, 8 feet, with Bridge, Roadway 18 feet	499·52 507·52	....	No. 27. „ „
141	4500	Syphon for drainage, 1 arch of 3 feet			
143	0	Bridge as before, Roadway 18 feet			
143	3000	Syphon for drainage, 1 arch of 3 feet			
144	3000	Ditto Ditto			
145	2500	Bridge as before, Roadway 18 feet.			
147	4000	Syphon for drainage 1 arch of 3 feet.			
148	0	Double lock, 6 feet, with Bridge, Roadway 18 feet	510·60 516·60	....	No. 28. „ „
150	1000	Syphon for drainage, 1 arch of 3 feet.			
150	4000	Bridge as before, Roadway 18 feet	......	......	Road to Allyghur Fort.
151	1000	Ditto Ditto.			
151	2000	Syphon for drainage, 2 arches of 10 feet.			
152	1000	Bridge as before, Roadway 18 feet.			
152	5000	Ditto Ditto 25 feet.			
154	0	Ditto Ditto 20 feet.			
155	0	Double lock, 8 feet, with Bridge, Roadway 18 feet	519·68 525·68	....	No. 29. „ „
156	3000	Bridge as before, Roadway 18 feet.			
157	4000	Syphon for drainage, 1 arch of 3 feet.			
158	0	Syphon, 6 feet, for Rajbuha			
158	3000	Bridge as before, Roadway 18 feet			
158	4000	Syphon, 2 arches of 10 feet	......	......	For Seyngoor Nullah.
160	0	Syphon, 6 feet, for Rajbuha			
160	2500	Bridge as before, Roadway 18 feet			
162	1000	Ditto Ditto 18 feet			
163	0	Syphon for Drainage, 1 arch of 3 feet			
164	1000	Double lock, 5 feet, with Bridge, 10 feet	529·56 534·56	....	No. 30. At Junction with Ganges Canal above Nanoon Regulator. „ „

Digitized by Google

APPENDIX C.

FORMULÆ FOR DISCHARGES, &c.

The formulæ employed for calculating velocities and discharges throughout these projects are as follows :—

1. Velocities in open channels "in train."

$$V = 90 \sqrt{\frac{R}{S}} \text{ for mean velocities up to 3 feet per second.}$$

$$V = 93 \sqrt{\frac{R}{S}} \text{ for mean velocities above 3 feet per second.}$$

where V = mean velocity in feet per second.
R = Hydraulic mean depth

$$= \frac{\text{Area of section}}{\text{Length of wetted perimeter.}}$$

S = Length in which the fall is 1 foot.

The co-efficients 90 and 93 are somewhat larger than those given in treatises on hydraulics; they are those, however, most nearly conformable with observation on the streams with which we have to deal in this country; where silt is as a rule held in suspension, by which the velocity of current is sensibly diminished. The nature of the soil in bed and banks also affects the mean velocity.

N. B.—All measures, whether lineal, superficial, or cubic, are in English feet, and decimals of feet.

2. Mean velocity (V) = ·81 × surface velocity.
= ·81 v

3. Discharge through trapezoidal notch, longest side uppermost.

$$D = \frac{2}{15} d \sqrt{2 g h} \left(3 b_b + 2 b_t \right) \times C_d$$

where D = discharge
$2g = 64{\cdot}403$
h = depth of water from surface to sill of notch.
d = length of notch (or height, if vertical)
b_b = width of notch at sill
b_t = ditto at top

C_d is a varying co-efficient, depending on proportion of width to height of notch, size and form of channel of approach, &c.; it has been taken at ·62 in the cases occurring in these calculations.

4. Approximate equation for proportion of lower to upper width of notches, or between grating bars.

A = upper width
M A = lower do.

$$M = 0{\cdot}62 \sqrt{\frac{\cdot 5}{h}}$$

where h = depth of water on sill of notch.

5. Discharge over weirs with vertical sides (fall "complete")

$$D = \frac{2}{3} C_d \, l \sqrt{2 g} \, (h + h_a)^{\frac{3}{2}}$$

where l = width of weir.
h = depth from normal surface of water above weir to top or sill of weir.
h_a = height due to velocity of approaching water.

Remainder as before.

Digitized by Google

The co-efficient C_d in the cases of the Canal overfalls has been taken at ·628, and if v_a represent mean velocity of approaching stream, $h_a = \frac{v_a^2}{C_d^2 \times \sqrt{2g}}$ and the above equation becomes by substitution and reduction.

$$D = 3\cdot36\, l \left(h + 0\cdot03937\ v_a^2 \right)^{\frac{3}{2}}$$

6. Discharge over weirs as before (fall "incomplete")

$$D = C_d\, l \sqrt{2\, g\, (d_1 + h_a)} \left\{ d_2 + \frac{2}{3}\, (d_1 + h_a) \right\}$$

d_1 = height of fall or difference between normal level of water above and below fall.

d_2 = depth of top of weir below normal surface level of water *below* fall.

Remainder as in last equation.

Substituting for C_d and h_a the same values as in last equation we obtain

$$D = 5\cdot0397\, l \sqrt{d_1 + 0\cdot03937\ v_a^2} \left\{ d_2 + \frac{2}{3} \left(d + 0\cdot03937\ v_a^2 \right) \right\}$$

The observations for discharge of the Ganges Canal channels taken for the purposes of this report were obtained as follows:—

Two cross sections of the stream were taken at a uniform distance apart of 200 feet, the depths of water being measured at every ten feet or less along the width of each section.

The velocities were obtained by noting the times of transit at several points in the width of the stream of floats from the upper to the lower section; these floats were made of painted deal rods about an inch square, loaded at one end so as to float nearly vertically and pass as close to the bed of the channel as possible without touching, their upper ends projecting a few inches above the water's surface. They were found in every case to float in a line closely parallel to the thread of the current. A very near approximation, it is evident, was thus obtained to the mean velocity in the vertical plane traversed by each. A correction for the small height of the end of the float above the bed was applied to each velocity before using them for the calculations of discharge, viz.—

$$C \text{ (or multiplier of velocity)} = 1 - 0\cdot116 \left\{ \left(\frac{D - D_1}{D} \right)^{\frac{1}{2}} - 0\cdot1 \right\}$$

where
D = depth of water
D_1 = length of rod immersed.

This was given in the report on the Mississippi by Captain Humphreys and Lieutenant Abbot as obtained by Mr. Francis in his experiments at the Lowell Water-works, where velocities of current were observed in a similar manner to the above.

Velocities were observed on the Ganges Canal and elsewhere also by a current meter of similar construction to that known as Woltmann's hydrometer as well as by surface floats, but no method I have yet tried seems to me so satisfactory as that of the floating rods. The declivity of the water's surface was also in most cases observed for the purpose of comparison and obtaining reliable co-efficients for calculation.

Digitized by Google

APPENDIX D.

Velocities of Current.

In a portion of the channel of the Eastern Jumna Canal lying in the old bed of the Muskurra torrent, where the current seemed perfectly adjusted to a *light sandy soil*, Major Brownlow, the Superintendent of the Canal, found the mean velocities of the surface to be from 2·38 to 2·28 feet per second, or mean velocities (multiplying by 0·81), 1·928 to 1·847 per second.

In the lower district of the same canal, near Barote and Deola, the maximum surface velocities with a fair supply were found to be 2·817 and 2·507 feet per second, or mean velocity of 2·282 and 2·03 feet per second. Silt is constantly being deposited here; the soil is similar to that below Sirdhanna on the Ganges Canal.

About 1000 feet below the Ghoona Falls on the same canal in *very* sandy soil, with nearly a full supply of water, I found the maximum surface velocity to be 3·077 feet per second, or mean velocity 2·492 feet per second: no erosion from bed or banks, except when a supply much in excess of the maximum allowed is passing down.

Below the Nyashahur bridge on the same canal, where the soil is very similar to that between the Myapoor and Kunkhul bridges on the Ganges Canal, clay, shingle and small boulders, Lieutenant Moncrieff, R. E., the Officiating Superintendent, found the mean surface velocity to be 6·751 feet per second, or the mean velocity about 5·468 per second.

The same officer observed the surface velocity at some distance below the Yarpoor Falls in the new centre division channel of the Eastern Jumna Canal, and obtained a mean of 3·957 feet per second, or about 3·205 feet per second mean velocity through entire section. The soil here is light and sandy, and the channel has been both widened and deepened by the current.

In one of the rajbuhas (or main water-courses) of the same canal I found weeds growing in the bed and on the sides with a maximum surface velocity of 2·12 feet per second, or mean velocity (V) of about 1·717 feet per second; the soil is sandy with a fair admixture of clay; silt accumulates to a troublesome extent.

In another rajbuha in the same neighbourhood I found a surface velocity of 2·38 feet per second, or mean about 1·927 feet. Silt deposits here, but no weeds appear to grow.

In the Muhmoodpoor left bank rajbuha on the Ganges Canal I found grass and weeds growing in the channel with a maximum surface velocity of 1·724 feet per second, or mean of 1·396 feet.

In the Buhadoorabad Lock Channel, Ganges Canal, weeds appear to grow wherever the maximum surface velocity is 2·38 feet, (or mean velocity 1·928 feet per second, or under); soil generally light and sandy.

On the Ganges Canal I found velocities as follow:—Below the Roorkee bridge on the main canal, where the deepened bed is covered with silt, and erosion from the sides has ceased, the mean velocity in the entire section with a supply less than the present maximum on the Roorkee gauge by two inches, was 2·92 feet per second, the soil sandy with a tolerable admixture of clay.

In the widened channel at the Toghulpoor sand hills, Mile 36, the mean velocity, with full supply now allowed to pass down, obtained by calculation from the area of the water section and the discharge observed below Roorkee (deducting expenditure *en route*) was 2·532 feet per second.

In the embanked channel across the Solanee Valley, with a supply two inches under the present maximum on the Roorkee gauge, the mean velocity, obtained by calculation from the area of water section there and the observed discharge through the masonry aqueduct, was 3·04 feet per second. The deepest portions of the channelling out here, I have stated elsewhere, have been silted up.

At the 50th mile main line, below the Jaolee Falls, with (present) full supply in the canal, the observed mean velocity was 3·059 feet per second. Erosion from the banks has ceased here; silt on the deepened bed, soil sandy.

Above Newarree bridge, 94th mile, in a stiff clay soil, with full supply in the observed mean velocity, was 4·117 feet per second: erosion trifling here; no silt deposit.

Observations communicated by Captain Dyas, R. E., *Director of Canals,* Punjab.

On the Hansi branch of the Western Jumna Canals, silt was deposited with mean velocities of from 2· to 2·25 feet per second. The deposition of silt, however, obviously depends on the quantity and specific gravity of the matter held in suspension by the water coming from above, and the ratio of the current velocities at different points along the channel.

Digitized by Google

He states, from observations on the channels of the Baree Doab Canal, that in sandy soil "2·7 feet per second appears to be the highest mean velocity for non-cutting as a general rule, for there are soft places where the bed *will* go with almost any velocity; but those sorts of places can be protected." Again, "Bad places might be scoured out with a mean velocity of 2·5 feet per second, but better soil would be deposited in place of the bad with a slightly smaller velocity than 2·5 feet; and as the supply is not always full, there would be no fear of not getting that slightly smaller velocity very frequently. The good stuff thus deposited would not be moved again by any velocity which did not exceed 2·5 feet per second."

In "Neville's Hydraulics," 0·83 or 1·17 feet per second are mentioned as the lowest mean velocities which will prevent the growth of weeds. This, however, will vary with the nature of the soil; vegetation also is much more rapid and vigorous in a tropical climate than where Mr. Neville made his observations.

In Captain Humphrey's and Lieutenant Abbott's report on the Mississippi, 1860, it is mentioned that the alluvial soil near the mouth of the river cannot resist a mean velocity of three feet per second; and that in the Bayou La Fourche, the last of its outlets, which resembles an artificial channel in the regularity of its section and general direction, and the absence of eddies, &c., in the stream, the mean velocity *does not exceed* three feet per second, and the banks are not abraded to any perceptible extent.

From the foregoing and other observations, which it would encumber this paper too much to place on record here, and taking into consideration that the higher the velocity the less the works will cost, I think the following may be taken as safe mean velocities with maximum supply in the Ganges Canal channels.

1. In the Ganges valley above Roorkee three feet per second.
2. In the sandy tract generally between Roorkee and Sirdhanna, 2·7 feet per second.
3. In very light sand, such as that met with at the Toghulpoor sand hills, not higher than 2·5 feet per second.
4. And for the channels south of Sirdhanna, 3·0 feet per second.

On the branches the same data to be assumed according to similarity of the soil.

There are soils, as Captain Dyas has noted, such as light quicksand, which will not stand velocities of even 1 foot or 1½ foot per second, but these are never found to any great extent in one place: erosion there can only have a local influence, and such places can be protected at a trifling expense. It is channelling out on long lines which is to be feared.

Digitized by Google

APPENDIX E.

Vertical Falls with Grating.

The grating consists of a number of wooden bars resting on an iron shoe built into the crest of the fall, and on one or more cross beams according to the length of the bars. These bars are laid at a slope of 1 in 3, and are of such length that the full supply level of the water in the canal tops their upper ends by half a foot. The scantling of the bars as well as that of the beams should of course be proportioned to the weight they have to bear, plus the extra accidental strains to which they are liable, from floating timber for instance, which may possibly pass between the piers and so come in contact with the grating. In consideration of strains and shocks of this nature the supporting beams are set with their line of depth at right angles to the bars instead of vertically.

2. The dimensions of the bars used on falls of the Baree Doab Canal; where the depth of water is 6.'6 feet, are as follows:—

Diyar wood.

Lower end of bars 0.50′ broad × 0.75 deep
Upper end of bars 0.25′ broad × 0.75 deep

and they are supported on two Diyar beams each measuring 1 foot in breadth × 1.5 foot in depth; the first beam being placed at a distance of 7.5 foot (horizontal measurement) from the crest of the fall, and the second 7.5 foot beyond the first beam. The bars of the gratings on these falls were originally placed touching each other (side by side) at their lower ends, as there was not then a full supply of water in the canal. There were thus 20 bars in each 10 foot bay. Since then the number of bars has been successively reduced to 19 and to 18, the present number. The reduction of the number of bars and the equal spacing of the remaining bars is done with ease, as they can be pushed sideways in the iron shoe and along the beams, to which latter they are held with spike-nails. Once the correct spacing is arrived at, cleats and blocks (as shown in the drawing) are preferable to spike-nails.

3. The end elevation of the bars, scale ½th full size, shows the way in which the bars are undercut from the point where they leave the shoe, *i. e.*, from the crest of the fall. This undercutting has the effect of making each space as it were "an orifice in a thin plate," and it facilitates the escape of small matters which may be brought down with the current. Large rubbish which accumulates on the grating is daily raked off and piled on one side of the fall. This is done by the establishment kept up for the neighbouring lock. There is considerable advantage in thus clearing the canal of rubbish which would otherwise stick in rajbuha heads or piers of bridges, &c., or eventually ground on the bed of the canal and become nuclei of large lumps and silt banks.

4. As one main object of the grating is to prevent the stream above the fall to which it is fixed from knowing that there is such a thing as a fall anywhere below it, the principle to go on in spacing the bars is to arrange them so that the velocity of no one thread of the stream shall be either accelerated or retarded by the proximity of the fall. This effected, it is evident that the surface of the water must remain at its normal slope, parallel to the bed of the canal, until it arrives at the grating. The half foot by which the water tops the bars of the grating above described causes a sudden drop there, but the acceleration to the current resulting from so small a fall as this is not practically felt to any distance back from the fall.

5. To take an example, let us assume that V (mean velocity) = 0.81 *v.* (surface velocity) and U (bottom velocity) = 0.62 *v.* (surface velocity) in every vertical line of the current flowing naturally. Then, if we make V = 2.5 feet per second, we shall have the following velocities at the given depths below surface in a stream 6 feet deep.

Depths below surface.		Velocities: feet per second.	Remarks.
Surface	0	3.0864	Common difference 0.1955 nearly.
	1′	2.8909	
	2′	2.6955	
Centre	3′	2.5000	
	4′	2.3046	
	5′	2.1091	
Bottom	6′	1.9136	

6. What is required, then, is to shape the sides of a given number of bars placed in a given width of bay so that the above velocities may be maintained till the water touches the grating, when in consequence of the clear fall the velocity becomes considerably accelerated. This accelerated velocity multiplied by the reduced area (of space between the bars) should

Digitized by Google

give the same discharge, with the canal running full, as the products of the original normal velocity and the original undiminished space, the width of which is of course the distance between the centre of two contiguous bars.

7. Thus, taking the lowest film (along the bed of the canal) whose normal velocity is 1.9136 feet per second, and supposing 20 to be the number of bars in each 10 feet bay, then the undiminished space for each portion of the stream will be half a foot, which multiplied by the above velocity gives a product of 0.9568. Again, taking the same lowest film as it passes through the grating, with a clear fall, and under a head of pressure of six feet, we find its velocity to be 19.654 feet per second. Now, if we call the required width of space between the bars at this point x_b and assume the co-efficient of contraction to be 0.6, we shall have $x_b = \frac{0.9568}{19.654 \times 0.6} = 0'.08$.

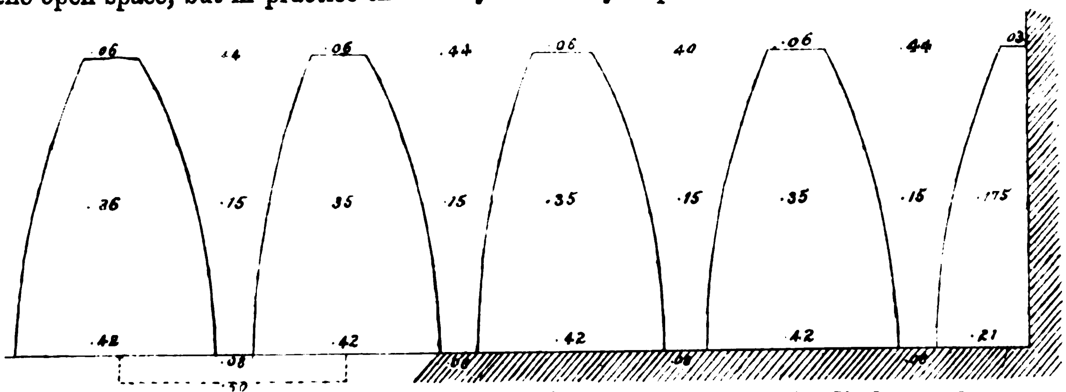
8. Similarly taking the film on the level of the tops of the bars, or 0.'5 below the surface of the water, the normal velocity of which is 2.9887, the undiminished space being as before 0'.5, we get a product of 1.4944; and as the velocity of the film falling through the bars is 5.673 feet per second, we get

$$x_t = \frac{1.4944}{5.673 \times 0.6} = 0'.44.$$

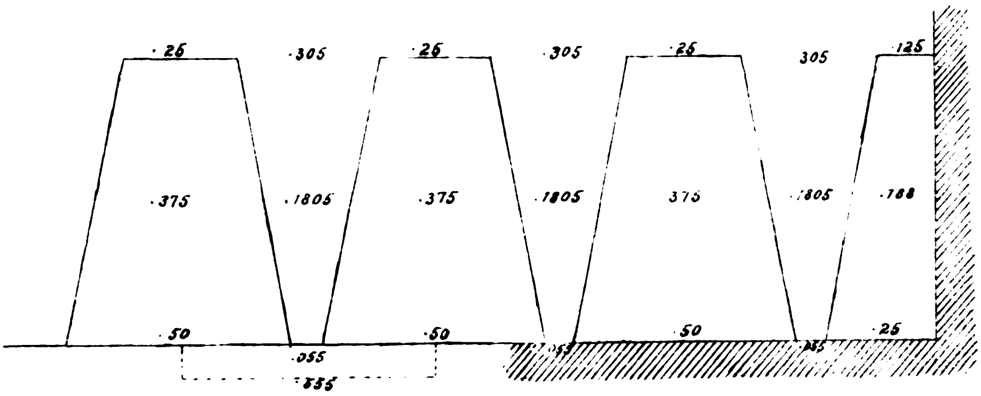
9. And lastly, taking the centre film, the normal velocity of which is 2.5 feet per second we have a product of 1.25, and as the velocity of the same film passing through the grating is 13.89 feet per second, we get

$$x_c = \frac{1.25}{13.89 \times 0.6} = 0'.15.$$

10. Hence it is seen that the sides of the bars should be cut to a curve convex towards the open space, but in practice this nicety is scarcely requisite.



The effect of cutting the bars straight is of course to increase the discharge through the centre of the grating, and to diminish it at the surface.



But this is not found objectionable in practice, for, as mentioned in para. 4, the surface velocity has already been somewhat accelerated by the half foot drop at the top of the grating, and in consequence of the tendency of the lower part of the grating to clog with matter brought down by the current, there is no risk of undue acceleration to the bottom velocity.

11. Niceties of detail have not been gone into in the foregoing calculations. For instance, the natural diminution of the velocity from the centre towards the side of the

H 2

Digitized by Google

earthen channel has not been taken into account, nor have the obstructions caused by the piers, the slope of the grating, and the accelerating effect (on the velocity through the grating), of the velocity of approach. The object of this paper is merely to indicate the general principle of the arrangement. Those who may have to fix gratings to falls would of course work out all needful details for themselves, according to the peculiar circumstances of each case; and should practice afterwards show that the theoretical spacing requires correction, the requisite re-adjustment of the bars is, as explained in para. 2, a very simple matter.

12. The above remarks have been limited to a consideration of the effect caused by the grating on the channel above the fall. Its effect on the channel below the fall is equally important, but this may be gone into separately. For the present it may suffice to remark that the formula in use on the Baree Doab Canal for the lower bed of the channel is

$$x = \sqrt{h}\,\sqrt[3]{d}$$

in which equation

x is the required depth of cistern

h, the height of fall, or the difference of level between the surface of the water above the fall and the surface of the water below it,

and d, the full supply depth of water in the channel. All the cisterns with depths thus obtained have answered admirably, having never required the slightest repair since they were built.

13. Another point may be mentioned as worthy of particular attention. The diminution of the waterway immediately under the grating and below the fall by the numerous piers of these falls as built on the Baree Doab Canal holds up the water, and causes it to rush out from the bays with considerable velocity. It might be found advantageous to turn arches through these piers, so as to give the water free side-play, or perhaps even to support the gratings and pathway on iron piles instead of on brickwork piers. In this case the road bridge if founded on piers of brickwork should be moved lower down to the point where the widening of the protected portion of the channel is greatest. The cisterns also, instead of ending abruptly with a vertical wall, might have their bottoms connected with the bridge flooring by a long counterslope so as to give the fallen water more room and time to get into the true normal velocity of the current in the open channel.

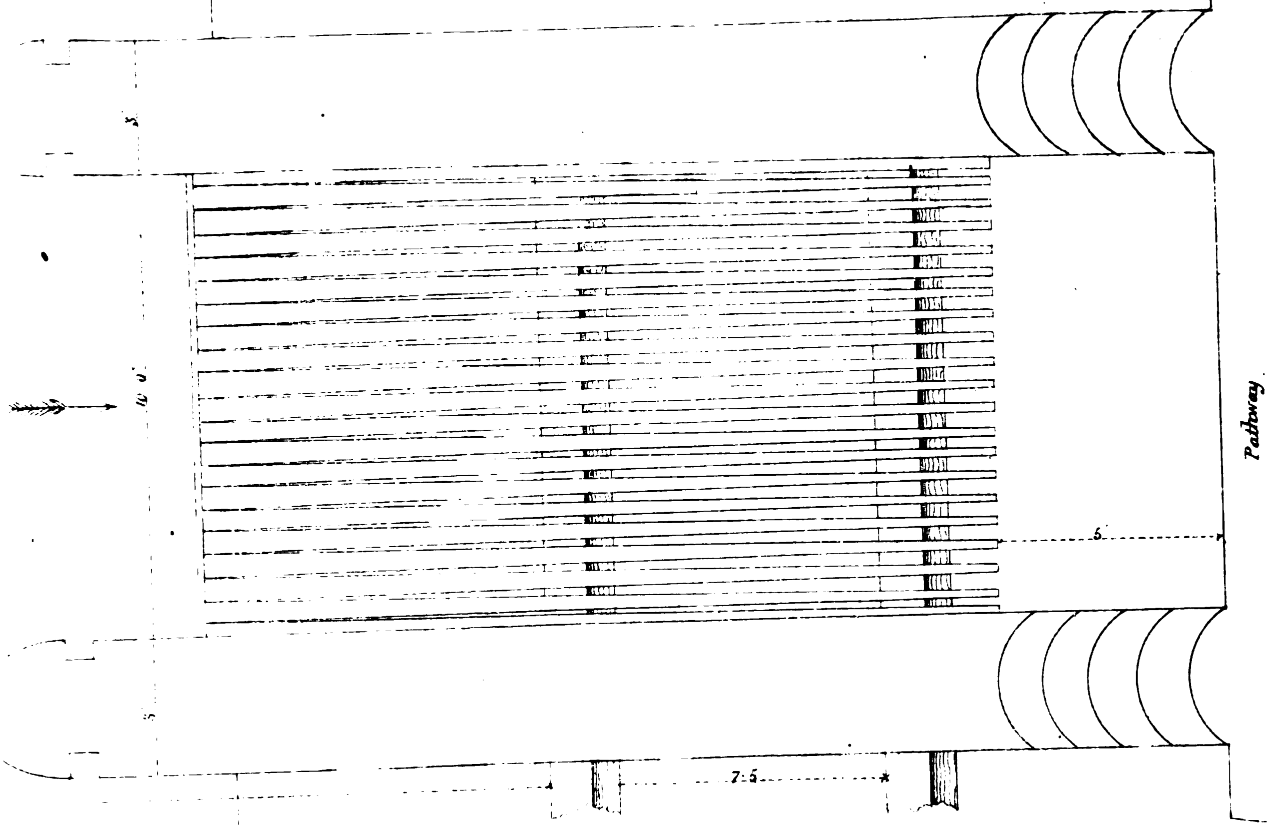
J. H. DYAS, *Captain, R. E.*

Dalhousie, 30*th July*, 1864.

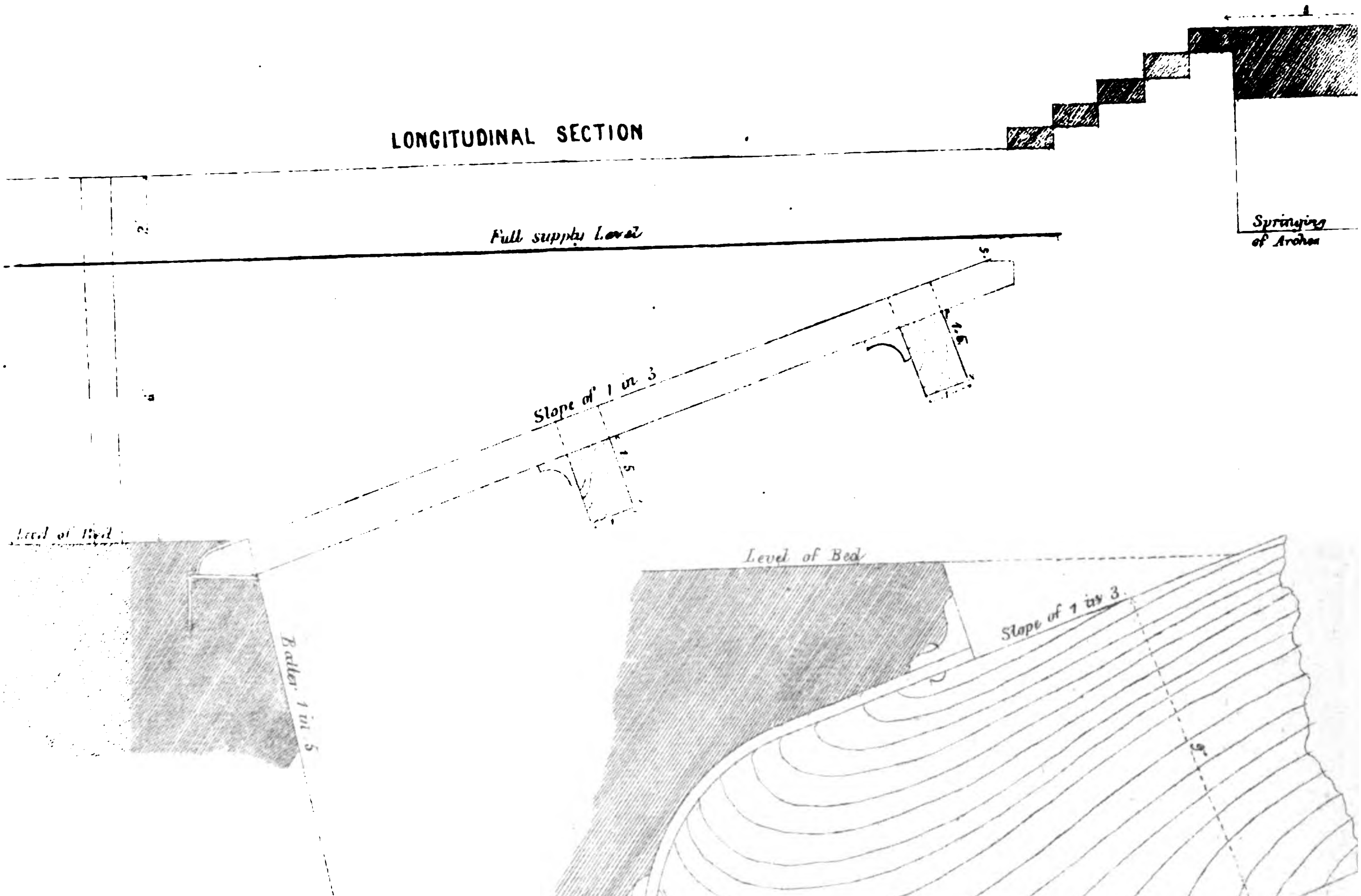
Digitized by Google

VERTICAL FALL WITH GRATING

PLAN

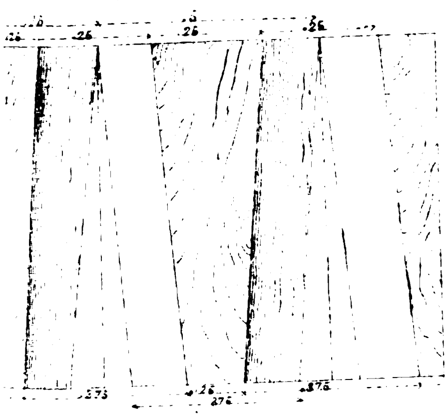


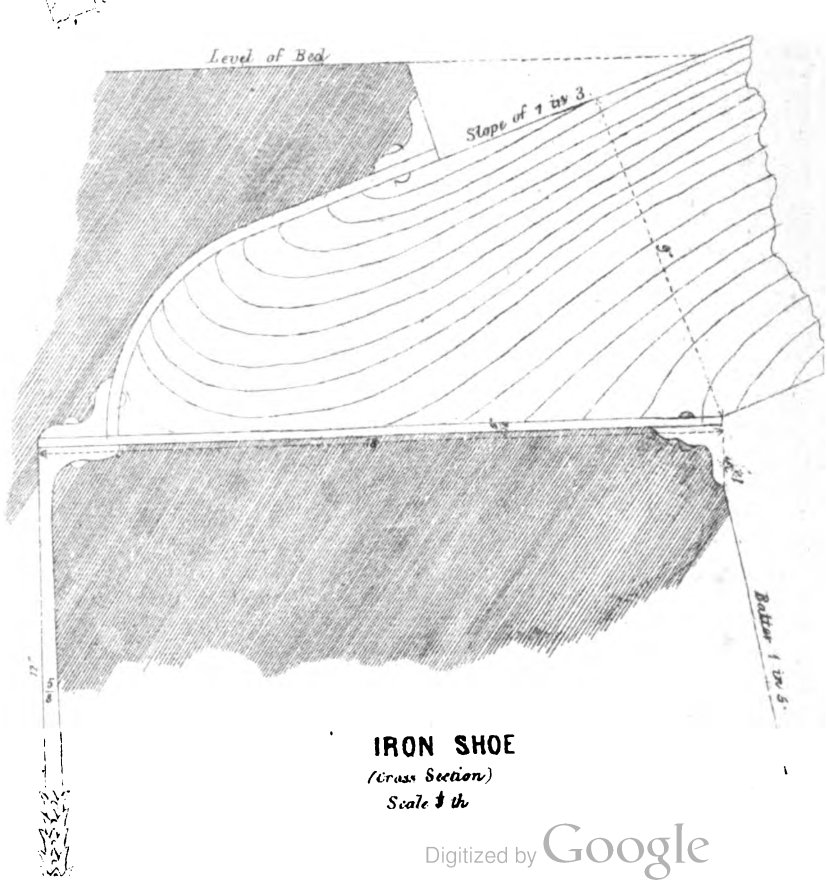
LONGITUDINAL SECTION



END ELEVATION OF BARS

Scale ⅛ th.





IRON SHOE

(Cross Section)

Scale ⅛ th

Digitized by Google

APPENDIX F,—*(continued)*.

Levels of the Surface of Springs along the line of the Ganges Canal.

Number of Miles from Head.	Distance from edge of Canal.		Reduced Levels.		Springs.		Remarks.
	Right Bank.	Left Bank.	Surface Springs.	Bed of Canal.	Above bed.	Below bed.	
106			R. 430.29	...	5.01	...	
			L. 430.64	435.30	4.66	...	
108			R. 434.47	...	3.58	...	
			L. 433.75	438.05	4.30	...	
$108\frac{2}{3}$		400	434.68	436.04	1.36	...	At Raolee Bridge.
110			R. 438.74	...	...	0.84	
			L. 435.25	437.90	2.65	...	
$110\frac{1}{3}$		300	434.37	437.64	3.27	...	At Bolundshuhur Branch Head.
117	500		445.95	449.32	3.37	...	Near Jarcha Bridge.
120	1500		450.37	451.34	0.97	...	Near Gusopoor Bridge.
123			454.06	455.21	1.15	...	Near Sunowta Bridge.
125	1200		457.08	457.61	0.53	...	
$128\frac{1}{2}$	100		462.23	460.33	...	1.90	At Dumkoura Bridge.
132			466.50	467.93	1.43	...	Near Urrowlee Bridge.
134			468.23	470.20	1.97	...	Near Wallipoora Bridge.
138			474.50	474.78	0.28	...	Near Manun Bridge.
139	600		476.27	475.79	...	0.48	
143			R. 479.23	479.41	0.18	...	Near Moonda Khera Bridge.
145			R. 482.29	481.26	...	1.03	Near Suhenda Bridge.
149			L. 492.37	491.59	...	0.78	Near Pulra Falls.
152			494.80	494.65	...	0.15	Near Koel Branch Head.
159			R. 503.85	498.06	...	5.79	Near Burolee Bridge.
162	33		503.30	507.72	4.42	...	Near Dubthulla Bridge.
172	213		521.05	524.89	3.84	...	
175	97		525.09	529.34	4.25	...	Near Chungeyree Bridge.
			Cawnpoor	*Branch.*			
2	156		538.83	538.12	...	0.71	
8	230		545.85	546.85	1.00	...	
12	121		550.82	551.31	0.49	...	
17	344		556.12	559.57	3.45	...	
21	228		562.62	565.08	2.46	...	
23	346		564.48	564.97	0.49	...	
30	68		572.38	574.65	2.27	...	
33	307		576.44	577.07	0.63	...	
37	427		582.82	584.01	1.19	...	
40	330		593.65	586.88	...	6.77	
43	154		593.38	590.44	...	2.94	
45	89		595.80	592.15	...	3.65	

Digitized by Google

APPENDIX G.

Statement of outlay on the Ganges Canal Works from commencement up to 30th April 1863.

Division or Section in which charges were made.	Original Works. Main Line.	Original Works. Cawnpoor Branch.	Original Works. Etawah Branch.	Original Works. Futtehgurh Branch.	Original Works. Boolundshuhur Branch.	Ordinary Repairs.	Rajbuhas.	Plantations.	*Sundries or Profit and Loss.	*Contingencies.	Establishment.	Totals.
	Rs. As. P.	Rs. As. P.	Rs. As. P.	Rs. As. P.	Rs. As. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
From commencement up to 31st July 1854.												
Northern, including material... ...	74,22,212 14 11	......	......	......	......	1,14,476 6 6	...	8,280 15 0	33,112 2 5	39,125 14 4	4,99,906 10 4	81,17,114 15 6
Upper Central ...	11,08,570 4 0	......	......	2,433 12 1	......	20,932 14 3	...	14,273 15 2	1,084 1 8	2,973 2 5	71,648 15 3	12,21,917 0 10
Lower „ ...	18,15,551 1 8	......	......	......	23,332 12 11 Koel Branch. 1,463 4 0	35,591 4 2	37,743 12 0	7,475 9 5	2,092 4 9	3,473 12 10	1,66,903 2 11	20,93,627 0 8
Cawnpoor	......	14,68,647 4 6	......	......	......	6,271 8 0	...	6,628 4 10	3,740 10 2	2,194 13 11	2,01,082 3 11	16,88,564 13 4
Etawah	......	......	7,12,090 12 5	......	......	3,057 9 0	...	5,342 10 9	1,505 4 9	1,535 9 7	90,067 11 4	8,13,599 9 10
Superintendent General's Office ...	... .	.....	......	......	......	......	......	......	......	......	2,48,323 5 2	2,48,323 5 2
Total up to 31st July 1854 ...	1,03,46,334 4 7	14,68,647 4 6	7,12,090 12 5	2,433 12 1	24,796 0 11	1,80,329 9 11	37,743 12 0	42,001 7 0	41,534 7 9	49,303 5 1	12,77,932 0 11	1,41,83,146 13 4
From 1st Augt. 1854 to 30th April 1863.												
Northern, including navigation and materials ...	7,48,542 11 4	......	......	......	......	8,57,831 8 10	4,40,232 12 7	28,774 13 1	......	27,020 3 10 4,906 7 10	4,65,551 3 11	25,72,859 13 5
Upper Central ...	41,971 2 11	......	......	6,82,572 5 8	......	1,94,851 13 6	6,15,065 8 7	15,267 3 9	......	15,140 13 5	1,94,457 9 1	17,59,326 8 11
Lower „ ...	71,976 12 0	......	......	......	81,638 4 9 Koel Branch. 216 4 2	3,14,644 2 8	11,38,745 11 8	47,238 4 3	......	47,413 6 9 4,152 13 7	3,48,668 2 7	20,61,351 12 4
Cawnpoor	......	3,19,114 15 8	......	......	......	2,17,534 7 4	5,55,960 9 10	28,020 13 3	......	16,356 7 4	2,58,465 7 1	13,95,452 12 6
Etawah	......	......	4,90,319 1 3 6,657 13 11	......	......	1,59,105 3 6	3,93,510 8 9	26,527 2 6	......	15,229 4 6	2,62,154 6 5	13,46,845 10 11
Superintendent General's Office ...	......	......	......	......	......	......	......	......	......	......	3,52,609 7 0	3,52,609 7 0
Totals ..	8,62,490 10 3	3,19,114 15 8	4,96,976 15 2	6,82,572 5 8	81,854 8 11	17,43,967 3 10	31,43,515 3 5	1,45,828 4 10	......	1,30,219 9 3	18,81,906 4 1	94,88,446 1 1
Grand Totals ...	1,12,08,824 14 10	17,87,762 4 2	12,09,067 11 7	6,85,006 1 9	1,06,650 9 10	19,24,296 13 9	31,81,258 15 5	1,87,829 12 0	41,534 7 9	1,79,522 14 4	31,59,838 5 0	2,36,71,592 14 5

* The aggregate of these two columns has been taken as "Contingencies."

Digitized by Google

APPENDIX H.

Statement of land required for projected lines, Ganges Canal.

Description.	Length in Feet.	Width in Feet.	Total in Acres.	Grand Total, Acres.
Alternative Line.				
From the head at Roorkee to the Junction Branch Head	322,080	600	4,436	
For the Junction Line	24,630	500	282	
Junction Branch Head to Boolundshuhur Branch Head	205,920	500	2,363	
Boolundshuhur Branch Head to Nanoon	353,760	400	3,248	
Escape No. 1	6,000	300	41	
Escape No. 2	53,800	200	247	
1st Class Chokies (4 in number)	300	300	8	
				10,625
Separate Navigation Channel	867,920	220	4,383	
				4,383
Navigation Channel along Cawnpoor Branch	892,320	220	4,507	4,507

Digitized by Google

REMODELLING.

GENERAL ABSTRACT OF ESTIMATES.

No. of Plan.	No. of Estimate.	No. of each.	Description.	Cost of each.	Total.	Due to Irrigation.	Due to Navigation.
			ABOVE ROORKEE.				
IV.	1	...	Excavation	...	77,941·90	76,044·90	1,900·00
X. 1	2	...	Alterations Myapoor Regulator	...	8,345·04	6,770·04	1,575·00
2	3	...	„ Kunkhul Bridge	...	34,703·17	5,649·41	29,053·76
	4	...	„ Jowalapoor Bridge	...	1,863·50	1,267·90	596·60
5, 6	5	...	„ Ranipoor Works	...	26,180·77	14,503·56	11,677·21
4	6	...	„ Buhadoorabad Fall, No. 1	...	39,414·14	39,414·14	...
4	7	...	„ „ „ No. 2	...	37,979·83	37,979·83	...
	8	...	„ Buhadoorabad Lock Channel	...	10,079·15	...	10,079·15
5, 6	9	...	„ Puttri Works	...	51,131·53	32,455·09	18,676·44
7	10	...	„ Rutmoo Works	...	26,320·50	19,501·93	6,818·57
	11	...	„ Peeran Kuliar Bridge	...	1,674·05	1,296·75	377·30
	12	...	„ Mahewar Bridge	...	1,871·32	1,275·72	595·60
	13	...	„ Solani Aqueduct	...	31,751·60	31,751·60	...
	14	...	„ Roorkee Bridge	...	1,995·60	1,400·00	595·60
			Total ...	...	3,51,255·10	2,69,310·87	81,944·23
			Add 5 per cent. for Contingencies	...	17,562·75	13,465·54	4,097·21
					3,68,817·85	2,82,776·41	86,041·44
			Add 7 per cent. for Establishment	...	25,817·24	19,794·34	6,022·90
			Total ...	...	3,94,635·09	3,02,570·75	92,064·34

Digitized by Google

No. of Plan.	No. of Estimate.	No. of each.	Description.	Cost of each.	Total.	Due to Irrigation.	Due to Navigation.
			FROM ROORKEE TO NANOON.				
IV.	1	...	Excavation	...	8,00,094·75	7,83,994·75	16,100·00
X. 8	15	...	Fall 4·07 at Roorkee	...	71,753·61	42,860·25	28,893·36
9	16	3	Additions, &c., to Guneshpoor, Liburheree, and Dimat Bridges	13,768·83	41,306·49	39,519·69	1,786·80
10	17	...	Alterations, Hafiznugger Falls	...	40,447·77	37,563·53	2,884·24
9	18	...	Ditto, Munglour Bridge	...	16,369·57	15,773·97	595·60
12	19	...	Fall 6·87 at Liburheree Bridge	...	75,165·61	43,215·71	31,949·90
9	20	4	Additions, &c., to Mundowlee, Toghulpoor, Bailra, and Bhopa Bridges ...	12,295·58	49,182·32	46,799·92	2,382·40
10, 11	21	...	Additions, &c., to Muhmoodpoor Falls	...	40,708·68	37,824·44	2,884·24
12	22	...	Fall 8·54 at Toghulpoor Bridge	...	77,174·01	44,854·01	32,320·00
10	23	...	Additions, &c., to Nirgajnee Falls	...	41,755·49	39,989·49	1,766·00
10	24	...	Ditto Jaoli ditto	...	39,751·09	37,985·09	1,766·00
13	25	...	Ditto Futtygurh branch head...	...	29,308·67	9,872·90	19,435·77
14	26	...	Dukheri Bridge and Fall 3·53	...	67,204·91	37,715·95	29,488·96
	27	4	Alterations to Nugla, Serai, Sutheree, and Aternah Bridges	2,409·63	9,638·52	7,256·12	2,382·40
	28	2	Ditto to Sirdhanna and Khutowlie Bridges	984·00	1,968·00	422·40	1,545·60
10	29	..	Ditto to Chitowra Falls	...	42,861·16	41,453·16	1,408·00
	30	3	Alterations to escapes at Khutoulie Aboo Nullah and Janni Khoord ...	259·20	777·60	777·60	...
	31	2	Falls at Khutowlie and Sirdhanna	49,464·33	98,928·66	39,950·74	58,977·92
16	32	2	Additions, &c., to Sulawur and Mussoorie Falls	41,484·52	82,969·04	78,431·04	4,538·00
	33	2	Ditto to Nanoon and Moradnugger Bridges	17,728·46	35,456·92	2,242·72	33,214·20
	34	4	Ditto to Jutpoora, Newari, Aboopoor, and Noorpoor Bridges	16,031·05	64,124·20	3,302·28	60,821·92
	35	...	Ditto to Sounda Bridge	...	15,205·25	...	15,205·25
	36	2	Ditto to Pooth and Nugla Bridges	16,526·33	33,052·66	1,804·28	31,248·38
16	37	...	Ditto to Bhola Falls	...	32,070·20	28,617·88	3,452·32
	38	...	Ditto to Janni Khoord Bridge	...	15,623·96	...	15,623·96
	39	5	Ditto to Raoli, Jarcha, Pukkana, Mamun, and Suhenda Bridges	14,414·36	72,071·80	4,429·15	67,642·65
	40	...	Ditto to Peepulherēe Bridge	...	14,860·43	934·77	13,925·66
13	41	...	Additions, &c., to Boolundshuhur Branch Head	...	23,392·08	7,271·45	16,120·63
	42	3	Ditto to Nidhaoli, Geesoopoor, and Sunowta Bridges	13,680·72	41,042·16	457·20	40,584·96

Digitized by Google

	43	...	Ditto to Dumkoura Bridge	...	13,738·52	210·00	13,528·52
	44	...	Ditto to Wullipoora Bridge	...	15,911·47	295·21	15,616·26
17	45	5	Falls at Wullipoora, Nugla, Aboopoor, Jarcha, and Pukkana	59,851·75	2,99,258·75	1,50,625·00	1,48,633·75
	46	...	Fall at Moonda Khera	...	61,274·66	31,547·91	29,726·75
	47	...	Alterations to Urrowli Bridge	...	15,016·22	286·00	14,730·22
	48	...	Ditto to Moonda Khera Bridge	...	14,184·52	656·00	13,528·52
	49	...	Ditto to Uchuhja Bridge	...	13,774·52	246·00	13,528·52
18	50	...	Ditto to Pulra Falls	...	19,371·85	17,334·34	2,03751.
	51	...	Ditto to Koel Branch Head	...	20,831·59	5,602·75	15,228·84
19	52	3	Ditto to Burrowlee Dubthulla and Chungeyree Bridges	13,135·53	39,406·59	2,362·50	37,044·09
	53	2	Falls at Burrowlee and Chungeyree	53,563·09	1,07,126·18	47,726·18	59,400·00
	54	...	Fall at Kasimpoor	...	54,511·75	24,811·75	29,700·00
18	55	...	Additions to Simra Falls	...	11,951·50	9,913·99	2,037·51
	56	...	Ditto to Kasimpoor Bridge	...	13,546·63	1,198·00	12,348·03
	57	2	Ditto to Barotha and Shekha Bridges	14,036·38	28,072·76	255·00	27,817·76
	58	2	Ditto to Daopoor and Machooa Bridges	12,348·03	24,696·06	...	24,696·06
20	59	...	Ditto to Nanoon Regulator	...	25,397·39	5,085·76	20,311·63
38	115	15	3rd Class Chokies	363·31	5,449·65	5,449·65	
					27,57,785·62	17,38,926·53	10,18,859·09
			Add 5 per cent. for Contingencies	...	1,37,889·28	86,946·32	50,942·95
					28,95,674·90	18,25,872·85	10,69,802·04
			Add 7 per cent. for Establishment	...	2,02,697·24	1,27,811·09	74,886·14
			Total ...	...	30,98,372·14	19,53,683·94	11,44,688·18

Digitized by Google

No. of Plan.	No. of Estimate.	No. of each.	Description.	Cost of each.	Total.	Due to Irrigation.	Due to Navigation.
			CAWNPOOR BRANCH.				
	1	...	Excavations	...	34,102·29	...	34,102·29
	60	...	Alterations, Keylunpoor Bridge	...	8,318·38	...	8,318·38
	61	4	Ditto bridges 3 arches of 33′, 18′ roadway	8,228·29	32,913·16	...	32,913·16
	62	2	Ditto ditto 20′ „	8,501·36	17,002·72	...	17,002·72
	63	...	Ditto ditto 18′ „	...	8,005·87	...	8,005·87
	64	...	Ditto bridges 3 arches of 31′, 18′ „	..	7,783·45	...	7,783·45
	65	...	Ditto ditto 3 „ 30′, 18′ „	...	7,611·03	...	7,611·03
	66	...	Ditto ditto ditto 20′ „	...	7,817·54	...	7,817·54
	67	...	Ditto ditto 3 „ 29′, 18′ „	...	7,326·58	...	7,326·58
	68	...	Ditto ditto ditto 20′ „	...	7,576·67	...	7,576·67
	69	2	Ditto ditto 3 „ 28′, 18′ „	7,104·16	14,208·32	...	14,208·32
	70	...	Ditto ditto ditto 20′ „	...	7,348·73	...	7,348·73
	71	...	Ditto ditto 3 „ 27′, 18′ „	...	6,881·74	...	6,881·74
	72	...	Ditto ditto ditto 20′ „	...	7,120·79	...	7,120·79
	73	2	Ditto ditto 3 „ 26′, 20′ „	6,892·85	13,785·70	...	13,785·70
	74	...	Ditto ditto ditto 25′ „	...	7,431·67	...	7,431·67
	75	...	Ditto ditto 2 „ 35′, 18′ „	...	5,928·20	...	5,928·20
	76	...	Ditto ditto ditto 20′ „	...	6,135·14	...	6,135·14
	77	3	Ditto ditto 2 „ 33′, 18′ „	5,631·64	16,894·92	...	16,894·92
	78	2	Ditto ditto 2 „ 32′, 18′ „	5,483·36	10,966·72	...	10,966·72
	79	...	Ditto ditto ditto 20′ „	...	5,679·26	...	5,679·26
	80	5	Ditto ditto 2 „ 30′, 18′ „	5,186·80	25,934·00	...	25,934·00
	81	3	Ditto ditto ditto 20′ „	5,375·34	16,126·02	...	16,126·02
	82	5	Ditto ditto 2 „ 25′, 18′ „	4,445·40	22,227·00	...	22,227·00
	83	...	Ditto ditto ditto 20′ „	...	4,615·54	...	4,615·54
	84	4	Ditto ditto ditto 15′ „	4,222·08	16,888·32	...	16,888·32
	85	5	Ditto ditto 1 „ 30′, 18′ „	2,803·27	14,016·35	...	14,016·35
	86	...	Ditto ditto ditto 20′ „	...	2,923·40	...	2,923·40
	87	...	Ditto ditto 1 „ 25′, 15′ „	...	2,308·57	...	2,308·57
	88	...	Ditto ditto ditto 20′ „	...	2,540·17	...	2,540·17

Digitized by Google

	89	...	Ditto Aima Bridge	...	374·53	...	374·53
	90	...	Ditto Upper Railway Bridge...	...	571·62	...	571·62
	91	...	Ditto Dubowli Bridge	...	804·28	...	804·28
	92	...	Ditto ditto locks	...	22,175·19	...	22,175·19
21	93	9	Ditto Duknapoor Bridge and others	359·69	3,237·21	...	3,237·21
22	94	...	Ditto Ghats at Cawnpoor	...	1,056·40	...	1,056·40
	95	...	Ditto Upper locks	...	292·99	...	292·99
	96	...	Ditto General Gunj Bridge	...	1,870·29	...	1,870·29
	97	...	Ditto No. 3 lock...	...	394·80	...	394·80
	...	2	3rd Class Chokies	363·31	726·62	...	726·62
			Add 5 per cent. for Contingencies	...	18,996·10	...	18,906·10
					3,98,918·28	...	3,98,918·28
			Add 7 per cent. for Establishment	...	27,924·27	...	27,924·27
			Total	...	4,26,842·55	...	4,26,842·55
			Grand Total above Roorkee	...	3,94,635·09	3,02,570·75	92,064·34
			Do. do. from Roorkee to Nanoon ...	...	30,98,372·14	19,53,683·94	11,44,688·18
			Ditto Cawnpoor Branch	...	4,26,842·55	...	4,26,842·55
			Grand Total Remodelling ...	...	39,19,849·78	22,56,254·69	16,63,595·07

Digitized by Google

ALTERNATIVE LINE.

GENERAL ABSTRACT OF ESTIMATES.

No. of Plan.	No. of Estimate.	No. of each.	Description.	Cost of each.	Total.	Due to Irrigation.	Due to Navigation.
			Section No. 1.				
VII	98	1	Excavation	...	19,07,956·56	19,07,956·56	
X 23	99	1	Regulator at Roorkee	...	96,632·06	69,523·92	27,108·14
„ 24	100	1	Ditto for Junction line	...	88,560·84	72,321·84	16,239·00
„ 26	101	9	Falls 6 feet, 11 bays of 15 feet, roadway 18 feet	89,649·56	8,06,846·04	5,18,762·70	2,88,083·34
„ 26	102	2	Ditto ditto ditto 20 „	90,942·38	1,81,884·76	1,17,880·60	64,004·16
„ 27	103	1	Ditto 6 ditto 14 feet on junction	...	53,715·04	21,705·78	32,009·26
„ 28	104	1	Fall escape and dam bridge	...	1,24,182·56	90,182·56	34,000·00
„ 29	104½	1	Ditto on escape into West Kalee Nuddy	...	47,453·92	47,453·92	
„ 30	105	1	Aqueduct upper crossing West Kalee Nuddy	...	1,25,912·00	1,25,912·00	
„ 31	106	...	Ditto lower ditto ditto	...	2,78,521·53	2,78,521·53	
„ 32	107	7	Bridges, 4 arches of 51 feet span, roadway 18 feet	22,446·08	1,57,122·56	1,46,231·96	10,890·60
„ 32	108	...	Ditto ditto ditto 20 „	...	23,741·46	22,023·24	1,718·22
„ 32	109	...	Ditto ditto ditto 25 „	...	26,880·24	24,906·12	1,974·12
„ 33	110	...	Ditto 3 ditto 40 ditto on junction	...	11,918·28	9,843·51	2,074·12
„ 35	111	1	Culvert, 2 arches of 20 feet	...	34,041·64	34,041·64	
„ 38	112	2	Ditto, 1 arch of 10 feet	11,472·72	22,945·44	22,945·44	
„ 35	113	1	Inlet for drainage	...	1,824·48	1,824·48	
„ 37	114	2	Rajbuha outlets	1,410·78	2,821·56	2,821·56	
„	...	4	1st Class Chokies	3,200·00	12,800·00	12,800·00	
„ 38	...	5	2nd do. do.	800·00	4,000·00	4,000·00	
„ 38	115	15	3rd do. do.	363·31	5,449·65	5,449·65	
					40,15,210·62	35,37,109·01	4,78,101·61
			Add 8 per cent. for Contingencies	...	3,21,216·84	2,82,968·72	38,248·12
					43,36,427·46	38,20,077·73	5,16,349·73
			Add 7 per cent. for Establishment	...	3,03,549·92	2,67,405·44	36,144·48
			Grand Total Rupees ...	...	46,39,977·38	40,87,483·17	5,52,494·21

Digitized by Google

			Section No. 2.			
VII	98	1	Excavation	...	5,01,446·50	
X 26	116	5	Falls 6 feet, 7 bays of 15 feet, roadway 18 feet	34,293·65	1,71,468·25	
„ 25	117	1	Fall escape and branch head for Boolundshuhur branch	...	52,022·74	
„ 33	118	1	Bridges, 3 arches of 40 feet span, roadway 25 feet	...	13,778·63	
„ 33	119	2	Ditto ditto ditto ditto 20 „	11,923·26	23,846·52	
„ 33	120	8	Ditto ditto 40 ditto ditto 18 „	11,181·24	89,449·92	
„	121	1	Syphons for drainage, 2 arches of 10 feet	...	7,674·58	
„	122	1	Culvert, 1 arch of 15 feet	...	11,214·16	
„ 34	123	1	Bridge on escape, 2 arches of 30 feet, roadway 25 feet	...	6,274·93	
„ 34	124	1	Ditto ditto ditto ditto 33 „	...	6,958·14	
„ 29	125	1	Fall on escape at tail	...	38,117·35	
„ 37	126	11	Rajbuha outlets	1,323·30	14,556·30	
„	...	7	2nd Class Chokies	800·00	5,600·00	
„ 38	115	7	3rd Do. do.	363·31	2,543·17	
			Total of Section No. 2 ...	...	9,44,951·19	
			Add 8 per cent. for Contingencies	...	75,596·9	
					10,20,547·28	
			Add 7 per cent. for Establishment	...	71,438·30	
			Grand Total Rupees ...	...	10,91,985·58	
			Section No. 3.			
VII	98	...	Excavation	...	3,80,977·05	
X 26	127	2	Falls 6 feet drop, 6 bays of 15 feet, roadway 18 feet	28,511·02	57,022·04	
„	128	1	Ditto ditto with deep foundations on wells, roadway 20 feet	...	35,449·71	
„	129	4	Fall and branch head for Koel Branch on well foundation	...	44,930·51	
„	130	4	Bridges, 3 arches of 35 feet span, roadway 18 feet	9,843·51	39,374·04	
„	130	4	Ditto ditto of 35 roadway 18 feet with deep foundations on wells ...	11,606·68	46,426·72	
„	131	2	Ditto ditto of 35 feet span, roadway 20 feet	10,492·39	20,984·78	
„	...	2	Ditto ditto with deep foundations on wells	12,306·90	24,613·80	
			Carried over ...	...	6,49,778·65	

Digitized by Google

ALTERNATIVE LINE.

General Abstract of Estimates,—continued.

No. of Plan.	No. of Estimate.	No. of each.	Description.	Cost of each.	Total.	Due to Irrigation.	Due to Navigation.
			Brought forward ...	...	6,49,778·65		
X	132	2	Bridges, 3 arches of 35′ span, roadway 25′, with deep foundations on wells ...	14,057·07	28,115·94		
„	133	1	Syphon for drainage, 2 arches of 10 feet	...	6,980·18		
„ 38	134	3	Ditto ditto 1 arch of 10 feet	3,944·44	11,833·32		
„ 37	135	13	Rajbuha outlets	1,240·89	16,131·57		
	...	6	2nd Class Chokies	800·00	4,800·00		
„	115	5	3rd do. do.	363·31	1,816·55		
			Total of Section No. 3 ...	...	7,19,456·21		
			Add 8 per cent. for Contingencies	...	57,556·49		
					7,77,012·70		
			Add 7 per cent. for Establishment	...	54,390·88		
			Grand Total Rupees ...	...	8,31,403·58		
			Section No. 4.				
VII	98	1	Excavation	...	2,13,501·91		
X 26	136	1	Fall 4 feet, 5 bays of 15 feet, roadway 18 feet, with deep foundations on wells...	...	27,935·07		
„ 34	137	5	Bridges, 3 arches of 30 feet, roadway 20 feet, ditto ditto ...	9,461·89	47,309·45		
„ 34	138	4	Bridges, 3 arches of 30 feet, ditto 18 „ ditto ditto ...	8,956·75	35,827·00		
„	139	1	Syphon for drainage, 2 arches of 10 feet	...	6,591·31		
„ 36	140	5	Ditto 1 arch of 3 feet	1,590·91	7,954·55		
„ 37	141	2	Rajbuha outlets	1,085·77	2,171·54		
„	...	3	2nd Class Chokies	800·00	2,400·00		
„ 38	115	1	3rd do. do.	363·31	363·31		
			Total of Section No. 4 ...	...	3,44,054·14		

Digitized by Google

			Add 8 per cent. for Contingencies	...	27,524·38		
					3,71,578·47		
			Add 7 per cent. for Establishment	...	26,010·49		
			Grand Total, Rupees ...	...	3,97,588·96		
			Repairs to present Main Line from Roorkee to Cawnpoor Branch Head.				
	59	...	Nanoon Regulator...	...	25,397·39	5,144·65	20,252·74
	142	...	Earth-work	...	20,857·28	7,757·28	13,100·00
	143	5	Repairs, &c., to Falls 200 feet waterway	4,443·90	22,219·50	22,219·50	...
	144	3	Ditto ditto 150 ditto	3,350·80	10,052·40	10,052·40	...
	145	...	Ditto Futteyghur Branch Head	...	1,866·80	1,866·80	...
15	146	...	Tow-paths under bridges	...	14,332·60	...	14,332·60
					94,725·97	47,040·63	47,685·34
			Add 8 per cent. for Contingencies	...	4,736·29	2,352·03	2,384·26
					99,462·26	49,392·66	50,069·60
			Add 7 per cent. for Establishment	...	6,962·35	3,457·48	3,504·87
			Grand Total Repairs to Line below Roorkee ...	...	1,06,424·61	52,850·14	53,574·47
			Grand Total Section No. 1 ...	...	46,39,977·38	40,87,483·17	5,52,494·21
			Ditto ditto „ 2 ...	...	10,91,985·58	10,91,985·58	
			Ditto ditto „ 3 ...	...	8,31,403·58	8,31,403·58	
			Ditto ditto „ 4 ...	...	3,97,588·96	3,97,588·96	
			Cost of Alternative Line ...	...	69,60,955·50	64,08,461·29	5,52,494·21
			Grand Total Repairs to Line below Roorkee ...	...	1,06,424·61	52,850·14	53,574·47
			Cost of Alternative Line project	...	70,67,380·11	64,61,311·43	6,06,068·68

Digitized by Google

NAVIGABLE LINE.

GENERAL ABSTRACT OF ESTIMATES.

No. of Plan.	No. of Estimate.	No. of each.	Description.	Cost of each.	Total.	Due to Irrigation.	Due to Navigation.
IV 3	147	...	Excavation	...	7,91,859·23		
X 39	148	1	Double lock chambers at exit from canal	...	32,269·53		
	...	1	Ditto ditto with deep foundations on wells	...	29,431·01		
40	149	20	Locks 6 feet drop, bridge roadway 18 feet wide	24,554·77	4,91,095·40		
	...	2	Ditto ditto, with deep foundations on wells	25,115·51	50,231·02		
	150	1	Ditto 12 ditto, bridge roadway 18 feet wide	...	29,897·05		
	151	1	Ditto 6 ditto, ditto 25 „	...	25,524·25		
	151	2	Ditto ditto, with deep foundations on wells	26,085·09	52,170·18		
	152	2	Ditto 8 ditto, bridge roadway 20 feet wide	26,284·08	52,568·16		
	153	1	Ditto 5 ditto, ditto 10 „	...	23,002·40		
	154	1	Ditto 9·73 ditto, ditto 10 „	...	27,015·82		
42	155	1	Aqueduct 2 arches of 40 „	...	31,181·81		
	156	1	Ditto 3 ditto 40 „	...	46,752·16		
	157	1	Ditto 3 ditto 30 „	...	30,513·50		
41	158	1	Bridges, 1 arch of 34, roadway 10 „	...	5,279·30		

Digitized by Google

	159	25	Ditto, ditto, ditto 18 „	5,789·44	1,44,736·00
	...	14	Ditto ditto with deep foundations on wells	6,149·50	86,093·00
	160	8	Ditto 1 arch of 34 feet, roadway 20 feet	6,056·90	48,455·20
X 41	160	2	Ditto 1 arch of wide deep foundations on wells	6,364·16	12,728·32
	161	7	Ditto 1 arch of 34 feet, roadway 25 feet	6,725·80	47,080·60
	...	3	Ditto ditto with deep foundations on wells	7,164·12	21,492·36
35	162	2	Culverts for drainage, 2 arches of 20 feet	13,600·03	27,200·06
	163	2	Ditto ditto 2 arches of 10 „	7,151·90	14,303·80
38	164	3	Syphons for ditto 1 arch of 10 „	2,376·78	7,130·34
	165	3	Ditto ditto 1 arch of 6 „	1,847·84	5,543·52
36	166	8	Ditto ditto 1 arch of 3 „	1,187·19	9,497·52
	167	1	Ditto ditto 2 arches of 6 „	...	2,932·01
38	168	2	Ditto ditto 2 arches of 10 „	4,045·68	8,091·36
	169	23	Rajbuha Syphons 1 arch of 6 „	1,327·44	30,531·12
36	170	1	Water-course ditto 1 „ 3 „	...	1,008·68
38	115	32	3rd Class Chokies...	363·31	11,625·92
					21,97,240·63
			Add 8 per cent. for Contingencies	...	1,75,779·25
					23,73,019·88
			Add 7 per cent. for Establishment	...	1,66,111·39
			Grand Total Rupees ..	...	25,39,131·27

Digitized by Google

MISCELLANEOUS ESTIMATES.

Number of Plan.	Number of Estimate.		Rate.	Quantity.	Total.
		Feet.			Feet.
X 15	171	Girder Bridges ... 55 span.	...	...	15,339·56
„	172	Ditto ... 30 „	...	...	6,921·54
	173	Towing paths ... 12 wide.			
	174	Ditto ... ... 7 „			
	175	Ditto ... ... 7 „ for Cawnpoor Branch ...			
X 11	176	*Muhmoodpoor Falls.*			
		Comparison cost of iron and	...	...	15,431·82
		Wooden and stone gratings	...	...	13,771·78
„ 26	177	*Falls on alternative line.*			
		11 bays of 15 feet without locks	...	...	59,238·30
		With locks	...	...	89,649·56
	178	*Lockage in present Muhmoodpoor Falls.*			
	179	Raising Sounda Bridge with masonry arches ...	...	...	6,044·14
			L. ft.		
	180	Temporary fall on diversions	59	150	8,850
			„	115	6,785
	181	Temporary diversions of main line above Jowlie	...	...	4,250
		Ditto ditto below Jowlee ...	...	...	3,350

Digitized by Google

CLASSIFICATION OF COST.

ALTERNATIVE LINE.

Description.	Section No. 1.	Remainder.	Total.
Earth-work	19,07,956·56	10,95,925·46	30,03,882·02
Falls and regulating bridges ...	13,99,275·22	4,26,945·67	18,26,220·89
Bridges	2,19,662·54	3,82,959·87	6,02,622·41
Drainage works, aqueducts, culverts, &c.	4,63,245·09	52,248·10	5,15,493·19
Irrigation outlets, &c., ...	2,821·56	32,859·41	35,680·97
Accommodation buildings ...	22,249·65	17,523·03	39,772·68
	40,15,210·62	20,08,661·54	60,23,672·16
Contingencies			4,81,893·75
Establishment			4,55,389·59
Grand Total Rupees ...			69,60,955·50

SEPARATE NAVIGABLE LINE.

Description.	Cost.
Earth-work	7,91,859·23
Lockage, including level chambers	8,13,204·82
Bridges	3,65,864·78
Drainage works, aqueducts, culverts, syphons, &c.	1,83,146·08
Irrigation culverts	31,539·80
Accommodation buildings	11,625·92
Total ...	21,97,240·63
Contingencies	1,75,779·25
Establishment	1,66,111·39
Grand Total Rupees ...	25,39,131·27

Digitized by Google

NOTES TO THE ESTIMATES.

All measurements are in English feet and decimals.

Cost in Rupees and decimals.

The cost of overfalls at the termination of the Khutowlee, Aboo Nulla, and Jannee Khoord Escapes on the main line of the Ganges Canal, have been omitted in the estimate for remodelling. They formed part of the original projection, but I was not aware, until these estimates had been completed, that they had not yet been built. As they will ultimately be necessary to the efficiency of the Escapes, their probable cost—Rs. 47,500 each, or Rs. 1,42,500 in the aggregate—should be added to the estimate.

J. CROFTON, *Captain, R. E.*

Digitized by Google

GOVERNMENT OF INDIA.

PUBLIC WORKS DEPARTMENT.

REPORT

ON

THE GANGES CANAL

BY

CAPT. J. CROFTON, R. E.,

WITH

ESTIMATES AND PLANS.

IN THREE VOLUMES.

VOL. II.—ESTIMATES.

Calcutta:
PUBLIC WORKS DEPARTMENT,
1865.

Digitized by Google

Digitized by Google

CONTENTS.

	Page.
Remodelling Estimates, Nos. 1 to 97	1
Alternative Lines, Nos. 98 to 146...	95
Navigable Line, Nos. 147 to 170	115
Miscellaneous Estimates, Nos. 171 to 181	125

Digitized by Google

Digitized by Google

GANGES CANAL.

REMODELLING ESTIMATES.

ESTIMATE No. 1.—EXCAVATION.

No. of Mile.	L.	B.	D.	Contents.	Total.	Grand Total.
		Area.				
1	5,280	40		211,200		
2	4,045	40		161,800		
„	300	776		232,800		
„	633	1,779		1,126,107		
3	5,280	990		5,227,200		
4	4,680	626		2,929,680		
5	5,280	650		3,432,000		
					13,320,787	
6	248	650		161,200		
„	4,232	441		1,866,312		
7	4,711	441		2,077,551		
8	1,896	379		718,584		
„	2,353	234		550,602		
9	5,280	142		749,760		
10	3,530	230		811,900		
„	400	500		200,000		
„	950	1,210		1,149,500		
					8,285,409	
11	5,280	1,522		8,036,160		
12	5,280	755		3,986,400		
13	3,879	284		1,101,636		
„	801	84		67,284		
14	28	84		2,352		
„	4,952	375		1,857,000		
15	300	359		107,700		
„	300B	66		19,800		
„	4,680	75		351,000		
19	1,072	849		910,128		
„	2,028	457		926,796		
					17,366,256	
20	3,252	1,125		3,658,500		
21	600	159		95,400		
„	4,680	1,135		5,311,800		
22	5,280	901		4,757,280		
23	3,490	901		3,144,490		
„	990	1,215		1,202,850		
24	5,280	1,197		6,320,160		
25	4,680	752		3,519,360		
					28,009,840	
26	5,280	784 }		5,008,976		
27	1,109	784 }				
„	300	554		166,200		
„	3,571	2,557		9,131,047		
28	5,280	1,999		10,554,720		
29	300	256		76,800		
„	300	156		46,800		
„	4,680	1,231		5,761,080		
30	5,280	790		4,171,200		
					34,916,823	
31	5,280	1,085		5,728,800		
32	194	1,085		210,490		
„	400	87		34,800		
„	4,286	711		3,047,346		
33	5,280	658		3,474,240		
34	4,680	751		3,514,680		
35	5,280	1,596		8,426,880		
					24,437,236	
		Carried over ...		...	126,336,351	

ESTIMATE No. 1.—EXCAVATION,—*continued.*

No. of Mile.	L.	B.	D.	Contents.	Total.	Grand Total.
		Brought forward ...		...	126,336,351	
		Area.				
36	5,280	1,577		8,326,560		
37	5,280	840		4,435,200		
38	5,280	739		3,901,920		
39	414	739		305,946		
"	300	157		47,100		
"	4,266	1,761		7,512,426		
40	5,280	1,625		8,580,000	33,109,152	
41	5,280	555		2,930,400		
42	5,280	944		6,811,904		
43	1,936	944				
"	400	150		93,200		
"	400	83				
"	2,544	1,696		4,314,624		
44	5,280	1,458		7,698,240		
45	300	123		75,600		
"	300	129				
"	4,680	782		3,659,760	25,583,728	
46	5,280	544		2,872,320		
47	300	75		22,500		
"	4,680	1,179		5,517,720		
48	5,280	608		3,210,240		
49	1,313	608		798,304		
"	3,167	1,121		3,550,207		
50	5,280	1,221		6,446,880	22,418,171	
51	4,680	590		2,761,200		
52	5,280	966		5,100,480		
53	2,380	258		614,040		
"	2,900	5,100		14,790,000		
54	2,047	258		528,126		
"	2,633	82		215,906		
55	4,680	359		1,680,120	25,689,872	
56	4,576	359		1,642,784		
"	304	501		152,304		
57	96	501		48,096		
"	5,184	1,003		5,199,552		
58	5,280	543		2,867,040		
59	300	83		56,400		
"	300A	105				
"	4,680	815		3,814,200		
60	5,280	806		4,255,680	18,036,056	
61	5,280	168		887,040		
62	5,280	327		1,726,560		
63	1,592	327		520,584		
"	300	321		96,300		
"	3,088	1,369		4,227,472		
64	5,280	594		3,136,320		
65	4,680	996		4,661,280	15,255,556	
66	5,280	803		4,239,840		
67	5,280	814		4,297,920		
		Carried over	...	8,537,760	266,428,886	

ESTIMATE No. 1.—EXCAVATION,—*continued.*

No. of Mile.	L.	B.	D.	Contents.	Total.	Grand Total.
		Brought forward ...		8,537,760	266,428,886	
		Area.				
68	1,950	814		1,587,300		
„	400	894		357,600		
„	2,530	1,290		3,263,700		
69	5,280	525		2,772,000		
70	5,280	704		3,717,120		
					20,235,480	
71	5,280	377		1,990,560		
72	4,680	459		2,148,120		
73	5,280	454		2,397,120		
74	5,280	229		1,209,120		
75	4,680	217		1,015,560		
					8,760,480	
76	5,280	531		2,803,680		
77	5,280	306		1,615,680		
78	300	116 }		52,800		
„	300	60 }				
„	4,680	493		2,307,240		
79	5,280	442		2,333,760		
80	4,680	265		1,240,200		
					10,353,360	
81	5,280	390		2,059,200		
82	5,280	461		2,434,080		
83	4,680	173		809,640		
84	5,280	60		316,800		
85	1,101	60		66,060		
„	3,379	242		817,718		
					6,503,498	
86	5,280	310		1,636,800		
87	5,280	320		1,689,600		
88	4,680	100		468,000		
89	5,280	98		517,440		
90	3,490	98		342,020		
„	300	177		53,100		
„	1,190	629		748,510		
					5,455,470	
91	5,280	469		2,476,320		
92	5,280	290		1,531,200		
93	5,280	290		1,531,200		
94	300	117		35,100		
„	4,680	290		1,357,200		
95	5,280	242		1,277,760		
					8,208,780	
96	5,280	242		1,277,760		
97	4,680	290		1,357,200		
98	5,280	290		1,531,200		
99	2,130	290		617,700		
„	2,550	230		586,500		
100	5,280	230		1,214,400		
					6,584,760	
101	4,080	270		1,263,600		
„	300	44		13,200		
102	5,280	162		855,360		
103	5,280	162		855,360		
104	4,680	230		1,076,400		
105	5,280	230		1,214,400		
					5,278,320	
		Carried over ...		...	337,809,034	

Digitized by Google

ESTIMATE No. 1.—EXCAVATION,—*continued.*

No. of Mile.	L.	B.	D.	Contents.	Total.	Grand Total.
		Brought forward ...		...	337,809,034	
		Area.				
106	2,712	230		623,760		
„	400	169		67,600		
„	1,768	502		887,536		
107	300	169		50,700		
„	4,680	730		3,416,400		
„	300	96		28,800		
108	5,280	440		2,323,200		
109	4,680	306		1,432,080		
110	5,280	404		2,133,120		
					10,963,196	
111	300	137		41,100		
„	1,446	404		584,184		
„	3,234	21		67,914		
112	5,280	21		110,880		
113	5,280	21		110,880		
114	4,680	21		98,280		
115	5,280	21		110,880		
					1,124,118	
116	5,280	21		110,880		
117	3,038	21		63,798		
„	1,642	214		351,388		
118	5,280	214		1,129,920		
119	5,280	214		1,129,920		
120	4,680	214		1,001,520		
					3,787,426	
121	5,280	214		1,129,920		
122	5,280	214		1,129,920		
123	4,680	214		1,001,520		
124	5,280	214		1,29,9120		
125	5,280	214		1,129,920		
					5,521,200	
126	2,927	214		626,378		
„	1,753	131		229,643		
127	5,280	131		691,680		
128	5,280	131		691,680		
129	4,680	131		613,080		
130	5,280	131		691,680		
					3,544,141	
131	5,280	131		691,680		
132	4,680	131		613,080		
133	5,280	131		691,680		
134	3,772	131		494,132		
„	908	269		244,252		
135	5,280	267		1,409,760		
					4,144,584	
136	5,280	313		1,652,640		
137	5,280	262		1,383,360		
138	4,680	245		1,146,600		
139	5,280	245		1,293,600		
140	4,680	245		1,146,600		
					6,622,800	
141	5,280	245		1,293,600		
142	5,280	245		1,293,600		
143	212	245		51,940		
„	300	330		99,000		
„	4,468	612		2,734,416		
		Carried over ...		5,472,556	373,516,499	

ESTIMATE No. 1.—EXCAVATION,—*continued.*

No. of Mile.	L.	B.	D.	Contents.	Total.	Grand Total.
		Brought forward ...		5,472,556	373,516,499	
		Area.				
144	5,280	536		2,830,080		
145	300	260		78,000		
"	4,680	805		3,767,400		
"	300	290		87,000		
					12,235,036	
146	5,280	481		2,539,680		
147	5,280	415		2,191,200		
148	5,280	398		2,101,440		
149	3,461	398		1,377,478		
"	400	106		42,800		
"	400	197		78,800		
"	1,019	535		545,165		
150	5,280	463		2,444,640		
					11,321,203	
151	5,280	458		2,418,240		
152	4,724	458		2,163,592		
"	300	98		29.400		
153	5,236	223		1,167,628		
154	5,280	223		1,177,440		
155	5,280	223		1,177,440		
					8,133,740	
156	4,680	223		1,043,640		
157	5,280	223		1,177,440		
158	5,280	223		1,177,440		
159	363	223		80,949		
"	300	804		241,200		
"	4,317	900		3,885,300		
160	5,280	260		1,372,800		
					8,978,769	
161	5,280	217		1,145,760		
162	4,680	217		1,015,560		
163	5,280	217		1,145,760		
164	1,557	217		337,869		
"	2,923	141		412,143		
165	5,280	141		744,480		
					4,801,572	
166	5,280	141		744,480		
167	2,053	141		289,473		
"	300	71		21,300		
"	2,627	203		533,281		
168	5,280	277		1,462,560		
169	5,280	170		897,600		
170	5,280	251		1,325,280		
					5,273,974	
171	300	120		36,000		
"	4,680	174		814,320		
172	5,280	176		929,280		
173	5,280	181		955,680		
174	4,680	186		870,480		
175	5,280	191		1,008,480		
					4,614,240	
176	2,058	191		393,078		
"	300	120		36,000		
"	2,622	296		776,112		
177	5,280	236		1,246,080		
178	300	42		12,600		
		Carried over ...		2,463,870	428,875,033	

ESTIMATE No. 1.—EXCAVATION,—*continued.*

No. of Mile.	L.	B.	D.	Contents.	Total.	Grand Total.
		Brought forward ...		24,63,870	428,875,033	
		Area.				
178	4,680	216		1,010,880		
„	300	58		17,400		
179	5,280	221		1,166,880		
180	5,280	226		1,193,280		
Part of 181 to Manoor Regulator ...	4,657	226		1,052,482	6,904,792	435,779,825
		Grand Total Main Line ...		..	...	435,779,825

Cawnpoor Branch.

1 to 3	14,624	80	·94	1,099,725		
		Area.				
165 to 168	14,280	342		4,883,760		
Through ...	2,420	158		382,360		
Cawnpoor ...	850	18		15,300		
		Grand Total Remodelling ...		...	6,381,145	6,381,145

Slopes Protected.

	Between Roorkee and Futtehgurh Branch head.					
	12,000	2×27	...	...	648,000	
	Between Futtehgurh Branch head to end Sirdhannah.					
	12,000	2×27	...	...	648,000	1,296,000

ABSTRACT OF COST OF ESTIMATE No. 1.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	38,972,452	Excavation from head to Roorkee, at Rs. ·2 per 1,000	77,944·90
„	396,807,373	„ „ Roorkee to Cawnpoor Branch head, at Rs. ·2 per 1,000 ...	7,93,614·75
S. feet	1,296,000	Protecting slopes head, at ·5 annas per 100 ...	6,480·00
Cubic feet	6,381,145	Excavation in Cawnpoor Branch, at Rs. ·2 per 1,000.	12,762·29
Miles	162	Repairing Tow-path ditto, at Rs. ·70 per mile ...	11,340
		Grand Total	912,141·94

Digitized by Google

ESTIMATE No. 2.—ALTERATIONS TO MYAPOOR REGULATOR.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
New Masonry.							
Under Arches	8	20	4	3·50	2,240	2,240	
Deduct—							
Arch-work	8	21	4	2	1,344	1,344	896
Girders	16	16·50	0	0	264	264	264
Sluice Gates	24	7	0	10	1,680	1,680	1,680
Chain (light)	48	12·50	0	0	600		
Deduct one-fifth	0	0	0	0	120	480	480
Chain (heavy)	4	12·50	0	0	50	50	50
Iron Gates	2	21	0	10	420	420	420

ABSTRACT OF ESTIMATE No. 2.

Quantity.		Description.	Total.
			Rs.
C. feet	896	New Masonry, at Rs. 22 per 100	197·12
„	1,344	Arch-work, at Rs. 28 per 100	376·32
		Regulating Apparatus.	
L. feet	264	Girders, at Rs. 9·4 per foot	2,481·60
Sq. feet	1,680	Sluice gates, wooden, at Re. 1·25 per foot	2,100·00
Number	16	Axle blocks, at Rs. 5 each	80·00
„	24	Windlasses (small), at Rs. 22 each	528·00
L. feet	480	Chain, at Rs. 9 annas per foot	432·00
„	50	Ditto, at Re. 1 per foot	50·00
Sq. feet	420	Iron drop gates, at Rs. 5 per foot	2,100·00
		Grand Total	8,345·04

Digitized by Google

ESTIMATE No. 3.—ALTERATIONS AT KUNKHUL BRIDGE.

DESCRIPTION.	No.	L.	B.	D.	CONTENTS.	TOTAL.	GRAND TOTAL.
Demolition.							
Tow-path side wall	...	70	2	10·50	1,470		
„ arch	...	46	10	2	920		
Flooring	3	55	21	2	6,930		
Curtain	3	55	250	2	825	10,145	10,145
Digging out cribs and boulders ...	...	251 40	10 5	5 5	12,550 1,000	13,550	13,550
Masonry.							
Foundations water-wings ...	...	16	4	6	384		
„ „	...	16	4	3	192		
Water-wings above bed... ...	2	16	2	10·50	672		
Steps	2	4	8	2	128		
Flooring...	3	55	21	2	6,930		
„	3	55	1	1	165		
Piers	9	10	2	14·50	2,610		
Raising water-wing up-stream ...	2	36	4	1	288		
„ „ „ ...	2	56	1·50	1	168	11,537	
Deduct—							
Brick-on-edge and stone ...	...	...	...	...	...	3,465	8,072
Boulder flooring	...	179	30	3	16,110	16,110	16,110
Driving 10′ *Piles*	...	179	...	...	179	179	179
Timber Work.							
Sâl Beams	12	14	1	1	168	168	168
Grating.							
10′ Kurries	144	...	...	...	144	144	144
Fixing old Cribs.							
Front of Steps	2 2	29 20	10 5	5 5	2,900 1,000	3,900	3,900
Brick-on-edge	3	55	17	1	2,805	2,805	2,805
Stone-work	3	55	4	·75	495	495	495

ESTIMATE No. 3.—ALTERATIONS AT KUNKHUL BRIDGE,—*continued.*

Lock Channel, &c.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Excavation.							
Channel...	...	900	26	14	327,600		
Foundations of retaining wall ...	2	900	5	4	36,000		
Tow-path	...	900	9	2	16,200		
Lock	...	130	26	17	57,460		
Lock foundations	2	130	5	4	5,200		
Channel below lock	...	130	45	17	99,450		
Old banks of canal	...	160	62	20	198,400		
" "	...	70	47	10	32,900		
" "	...	250	95	20	475,000		
" "	...	150	27	10	40,500		
						1,288,710	
							1,288,710
Foundations—Masonry.							
Retaining walls	...	2,125	5	4	42,500		
Flooring of bridge	...	17	17	2	578		
Curtains of bridge	2	17	2	4	272		
Drop wall of lock	...	18	3	7	378		
Flooring of lock	...	131	17	2	4,454		
Curtain of lock	...	25	2	4	200		
						48,382	
Deduct—							
Brick-on-edge	...	...	...	...	...	2,736	
							45,646
Masonry Superstructure.							
Revetment and lock walls ...	...	2,125	3·50	12	89,250		
Thickening of walls at gates ...	4	10	3	16	1,920		
Abutments of bridge	2	21	6	13	3,276		
Backing of arch bridge ...	2	13	21	1·50	819		
Spandrils above arch & abutments	2	38	2	2·25	342		
Wing walls	4	18	2·50	12	2,160		
Parapets	2	72	1·50	2·25	486		
						98,253	
Brick-on-edge.							98,253
Flooring of bridge	...	18	21	1	378		
Ditto of lock	...	131	18	1	2,358		
						2,736	
							2,736
Arch-work	...	30	21	2	1,260		
						1,260	
							1,260
Grand Total, Masonry ...	...	...	..	...	...	...	147,895
Metalling	...	100	16	·75	1,200		
						1,200	
							1,200
Lock Gates	2	9·54	{10 / 13}	...	438·84		
						...	
							439
Chain	2	25·50	...	...	51		
	2	27·50	...	...	55		
						106	
							106

ABSTRACT OF ESTIMATE No. 3.

Quantity.		Description.	Total.
			Rs.
Cubic feet	10,145	Demolition, masonry, at Re. 1 per 100	101·45
„	13,550	Digging out cribs and boulders, at Rs. 7 per 1,000 ...	94·85
„	4,206	Boulder masonry, at Rs. 14 per 100	588·84
„	3,866	Brick-work, at Rs. 22 per 100	850·52
„	16,100	Boulder flooring dry, at Rs. 7 per 100	1,127·70
Lineal feet	179	10′ Piles, including driving, at Rs. 2·5 per foot ...	447·50
Cubic feet	168	Sâl wood in grating supports, at Rs. 3 „	504·00
Number	144	10′ Kurries, at Re. 1·5 each	216·00
Cubic feet	3,900	Fixing and filling old cribs, at Rs. 7 per 1,000 ...	27·30
„	2,805	Brick-on-edge, at Rs. 25 per 1,000	701·25
„	495	Stone-work, at Rs. 2 per foot	990·00
		Total for Bridge, &c.	5,649·41
		Lock Channel, &c.	
Cubic feet	1,288,710	Excavation, at Rs. 2·25 per 1,000	2,899·60
„	132,899	Boulder masonry, at Rs. 14 per 100	18,605·86
„	11,000	Brick-work, at Rs. 22 per 100	2,420·00
„	2,736	Brick-on-edge, at Rs. 25 per 100	684·00
„	1,260	Arch-work, at Rs. 28 per 100	352·80
„	1,200	Metalling, at Rs. 6 per 100	72·00
		Lock Apparatus.	
Square feet	439	Lock gates, at Rs. 6·5 per foot	2,853·50
Lineal feet	106	Chain, at Re. 1 per foot	106·00
Number	4	Pulleys, at Rs. 5 each	20·00
„	4	Crabs, „ 135 „	540·00
„	4	Sluices, „ 125 „	500·00
		Total, Lock Channel, &c.	29,053·76
		Grand Total, Bridge and Lock Channel	34,703·17

Digitized by Google

ESTIMATE No. 4.—ALTERATIONS AT JOWALAPOOR BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, Masonry.							
Curtains	6	55	2·50	1·13	932·25		
Flooring	3	55	21	2	6,930	7,862	7,862
Digging out Boulders	2	179	10	1·13	4,045·40	4,045	4,045
Masonry Flooring	3	55	21	1·5	5,197·5	5,197·5	5,197·5
Brick-on-edge.							
Flooring	3	55	21	·5	1,732·5	1,732·5	1,732·5

ABSTRACT OF ESTIMATE No. 4.

Quantity.		Description.	Total.
			Rs.
Cubic feet	7,862	Demolition old masonry, at Re. 1 per 100	78·62
„	4,045	Digging out boulders, at Rs. 7 per 1,000	28·31
„	5,198	Boulder masonry, at Rs. 14 per 100	727·72
„	1,733	Brick-on-edge, at Rs. 25 per 100	433·25
		Tow-path, *vide* Estimate No. 173	595·60
		Grand Total	1,863·50

Digitized by Google

ESTIMATE No. 5.—ALTERATIONS, RAMPOOR WORKS.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, Masonry.							
Tow-path up stream	...	140	3	6·50	2,730		
" "	...	140	4·50	6·50	4,095		
" "	...	140	1·50	2·50	525		
" "	...	140	·6	1	840		
Navigable channel wall down stream...	...	80	4·75	12·66	4,388·71		
Ogees of fall	8	25	20	4·61	18,440		
" "	8	24	25	1	4,800		
						35,818·71	
							35,819
Digging out boulders in crib-work down stream	...	232	70	1	16,240		
						16,240	
							16,240
Masonry.							
Raising piers	7	18	4·50	4·66	2,642·22		
" water-wings	...	205	4·50	4·66	4,298·80		
" "	...	205	4·50	7·5	6,918·75		
" "	2	205	3	7·5	9,225·00		
" "	...	150	3·50	7·5	3,937·50		
" "	...	205	4	7·5	6,150·00		
New piers	8	18	3	8	3,456·00		
"	8	13	3	6	1,872·00		
12 feet bridge parapet	2	10	1·50	2	60·00		
Round head of lock wall ...	...	10	4	5	200·00		
" " " " ...	...	12	3	14	504·00		
New flooring at Ogee	8	25	20	3	12,000·00		
Parapet	...	205	2	2·25	922·50		
						52,186·77	
							52,187
Arch-work.							
Tow-path	...	200	8	1	1,600		
Under piers	8	13	3	1	312		
12′ Bridge	...	10	12	1	120		
						2,032	
							2,032
Embankment	...	45	60	15	40,500		
						40,500	
							40,500
Stone-work	8	30	25	·75	4,500		
						4,500	
							4,500
Wood-work.							
Beams to support grating ...	16	12·50	·75	·75	112·50		
						112·50	
							113
14′ *Kurries*	128	...	...	...	128		
						128	
							128
Sluice Gate	...	10·5	...	13	136·5		
							136·5
New Lock Gates	2	9·54	...	$\frac{13}{24}$	667·8		
							667·8
Chains	2	11	...	...	22	22	22

Digitized by Google

ABSTRACT OF ESTIMATE No. 5.

Quantity.		Description.	Total.
			Rs.
Cubic feet	35,819	Demolition, old masonry, at Re. 1 per 100	358·19
„	16,240	Digging boulders out of crib work, at Rs. 7 per 1,000...	113·68
„	39,483	Brick-work, at Rs. 22 per 100	8,686·26
„	12,704	Boulder masonry, at Rs. 14 per 100	1,778·56
„	2,032	Arch-work, light, at Rs 28 per 100	568·96
„	40,500	Embankment, at Rs. 2 per 1,000	81·00
„	4,500	Stone-work in flooring, at Rs. 2 per foot	9,000·00
„	113	Sâl wood in grating supports, at Rs. 3 per feet ...	339·00
Number	128	Kurries 14′ long, at Re. 1·5 each	192·00
Square feet	136·5	Sluice gates, at Rs. 1·25 per feet	170·62
„	667·8	Lock gates, at Rs. 6·5 per foot...	4,340·70
Number	14	Sluices in lock gates, at Rs. 125 each	500·00
„	1	Windlasses, at Rs. 22 each	22·00
„	2	Axle blocks, „ 5 „	10·00
Lineal feet	22	Chain, at Rs. 0·9 per feet	19·80
		Grand Total	26,180·77

Digitized by Google

ESTIMATE No. 6.—ALTERATIONS, BAHADOORABAD FALL, No. 1.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Earth-work.							
Approaches	2	400	30	3	72,000		
„	2	400	30	2	24,000		
						96,000	
							96,000
Demolition.							
Arches	8	25	28	2·93	16,408		
Parapets	12	25	1·50	2	900		
Pillars	4	3	3	2	72		
Stairs	3	20	4·50	3·75	900		
In Ogee	4	54·50	10	2	4,360		
Flooring	4	54·50	40	1	8,720		
						31,360	
							31,360
New Masonry.							
Lengthening piers	4	25·50	4·50	·23	10,453·50		
„ „	4	10	4·50	2·36	424·80		
„ „	5	23	4·50	11	5,692·50		
„ „	5	10	4·50	2·36	531·00		
Stairs	5	20	4·50	3·33	1,500·00		
Arches and spandrils	8	25	28	2·93	16,408·00		
Piers and abutments	9	32	4·50	5·86	7,594·56		
Parapet	12	25	1·50	2	900·00		
Pillars	4	3	3	2	72·00		
Raising chamber walls	3	48	4·50	2	1,296·00		
„ revetments	2	165	4·50	2	2,970·00		
New piers	8	34	3	23	18,768·00		
Weir	8	25	5	6	6,000·00		
Raising water-wings	2	28	4·50	7	1,764·00		
Pillars	4	4	4	5·86	375·04		
						74,749·40	
Deduct	...	...	...	...	...	12,456·00	
							62,293
Arch-work	8	27	28	2	12,096		
	5	16	4·50	1	360		
						12,456	
							12,456
Stone-work	4	54·50	40	·75	6,540		
						6,540	
							6,540
Grating	16	11	28·5	...	5,016		
						5,016	
							5,016
Girders	32	13	...	...	416		
						416	
							416
Wallplates	16	11	...	...	176		
						176	
							176

Digitized by Google

ABSTRACT OF ESTIMATE No. 6.

Quantity.		Description.	Total.
			Rs.
Cubic feet	96,000	Earth-work, at Rs. 2 per 1,000	192·00
„	31,360	Demolition at Re. 1 „ 1,000	313·60
„	62,293	New masonry at Rs. 22 „ 100	13,704·46
„	12,456	Arch-work „ 28 „ 100	3,487·68
„	6,540	Stone-work „ 2 per foot	13,080·00
Square feet	5,016	Grating at Re. 1·15 per square foot	5,768·40
Lineal feet	416	Girders at Rs. 4·25 per foot	1,768·00
„	176	Wall plate at Rs. 6·25 „	1,100·00
		Grand Total	39,414·14

Digitized by Google

ESTIMATE No. 7.—ALTERATIONS, BAHADOORABAD FALL, No. 2

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Earth-work.							
Approaches	2	400	30	3	72,000		
	2	200	30	2	24,000		
						96,000	96,000
Demolition.							
Arches	8	25	18	2·93	10,548		
Parapet	12	25	1·50	2	900		
Pillar	4	3	3	2	72		
Stairs	3	2	4·50	3·33	900		
In Ogee...	4	54·50	10	2	4,360		
Flooring...	4	54·50	40	1	8,720		
						25,500	25,500
New Masonry.							
Lengthening piers	4	35·25	4·50	23	14,593·50		
" "	4	10	4·50	2·36	424·80		
" "	5	33	4·50	11	8,167·50		
" "	5	10	4·50	2·36	531·00		
Stairs	5	20	4·50	3·33	1,500·00		
Arches and spandrils	8	25	18	2·93	10,548·00		
Piers and abutments	9	22	4·50	5·86	5,221·26		
Parapet	12	25	1·50	2	900·00		
Pillars	4	3	3	2	72·00		
"	4	4	4	5·86	375·04		
New piers	8	34	3	23	18,768·00		
Weir	8	25	5	6	6,000·00		
Raising water-wings	2	28	4·50	7	1,764·00		
						68,865·10	
Deduct—							
Arching	...	...	...	...	......	8,136	
							60,729
Arch-work	8	27	18	2	7,776		
	5	16	4·50	1	360		
						8,136	8,136
Excavating boulders out of crib-work	...	227	80	1·4	25,424	25,424	25,424

Grating and stone-work as in Estimate No. 6.

ABSTRACT OF ESTIMATE No. 7.

Quantity.		Description.	Total.
			Rs.
Cubic feet	96,000	Earth-work, at Rs. 2 per 1,000	192·00
"	25,500	Demolition, old masonry, at Re. 1 per 100	255·00
"	60,729	New masonry, at Rs. 22 per 100	13,360·38
"	8,136	Arch-work, at Rs. 28 per 100...	2,278·08
"	25,424	Digging boulders out of crib, at Rs. 7 per 100	177·97
"	...	Stone-work as Estimate No. 6	13,080·00
		Grating, &c., as Estimate " 6	8,636·40
		Grand Total	37,979·83

Digitized by Google

ESTIMATE No. 8.—ALTERATIONS IN BAHADOORABAD LOCK CHANNEL.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Excavation.							
Channel	2	1,500	33·50	9	904,500		
						904,500	
							904,500
Demolition, old Masonry.							
Bridge of lower lock	2	18	1·50	2·50	121·50		
" "	2	23	1·50	2·50	155·25		
" "	...	16	18	3	864·00		
" "	...	11	18	5·50	1,089·00		
" "	...	23	1·50	2·25	77·62		
						2,307·37	
							2,307
New Masonry.							
Raising walls	...	140	9	3·50	4,410·00		
"	...	11	9	3·50	346·50		
"	...	143	4·50	3·50	2,252·25		
"	...	46	4·50	3·50	724·50		
New bridge	...	18	9	3·50	567·00		
"	2	18	4·50	3·50	567·00		
"	...	16	18	3	864·00		
"	...	11	18	5·50	1,089·00		
Parapets	2	28	1·50	2·25	189·00		
"	2	33	1·50	2·25	222·75		
Wings	4	10	2·50	5·50	550·00		
"	0	23	2	3·50	161·00		
"	0	23	1·50	2·25	77·62		
						12,020·62	
Deduct—							
Arching	...	...	...	...		594	
							11,427
Arch-work	...	16	18	1	288		
"	...	17	18	1	306		
						594	
							594
Lock Gates.							
Upper lock	2	9·54	...	{ 13 22	667·8		
							667·8

ABSTRACT OF ESTIMATE No. 8.

Quantity.		Description.	Total.
			Rs.
Cubic feet	904,500	Excavation, at Rs. 2·25 per 1,000	2,035·12
"	2,307	Demolition, old masonry, at Re. 1 per 100	23·07
"	11,427	New masonry, at Rs. 22 per 100	2,513·94
"	594	Arch-work, at Rs. 28 per 100...	166·32
Square feet	667·8	Lock gates, at Rs. 6·5 per foot	4,340·70
Number	8	Sluices, at Rs. 125 per each	1,000·00
		Grand Total	10,079·15

Digitized by Google

ESTIMATE No. 9.—ALTERATIONS AT PUTRI WORKS.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Tow-path up stream	...	140	3	6·50	2,730		
" "	...	140	4·50	6·50	4,095		
" "	...	140	1·50	2·50	525		
" "	...	140	6	1	840		
Ogee of fall	8	25	20	4·61	18,440		
" "	8	24	25	1	4,800		
	...	205	1·50	2·50	768·75		
						32,198·75	
							32,199
Excavation.							
Boulders and crib-work ...	...	261	70	5	91,350		
						91,350	
							91,350
Masonry down stream.							
In wells	93	14·13	1·50	10	19,711·35		
"	2	4	1·50	10	120		
"	...	20·4	2·	10	408		
Piers	7	14	4·50	20	8,820		
"	8	14	3	20	6,720		
Curtain	...	240	4	2	1,920		
Flooring of lock	...	55	26	2	2,860		
" "	...	17	25·50	2	867		
" "	...	41	21	2	1,722		
" "	...	9	30	2	540		
Lock walls	...	122	4	15	7,320		
"	...	16	1	15	240		
"	...	88	4·50	15	5,940		
"	...	88	8	50	352		
Up stream.							
Raising piers	7	18	4·50	4·66	2,646		
" water-wings... ...	...	77	4·50	4·66	1,617		
" tow-path	...	205	4·50	7·5	6,918·75		
" "	2	205	3	7·5	9,225		
Retaining wall	...	150	3·50	7·5	3,937·50		
Parapet	...	205	2	4·25	922·50		
Round head of lock wall ...	...	10	4	5	200		
" " ...	...	12	3	14	504		
New flooring at Ogee ...	8	25	20	3	12,000		
New piers	8	18	3	8	3,456		
"	8	13	3	6	1,872		
Culvert	...	60	2	6·50	780		
"	...	60	8	1	480		
						102,093·10	
							102,093
Arch-work.							
Tow-path	...	200	8	1	1,600		
Piers	8	13	3	1	312		
Culvert	...	60	9	1	540		
						2,452	
							2,452
Embankment	...	45	60	15	40,500		
						40,500	
							40,500

Digitized by Google

ESTIMATE No. 9.—ALTERATIONS AT PUTRI WORKS,—*continued.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Boulder Flooring.							
In cement	...	231	46	1·50	15,937	15,937	15,937
Stone-work	8	30	25	·75	4,500	...	4,500
Boulder flooring, dry, ...	...	231	46	2·50	26,565	26,565	26,565
Timber work.							
Sâl-wood in grating supports..	32	13·50	·75	·75	225	225	225
Sluice Gate	...	4	4	...	16	16	16
Lock Gates	2	9·54	{ 13 22 13	...	915·84		916
Chain	2	27·50	...	...	55	55	55

ABSTRACT OF ESTIMATE No. 9.

Quantity.		Description.	Total.
			Rs.
Cubic feet	32,199	Demolition, old masonry, at Re. 1 per 100	321·99
"	91,350	Excavation boulders out of crib-work, at Rs. 7 per 1,000	639·45
Number	95	Curbs, small, at Rs. 20 each	1,880·00
Cubic feet	17,989	Boulder masonry in flooring, at Rs. 14 per 100 ...	2,518·46
"	84,104	Brick-work, at Rs. 22 per 100	18,502·88
Lineal feet	940	Well-sinking, at Rs. 5 per foot	4,700·00
Cubic feet	2,452	Arch-work, at Rs. 26 per 100	637·52
"	40,500	Embankment, at Rs. 2 per 1,000	81·00
"	15,937	Masonry flooring of boulders, at Rs. 12 per 100 ...	1,912·68
"	4,500	Stone flooring, at Rs. 2 per foot...	9,000·00
"	26,565	Boulder flooring, dry, at Rs. 7 per 100	1,859·55
Number	256	14′ Kurries (Sâl), at Rs. 5·25 each	1,344·00
Cubic feet	225	Sâl-wood, at Rs. 3 per foot	675·00
Sq. feet	16	Sluice gate, at Rs. 1·25 per foot	20·00
"	916	Lock gates, at Rs. 6·5 per foot	5,954·00
Number	2	Crabs, at Rs. 135 each	270·00
"	2	Pulleys, at Rs. 5 each	10·00
"	6	Sluices, at Rs. 125 each	750·00
Lineal feet	55	Chain, at Re. 1 per foot	55·00
		Grand Total	51,131·53

Digitized by Google

ESTIMATE No. 10—ALTERATIONS TO RUTMOO WORKS.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Earth-work.							
Approaches	2	240	30	2·5	36,000		
For culvert	...	100	24	16	38,400		
						74,400	
Demolition, old Masonry.							74,400
Arch and spandril	2	20	22	3·5	3,080		
Abutments	2	22	6	5	1,320		
Parapet	2	55	1·5	1·5	247·5		
"	2	25	1·5	1·5	112·5		
Pillars	4	4	4	1·5	96		
Parapet at Dhunouri Bridge revetment	2	30	2·5	5·25	787·5		
						5,643	
New Masonry.							5,643
Abutments	2	22	5	13	2,860		
"	2	22	4	5	880		
Backing	2	22	26	1·75	2,002		
Wing walls	2	55	2·5	3·5	962·5		
"	2	25	2·5	3·5	437·5		
Parapets	2	55	1·5	1·5	247·5		
"	2	25	1·5	1·5	112·5		
Pillars	4	4	4	5	320·0		
Spandril walls	4	188	2	3·5	5,264		
"	...	188	3	5	2,820		
"	...	188	19	1·5	5,358		
Piers	22	5	4	5	2,200		
Wells or blocks of inlet ...	2	95	2	12	4,560		
" "	18	10	2	12	4,320		
Retaining wall	...	95	4	16	6,080		
steps	...	19	6·5	3·5	432·25		
flooring	...	9	30	1·5	405		
Head wall	...	19	3	5·5	313·5		
Walls of culvert	...	100	10	4·5	4,500		
Flooring	2	100	7	2·5	3,500		
Arch-work.							47,575
Bridge	2	27	22	1·75	2,079		
Culvert or inlet	2	100	13·32	1·5	3,996		
						6,075	
							6,075
Grand Total, Masonry ...	...	...	...	...	...	...	53,650
Digging out crib-work	...	236	20	5	23,600		
						23,600	
Iron Girders.							23,600
For regulating gates	16	16	...	...	256		
						256	
New boulder flooring (dry) ...	...	236	82	3	58,056		256
In front of inlet...	...	100	10	3	3,000		
						61,056	
Pitching.							61,056
Slopes	2	50	24	1	2,400		
						2,400	
							2,400

Digitized by Google

ESIMTATE No. 10.—ALTERATIONS TO RUTMOO WORKS,—*continued.*

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Sluice gates	2	8	6	...	96	96	96
Grooves, cast-iron	4	15	...	...	60	60	60
Chain	36	17	...	...	612	612	612
Iron drop gates	2	20	...	10	400	400	400
Wooden drop gates	24	6·33	...	10	1,519	1,519	1,519

ABSTRACT OF COST OF ESTIMATE No. 10.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	74,400	Excavation, at Rs. 2 per 1,000	148·80
„	5,643	Demolition, old masonry, at Re. 1 per 100	56·43
„	23,680	Boulder masonry, at Rs. 14 per 100	3,315·20
„	23,895	Brick-work, at Rs. 23 per 100	5,256·90
„	6,075	Arch-work „ 26 „ 100	1,579·50
„	23,600	Digging out cribs and boulders, at Rs. 7 per 1,000 ...	165·20
„	...	Tow path under Dhunowra Bridge	595·60
„	236	12′ Piles, including driving, at Rs. 5 per foot... ...	1,180·00
Lineal feet	256	Iron girders for sluice gates, at Rs. 9·4 per foot	2,406·40
Cubic feet	61,056	Boulder flooring "dry" at Rs. 7 per 100	4,273·92
„	2,400	Pitching on slopes, at Rs. 10 per 100	240·00
Lineal feet	108	Wells, sinking, at Rs. 7 per foot	756·00
Square feet	96	Sluice gate, at Rs. 1·25 per foot	120·00
Number	9	Curbs, at Rs. 90 each	810·00
Lineal feet	60	Iron grooves, at Rs. 5 per foot	300·00
Number	19	Axle Blocks, at Rs. 5 each	95·00
„	26	Windlasses, at Rs. 22 each	572·00
Lineal feet	612	Chain, at Rs. 0·9 per foot	550·80
Square feet	400	Iron Drop gates, at Rs. 5 per foot	2,000·00
„	1,519	Wooden Drop gates	1,898·75
		Grand Total	26,320·50

Digitized by Google

ESTIMATE No. 11.—ALTERATIONS AT PEERAN KULEEUR BRIDGE.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Curtains	2	156	2·5	2·95	2,301		
Flooring	...	156	23	2	7,176		
						9,477	
New Masonry.							9,477
Flooring	...	156	23	1·5	5,382		
						5,382	
Brick-on-edge.							5,382
Flooring	...	156	23	·5	1,794		
						1,794	
							1,794

ABSTRACT OF COST OF ESTIMATE No. 11.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	9,477	Tearing down old masonry, at Re. 1 per 100	94·77
„	5,382	Boulder masonry, at Rs. 14 per 100	753·48
	1,794	Brick-on-edge, at Rs. 25...	448·5
		Tow-path 7′ wide; *vide* Estimate No. 174	377·30
		Grand Total	1,674·05

ESTIMATE No. 12.—ALTERATIONS AT MEHEWUR BRIDGE.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Curtains	2	150	2	1·79	1,074		
Flooring	...	150	21	2	6,300		
						7,374	
New flooring, as Estimate No. 11.							7,374

ABSTRACT OF COST OF ESTIMATE No. 12.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	7,374	Tearing down old masonry, at Re. 1 per 100	73·74
		Flooring as Estimate No. 11	753·48
		Brick-on-edge as Estimate No. 11	448·50
		Tow-path 12′ wide	595·60
		Grand Total	1,871·32

Digitized by Google

ESTIMATE No. 13.—ALTERATIONS ON SOLANI AQUEDUCT AND EMBANKMENT.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Driving 8 feet stakes	63	150	...	...	9,450	...	9,450
Clay over Aqueduct	...	914	170	·5	77,690	77,690	77,690
Masonry.							
Raising edges of Aqueduct tow-path	2	914	1·5	1	2,742	2,742	2,742
Brick-on-edge in cement ...	...	914	170	·5	77,690	77,690	77,690

ABSTRACT OF COST OF ESTIMATE No. 13.

Quantity.		Description.	Cost.
			Rs.
Lineal feet	9,450	Staking 8′ deep, at Re. 1 per lineal feet	9,450·00
Cubic feet	77,690	Puddled clay, at Rs. 3 per 100	2,330·70
„	77,690	Brick-on-edge, at Rs. 25 per 100	19,422·5
„	2,742	Brick-work, at Rs. 20 per 100	548·40
		Grand Total	31,751·6
Square feet	155,380	N. B.—Cost of layer of Seyssel Asphalte, ½ inch thick, (914 × 170) = ...	1,55,380

ESTIMATE No. 14.—ALTERATIONS TO ROORKEE BRIDGE.

Description of Work.	No.	L.	B.	D.	Quantity	Total.	Grand Total.
Masonry.							
Raising channel revetments down-stream	...	3·500	2	1	7,000	7,000	7,000

ABSTRACT OF COST OF ESTIMATE No. 14.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	7,000	New tow-path	595·6
		New masonry, at Rs. 20 per 100	1,400
		Grand Total	1,995·6

Digitized by Google

ESTIMATE No. 15.—FALL 4·07 AT ROORKEE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Foundations.							
Waterways up-stream ...	2	25	5·50	8	2,200		
Curtain „	2	16	3	5	480		
Drop walls	2	16	3	8·07	774·72		
„	2	16	3	4	384		
Curtains under lower gates ...	4	16	3	3	576		
Curtain down-stream... ...	2	16	2	10	640		
Sides of wells...	2	14	6	4	672		
Abutments of gates up-stream..	2	16·50	6·50	8	1,716		
„ „ down-stream	2	16·50	12	2·50	990		
Side walls of locks	2	106	9	2·50	4,770		
Abutments of bridge... ...	2	3	6	2·50	90		
Side wall down-stream ...	2	50	2·50	6	1,500		
Flooring up-stream	2	16	17	3	1,632		
„ of well	2	16	7·25	3	696		
„ under gates... ...	2	16	10·50	2·50	840		
Backing of inverts	2	168·50	16	1·75	9,436		
Division wall of lock... ...	2	18	7	8	2,016		
„ sides of well ...	2	14	7	11·07	2,169		
„ „ of lock ...	2	77	7	8	8,624·72		
„ „ „ ...	2	94	7	5·50	7,238		
Drop wall of fall	...	177	5·50	9·57	9,316·39		
Curtain of fall	...	177	3	12	6,372		
„ „	...	177	3	1·50	796·5		
Flooring of fall	...	177	70	1·50	18,585		
Curtain of basin	...	220	3	12	7,920		
Retaining walls of basin ...	2	140	5·50	12	18,480		
						108,914·33	
Deduct.							
Brick-on-edge.							
Lock flooring	2	16	17	1	544		
„	2	16	7·25	1	232		
„	2	16	10·50	1	336		
Flooring of fall	...	177	70	1	12,390		
Top of drop of fall	...	177	5	1	885		
„ curtain ...	...	177	3	1	531		
Hollow foundations.							
Retaining walls	2	25	1·50	4	300		
„	2	140	1·50	8	3,360		
						18,578	
Superstructure.							90,336
Water wings up-stream ...	2	25	3·50	14	2,450		
Abutment of gate „ ...	2	16·50	6	14	2,772		
„ down-stream...	2	16·50	9	18·07	5,366·79		
Abutment of bridge ...	2	3	5	13	390		
Counterforts	2	3	3·50	8	168		
Wing walls of bridge ...	2	12	9·50	9	2,052		
Side walls down-stream ...	2	50	3·50	13	4,550		
„ of lock	2	112·50	6	18·07	24,394·50		
Division wall of lock... ...	2	109	7	14	21,364		
„ „	2	44	7	18·07	11,131·12		
„ „	2	53	7	13	9,646		
Piers	9	40	22·07	3	23,835·60		
„	9	5	3	14	1,890		
Carried over ...	...	...	...	...	110,010.01	...	90,336

ESTIMATE No. 15.—FALL 4·07 AT ROORKEE,—*continued.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Brought forward ...	...	...	...	...	110,010·01	...	90,336
Superstructure,—contd.							
Steps	2	16	7	2	448		
"	2	8	3	2	96		
Backing of arches ...	10	15	3	1	450		
" "	2	18	3	1	108		
Abutment of bridge ...	2	3	3	9·50	171		
Retaining wall down-stream	2	140	3·50	13	12,740		
						124,023·01	
Deduct.							
Hollows in walls	2	90	2	17	6,120		
"	2	28	2	17	1,904		
"	2	50	2	14	2,800		
Piers	9	33	3	8	7,128		
Arches of piers	9	42	3	1·50	1,701		
						19,653	
							104,370
Arch-work.							
Inverts	2	168·50	16·50	1·50	8,340·75		
Arches over fall	10	16	3	1	480		
" lock	2	19	3	1	114		
Piers	9	42	3	1·50	1,701		
						10,636	
							10,636
Brick-on-edge.							
Lock flooring	2	16	17	1	544		
"	2	16	7·25	1	232		
"	2	16	10·50	1	336		
Flooring of fall basin ...	...	177	70	1	12,390		
Top of drop wall	...	177	5	1	885		
" curtain	...	177	3	1	531		
Roadway of bridge ...	...	227	3	·25	340·5		
						15,258	
							15,258
Grand Total Brick-work	...	...	...	...	...	...	220,600
Concrete	...	77	177	3	40,887		
						40,887	
							40,887
Puddle	...	177	2·50	8	3,540		
	2	75	2	18	5,400		
	2	50	2	13	2,600		
						11,540	
							11,540
Kunkur or Boulders ...	...	177	15	2	5,310		
						5,310	
							5,310
Excavation.							
Foundations	...	...	...	...	108,914		
Basin	...	177	70	4	49,560		
Drainage cut	...	2,000	27	24	1,296,000		
						1,454,474	
							1,454,474

Digitized by Google

ESTIMATE No. 15.—FALL 4·07 AT ROORKEE,—*continued.*

Description.	No.	L.	B.	D.	Quantity	Total.	Grand Total.
Pitching slopes	2	50	24	1	2,400	2,400	2,400
Demolition.							
Revetment wall	...	300	4	12·50	15,000	15,000	15,000
Grating	10	15	37·5	...	5,625	...	5,625
Girders	30	17	...	...	510	...	510
Wall-plates	10	15	...	...	150	...	150
Lock gates	4	9·54	{ 13 / 17 }	...	1,144·8	...	1,144·8
Crabs	8	...	...	...	8	8	8
Chain	4	27·50	...	...	110		
	4	29·50	...	...	118	228	228

ABSTRACT OF COST OF ESTIMATE No. 51.

Quantity.		Description.	Total.
			Rs.
Cubic feet	90,336	Boulder masonry in foundations, at Rs. 14 per 100 ...	12,647·04
„	74,370	„ „ superstructure, „ „ 20 „ 100 ...	14,874·00
„	30,000	„ „ „ „ „ 24 „ 100 ...	7,200·00
„	10,636	Arch-work, at Rs. 26 per 100	2,765·36
„	15,258	Brick-on-edge, at Rs. 25 per 100	3,814·50
„	40,887	Concrete, at Rs. 14 per 100	5,724·18
„	11,540	Puddle, at Rs. 10 per 1,000	115·40
„	5,310	Boulder flooring, dry, at Rs. 7 per 100	371·70
„	2,400	Pitching slopes, at Rs. 10 per 100	240·00
„	15,000	Demolition, old masonry, at Re. 1 per 100	150·00
„	1,454,474	Excavation, at Rs. 2·5 per 1,000	3,636·18
Square feet	5,625	Grating, at Rs. 1·15 per square foot	6,468·75
Lineal feet	510	Girders, at Rs. 4·25 per foot	2,167·50
„	150	Wall-plates, at Rs. 6·25 per foot	937·50
Number	72	Sleepers, at Rs. 11·625 each	837·00
Square feet	1,145	Lock gates, at Rs. 6·5 per foot	7,442·50
Number	8	Crabs, at Rs. 135 each	1,080·00
„	8	Sluices, at Rs. 125 each	100·00
„	8	Pulleys, at Rs. 5 each	40·00
Lineal feet	228	Chain, at Re. 1 per foot	228·00
Number	2	Hooks, at Rs. 7 each	14·00
		Grand Total	71,753·61

Digitized by Google

ESTIMATE No. 16.—ADDITIONS, &c., TO GUNESHPOOR, LIBURHEREE AND DIMAT BRIDGES.

DESCRIPTION.	No.	L.	B.	D.	QUANTITY	TOTAL.	GRAND TOTAL.
Digging boulders out of crib-work	2	179	10	3·68	13,174·40		
" " ...	2	70	10	3·68	5,152·00		
						18,326	
							18,326
Demolition, old Masonry.							
Flooring	3	55	21	2	6,930		
Curtains	6	55	2	3·68	2,428·80		
Water-wings	...	110	2	10	2,200		
"	...	29	2	15	870		
Steps or Ghat	...	32	14	4	1,792		
Steps	...	18	3	5	270		
"	2	12	6	15	2,160		
"	2	6	8	17	1,632		
"	2	12	15	3·50	1,260		
Counterforts	3	4	6	14	1,008		
Pillars	2	4	4	18	576		
Wing-walls	2	40	2·75	12	2,640		
"	2	31	2·75	6	1,023		
"	2	14	2·75	22	1,694		
Parapet	2	40	1·50	3	360		
Pillars	2	3	3	3	54		
						26,897·80	
New Masonry.							26,898
Wells	2	28·25	2	9	1,017		
"	2	38·48	1·50	...	115·44		
"	...	25·12	2	9	452·16		
"	...	28·27	1·50	...	42·40		
"	2	15·71	2	9	565·56		
"	2	7·06	1·50	...	21·18		
Abutments	...	21	7·50	23	3,622·50		
Counterforts	2	6	4	17	816		
Backing of arch...	...	21	8	6	1,008		
"	...	21	7	10	1,470		
Spandrils	4	20	2·50	3	600		
"	2	70	2·50	3	1,050		
Wing-walls	2	40	2·75	12	2,640		
"	2	31	2·75	6	1,023		
"	2	14	2·75	22	1,694		
Pillars	2	4	4	18	576		
Parapet	2	102	1·50	3	918		
Pillars	2	3	3	3	54		
Pillaster	2	7	1	16	224		
Piers	2	7	3	16	672		
Cornice	2	102	·75	1·50	229·5		
Foundations of water-wings ...	...	90	4·50	5	2,025		
" stairs	...	18	3	5	270		
Water-wings	...	86	2	10	1,720		
"	...	29	2	15	870		
Ghat	...	32	14	4	1,792		
Steps	2	12	6	15	2,160		
"	2	6	8	17	1,632		
Flooring	4	55	21	1	4,620		
Superstructure steps	...	18	3	5	270		
						34,170	
							34,170

Digitized by Google

ESTIMATE NO. 16.—ADDITIONS, &c., TO GUNESHPOOR, LIBURHEREE AND DIMAT BRIDGES,—*continued.*

Description.	No.	L.	B.	D.	Quantity	Total.	Grand Total.
Arch-work	...	57	21	3	3,591	3,591	3,591
Brick-on-edge.							
Roadway...	...	70	18	·5	630		
Flooring	4	55	21	·5	2,310	2,940	2,940
Boulder flooring, dry	2	55	10	5	5,500	5,500	5,500
Filling in old boulders	2	179	10	5	17,900		
	2	70	10	5	7,000	24,900	24,900
Sheet piling 10 × $\frac{3}{4}$ × $\frac{3}{4}$ ...	262	...	...	...	262	262	262
Waling pieces	2	55	1	·50	55	55	55
Metalling	...	70	13	·75	682·5	682	682
Excavation	...	130	60	12	93,600		
	...	130	40	15	78,000	1,71,600	1,71,600

ABSTRACT OF COST OF ESTIMATE No. 16.

Quantity.		Description.	Total.
			Rs.
Cubic feet	18,326	Digging boulder out of cribs, at Rs. 7 per 1,000 ...	128·28
„	26,898	Demolition, old masonry, at Re. 1 per 100	268·98
„	34,170	Brick-work, at Rs. 22 per 100	7,517·40
„	3,591	Arch-work, heavy, at Rs. 32 per 100	1,149·12
„	2,940	Brick-on-edge, at Rs. 25 per 100	735·00
„	5,500	Boulder flooring, dry, at Rs. 7 per 100...	385·00
„	24,900	Filling old boulders, at Rs. 7 per 1,000...	174·30
Lineal feet	45	Well, sinking, at Rs. 7 per foot...	315·00
Number	262	Piles, at Rs. 5,625 each	1,473·75
Cubic feet	55	Waling pieces, at Re. 1 per foot	55·00
„	682	Metalling, at Rs. 6 per 100	40·92
Number	5	Large curbs, at Rs. 90 each	450·00
Cubic feet	171,600	Excavation, at Rs. 2·8 per 1,000	480·48
		Tow-path	595·60
		Grand Total	13,768·83

Digitized by Google

ESTIMATE No. 17.—ALTERATIONS TO HAFEZNUGGUR FALLS.

Description of Works.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Excavation.							
New channels to locks ...	...	1,500	42·5	15	956,250		
Filling behind side walls of falls	2	40	16	8	10,240		
						966,490	
							966,490
DEMOLITION, OLD MASONRY.							
At head of Lock Channel.							
Retaining walls	...	260	3	8	6,240		
"	...	260	2	3	1,560		
Counterforts	5	4	3	8	480		
Ghat	...	102	4	4	1,632		
"	...	102	3	4	1,224		
"	...	102	5	1·5	765		
"	...	102	1·5	8·5	1,300·5		
"	...	102	5	3	1,530		
"	...	102	4	2	816		
"	...	47	6	11	3,102		
Rajbuha head	2	32	17	3	3,264		
" "	...	20	10	4	800		
On Locks.							
Bridge	2	21·5	1·5	2·25	145·12		
"	2	14·5	1·5	2·25	97·87		
"	2	18	10	2·5	900		
"	2	18	16	2·5	1,400		
Falls.							
Flooring	4	95	54·5	2·65	54,881·50		
"	2	95	5	2·65	2,517·50		
"	3	12·5	4·5	2·65	447·18		
Curved ends of chamber walls	2	110	3	5·5	3,630		
	2	40	3	8	1,920		
	2	30	3	4	720		
	2	40	16	2	2,560		
						91,973	
							91,973
Digging boulders out of cribs	...	177	80	0·82	11,611·20		
" "	2	70	37	0·82	4,247·60		
						15,859	
							15,859
RAJBUHA HEAD, *vide* ESTIMATE No. 114.							
Masonry.							
Lock bridge abutments ...	2	18	4·5	1·65	267·30		
" " ...	...	18	9	1·65	267·30		
Wings	4	10	1·5	3	180		
Parapets	2	21·5	1·5	2·25	145·12		
"	2	14·5	1·5	2·25	97·87		
Backing of arches... ...	...	10	18	1·25	225		
"	...	16	18	1·25	360		
Carried over ...	...	...	...	...	1,542·59		

ESTIMATE No. 17.—ALTERATIONS TO HAFEZNUGGUR FALLS,—*continued.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Brought forward ...	...	...	...	...	1,542·59		
Fall.							
Up-stream wings	2	30	4·5	5	1,350		
Drop-wall on Ogee... ...	4	54·5	5	4·5	4,905		
Raising side walls	2	43	4·5	7·35	2,844·45		
„ chamber walls ...	3	43	4·5	9·35	5,427·67		
Lengthening piers... ...	4	34	4·5	19·35	11,842·20		
New piers	8	34	3	19·35	15,789·60		
Counterforts	4	3	3	7·35	264·60		
						43,966·11	
Deduct.		Area.					
Openings and arches of piers	4	286		4·5	5,148		
„ „ „	8	286		3	6,864		
						12,012	
							31,954
Arch-work.							
Lock bridge	...	17	18	1	306		
„	...	11	18	1	198		
Under piers	4	40	4·5	1·5	1,080		
„	8	40	3	1·5	1,440		
						3,024	
							3,024
Brick-on-edge	4	45	54·5	1	9,810		
	2	45	7	1	630		
	3	12·5	4·5	1	168·75		
						10,608·75	
							10,609
Stone flooring	4	54·5	50	·75	8,175		
						8,175	
							8,175
Grating	16	11	27	...	4,752		
						4,752	
							4,752
Girders	32	13	...	...	416		
						416	
							416
Wall-plates...	16	11	...	...	176		
						176	
							176
Pitching slopes	2	100	31	1	6,200		
						6,200	
							6,200

ABSTRACT OF COST OF ESTIMATE No. 17.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	966,490	Excavation, at Rs. 2·25 per 1,000	2,174·60
„	91,973	Demolition, old masonry, at Re. 1 per 100	919·73
„	15,859	Boulder digging, at Rs. 7 per 1,000	111·01
„	...	Rajbuha head	1,410·78
„	31,954	Masonry, at Rs. 22 per 100	7,029·88
„	3,024	Arch-work at Rs. 28 per 100	846·72
„	10,609	Brick-on-edge, at Rs. 25 per 100	2,652·25
„	8,175	Stone flooring, at Rs. 2 per foot	16,350·00
Square feet	4,752	Grating, at Rs. 1·15 per foot	5,464·80
Lineal feet	416	Girders, at Rs. 4·25 per foot	1,768·00
„	176	Wall-plates, at Rs. 6·25 per foot	1,100·00
Cubic feet	6,200	Pitching, at Rs. 10 per 1,000	620·00
		Grand Total	40,447·77

Digitized by Google

ESTIMATE No. 18.—ALTERATIONS TO MUNGLOUR BRIDGE.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Water-wings	2	53	3	10	3,180		
Wall behind Ghat	2	37	5	14	5,180		
Steps	2	40	15·5	3	3,720		
Retaining walls...	2	69	3·5	2	966		
„ „	2	69	3·25	9·25	4,148·62		
„ „	2	69	2·5	8	2,760		
Parapet	2	52	1·25	3	390		
Pillars	4	3	3	3	108		
Slope of ditto	4	12	·75	·5	18		
Stair	2	32	1·25	3	240		
„	2	20	7·5	4	1,200		
„	2	12	1·5	19·5	702		
„	2	6	6	1	72		
Wing-walls	2	31	2·5	10	1,550		
„	2	23	3·25	9	1,345·50		
Parapets	2	31	1·25	3	232·50		
Pillars	2	3	3	3	54		
Cope	2	12	·75	·5	9		
Counterforts	3	4	6	13	936		
						26,811·62	26,812
Digging out boulders and cribs ...	2	76	10	5	7,600		
						7,600	7,600
Earth-work Ghats	...	170	33	10	56,100		
	...	170	50	25	212,500		
						268,600	268,600
Masonry.							
Wells	2	28·25	2	9	1,017		
„	2	Area. 38·48		1·5	115·44		
„	...	25·12	2	9	452·16		
„	...	Area. 28·27		1·5	42·40		
„	2	15·71	2	9	565·56		
„	2	Area. 7·06		1·5	21·18		
Abutment	...	21	7·5	23	3,622·50		
Counterforts	2	6	4	17	816		
Backing arch	...	21	8	6	1,008		
„	...	21	7	10	1,470		
Spandrils	4	20	2·5	3	600		
„	2	70	2·5	3	1,050		
Wing-walls	2	30	2·75	10	1,650		
„	2	20	2·75	9	990		
Pillars	2	4	4	19	608		
Retaining walls...	2	50	3·5	2	700		
„	2	50	3·25	9·25	3,000		
„	2	50	2·5	8	2,000		
Pillars	4	4	4	19·5	1,232		
Pillars in parapet	6	3	3	3	162		
Cornice of „	6	12	·5	·5	18		
Parapets	2	105	1·5	3	945		
„	2	44	1·5	3	396		
Stair	2	32	1·25	3	240		
„	2	20	7·5	4	1,200		
Carried over ...	...	...	...	...	23,921·24		

Digitized by Google

ESTIMATE No. 18.—ALTERATIONS TO MUNGLOUR BRIDGE,—*continued.*

Description.	No.	L.	B.	D.	Quantity	Total.	Grand Total.
Brought forward ...	...	...	...	...	23,921·24		
Stair	2	12	1·5	19·5	702		
"	2	6	6	1	72		
Ghat on right side	2	41	6	3	1,476		
" "	2	18	2	3	216		
Ghat	2	56	4·5	5	2,520		
"	2	18	3	10	1,080		
"	2	37	3	14	3,108		
"	2	40	20	1·5	2,400		
Pier	2	7	1	10	140		
Pillasters	2	7	1	28	392		
Flooring	...	46	21	1	966		
						36,999	
Arch-work.							36,999
Ghats, light	2	40	20	1	1,600		
Arch, heavy	...	70	21	3	4,410		
						6,010	
Brick-on-Edge.							6,010
Roadway	...	70	18	·5	630		
Flooring	...	46	21	·5	483		
						1,113	
							1,113
Boulder flooring, "dry"	...	212	10	5	10,600		
						10,600	
Wood-work.							10,600
Waling pieces	2	46	1	·5	46		
						46	
							46
Metalling	...	70	13	·75	682·5		
						682	
							682

ABSTRACT OF COST OF ESTIMATE No. 18.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	26,812	Demolition, old masonry, at Re. 1 per 100	268·12
"	7,600	Digging out cribs and boulders, at Rs. 7 per 1,000 ...	53·20
"	268,600	Earth-work, at Rs. 2·5 per 1,000	671·50
"	36,999	Masonry, at Rs. 22 per 100	8,139·78
"	1,600	Arch-work, light, at Rs. 25 per 100	400·00
"	4,410	" heavy, at Rs. 32 per 100	1,411·20
"	1,113	Brick-on-edge, at Rs. 25 per 100	278·25
"	10,600	Boulder flooring, "dry," at Rs. 7 per 100	742·00
Lineal feet	45	Well, sinking, at Rs. 7 per lineal foot	315·00
Number	272	Sheet piles, at Rs. 5·625 each	1,530·00
Cubic feet	46	Waling pieces, at Re. 1 per foot	46·00
Lineal feet	204	15′ Piling, at Rs. 7 per lineal foot	1,428·00
Cubic feet	682	Metalling, at Rs. 6 per 100	40·92
Number	5	Curbs, at Rs. 90 each	450·00
		Tow-path	595·60
		Grand Total	16,369·57

Digitized by Google

ESTIMATE No. 19.—FALL 6·87 AT LIBURHEREE BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Foundations.							
Water-wings up-stream ...	2	25	5·5	8	2,200		
Curtain " ...	2	16	3	5	480		
Drop walls...	2	16	3	10·87	1,043·52		
"	2	16	3	4	384		
Curtain under lower gates...	4	16	3	3	576		
Sides of wells	2	14	6	4	672		
Abutments of gates up-stream	2	16·5	6·5	8	1,716		
Abutments of gates down-stream	2	16·5	12	2·5	990		
Side walls of locks... ...	2	106	9	2·5	4,770		
Abutment of bridge ...	2	3	6	2·5	90		
Side walls down-stream ...	2	50	6	2·5	1,500		
Flooring up-stream ...	2	16	17	3	1,632		
" of well	2	16	7·25	3	696		
" under gates ...	2	16	10·5	2·5	840		
Backing of inverts ...	2	168·5	16	1·75	9,436		
Outer wall of lock... ...	2	18	7	8	2,016		
" sides of well ...	2	14	7	13·87	2,718·52		
" of lock	2	77	7	8	8,624		
" "	2	94	7	5·5	7,238		
Drop wall of fall	...	213	5·5	12·37	14,491·45		
Curtain of fall	...	213	3	4	2,556		
" "	...	213	3	1·5	958·50		
Flooring of fall	...	213	66	1·5	21,087		
Wells	...	14·12	1·5	7	3,854·76		
"	...	18·8	2	9	2,030·40		
"	...	14·12	1·5	9	5,718·60		
Covering of wells in curtain	26	7·06	...	15	275·34		
" " in division walls	2	22	7	2	616		
Covering of wells in basin...	2	105	6	2	2,520		
						101,730	
Deduct.							
Vide Estimate No. 22	...	...	...	...	... ...	17,174	
							84,556
Superstructure.							
Water-wings up-stream ...	2	25	3·5	14	2,450		
Abutments of gates up-stream	2	16·5	6	14	2,772		
Abutments of gates down-stream	2	16·5	9	20·87	6,198·39		
Abutments of bridge ...	2	3	5	14	390		
Counterforts	2	3	3·5	8	168		
Wing walls of bridge ...	2	12	9·5	9	2,052		
Side walls down-stream ...	2	50	3·5	14	4,900		
" of lock	2	112·5	6	20·87	28,174·50		
Outer wall of lock... ...	2	109	7	14	21,364		
" "	2	41	7	20·87	11,979·38		
" "	2	53	7	14	10,388		
Piers	11	37	3	24·87	30,366·27		
"	11	5	3	14	2,310		
Steps	2	18	7	2	504		
"	2	2	1	2	8		
Backing of arches... ...	12	15	3	1	540		
" "	2	18	3	1	108		
Carried over ...	...	...	...	...	124,672·54		

Digitized by Google

ESTIMATE No. 19.—FALL 6·87 AT LIBURHEREE BRIDGE.—*continued.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Brought forward ...	...	...	...	...	124,672·54		
Superstructure—contd.							
Abutment of bridge ...	2	3	3	9·5	171		
Retaining walls down-stream	2	105	3·5	14	10,290		
						135,133·54	
Deduct—							
Vide Estimate No. 22 ...	...	...	...	...	...	25,082·50	
							110,051
Lock gates...	4	9·54	...	11 18	1,106·64		
						...	1,107
Remainder as Estimate No. 22.							

ABSTRACT OF ESTIMATE NO. 19.

Quantity.		Description.	Total.
			Rs.
Cubic feet.	84,556	Masonry in foundations, at Rs. 20 per 100	16,911·20
„	70,051	„ „ superstructure, at Rs. 20 per 100	14,010·20
„	40,000	„ „ „ at Rs. 24 per 100	9,600
Square feet.	1,107	Lock gates, at Rs. 6·5 per square foot...	7,195·5
		Remainder as Estimate No. 22	27,448·71
		Grand Total	75,165·61

ESTIMATE No. 20.—ALTERATIONS TO MUNDOWLEE TOGLUGHPOOR BAILRA BHOPA BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old masonry.							
Water-wings	2	37	2	10	1,480		
Stairs	2	23	3	5	690		
Stair on wing-wall	2	8·33	3	12	600		
" "	2	8·33	3	15·29	764·5		
" "	2	11	3	5	330		
Counterforts	3	4	5	16	960		
Pillars	2	4	4	15·29	489·28		
Wing-walls	2	30	2·75	24·25	4,001·25		
Parapets	2	30	1·50	3·25	292·50		
Pillar	2	3	3	3·25	58·50		
Flooring	3	55	21	2	6,930		
Curtains	6	55	2	3·68	2,428·80		
Flooring under tow-path ...	...	Area. 226·19		2	452·38		
Curtains	...	58	2	3·68	426·88		
						19,904·09	19,904
New masonry.							
Wells	2	28·25	2	9	1,017		
"	2	Area. 38·48		1·50	115·44		
"	...	25·12	2	9	452·66		
"	...	Area. 28·27		1·50	42·40		
"	2	15·71	2	9	565·56		
"	2	Area. 7·06		1·50	21·18		
Abutments	...	24	7·50	21	3,780		
Counterforts	2	6	4	15	720		
Backing of arch	...	21	8	6	1,008		
"	...	21	7	10	1,470		
Spandrils	4	20	2·50	3	600		
"	2	70	2·50	3	1,050		
Wing-walls	2	30	2·75	24·25	4,001·25		
Pillars	2	4	4	15·29	489·28		
Parapets	2	95	1·50	3·25	926·25		
Pillars	2	3	3	3·25	58·50		
Stair on wing-wall	2	8·33	3	12	600		
" "	2	8·33	3	15·29	764·5		
" "	2	11	3	5	330		
Cornice	2	95	·75	1·50	213·75		
Foundations of water-wings ...	2	37	4·50	5	1,665		
" stairs... ...	2	23	3	5	690		
Superstructure "	2	23	3	5	690		
Flooring	4	55	21	1	4,620		
Curtain	2	55	2	3	660		
Pillasters	2	7	1	14	196		
Water-wings	2	37	2	10	1,480		
						28,226·27	28,226
Arch-work.							
Vide Estimate No. 16.							
Sheet Piles 10 × ¾ × ¾ ...	245	...	...	...	245	245	245
Remainder as Estimate No. 16.							

Digitized by Google

ABSTRACT OF ESTIMATE No. 20.

Quantity.		Description.	Total.
			Rs.
Cubic feet	19,904	Demolition, old masonry, at Re. 1 per 100 ...	199·04
„	28,226	Brick-work, at Rs. 22 per 100	6,209·72
Number	245	Sheet piles, at Rs. 5·625 each	1,378·12
		Remainder as Estimate No. 16	4,508·7
		Grand Total	12,295·58

ESTIMATE No. 21.—ADDITIONS TO MUHMOODPOOR FALLS.

Description.	No.	L.	B.	D.	Quantity	Total.	Grand Total.
Demolition, old masonry.							
Vide Estimate No. 17	...	...	...	...	91,973		
Additional in flooring	4	95	54·50	0·91	18,846		
	2	95	5	0·91	864·5		
	3	12·50	4·50	0·91	153·5		
						111,837	111,837
Digging boulders out of cribs ...	2	117	80	1·28	18,124·80		
		70	37	1·28	6,630·40		
						24,755	24,755
Remainder as Estimate No. 17.							

ABSTRACT OF ESTIMATE No. 21.

Quantity.		Description.	Total.
			Rs.
Cubic feet.	111,837	Demolition old masonry, at Re. 1 per 100	1,118·37
„	24,755	Boulder digging, at Rs. 7 per 1,000	173·28
		Remainder as Estimate No. 17	39,417·03
		Grand Total	40,708·68

Digitized by Google

ESTIMATE No. 22.—TOGLUGHPOOR FALLS.

Description of Work.	No.	L.	B.	D.	Quantity	Total.	Grand Total.
Foundations.							
Water-wings up-stream ...	2	25	5·5	8	2,200		
Curtain	2	16	3	5	480		
Drop walls	2	16	3	12·54	1,203·84		
„	2	16	3	4	384		
Curtains under lower gates ...	4	16	3	3	516		
„ sides of wells ...	2	14	6	4	672		
Abutments of gates up-stream	2	16·5	6·5	8	1,716		
„ „ down-stream	2	16·5	12	2·5	990		
Side walls of locks	2	106	9	2·5	4,770		
Abutments of bridge... ...	2	3	6	2·5	90		
Side wall down-stream ...	2	50	2·5	6	1,500		
Flooring up-stream ...	2	16	17	3	1,632		
„ of well	2	16	7·25	3	696		
„ under gates... ...	2	16	10·5	2·5	840		
Backing of inverts	2	168·5	16	1·75	9,436		
Division wall of lock ...	2	18	7	8	2,016		
„ „ sides of well ...	2	14	7	15·54	3,045·84		
„ „ of lock ...	2	77	7	8	8,624		
„ „ „ ...	2	94	7	5·5	7,238		
Drop wall of fall	...	213	5·5	14·04	16,447·86		
Curtain of fall	...	213	3	4	2,556		
„	...	213	3	1·5	958·50		
Flooring of fall	...	213	66	1·5	21,087		
Wells	26	14·12	1·5	7	3,854·76		
„	6	18·8	2	9	2,030·40		
„	30	14·12	1·50	9	5,718·60		
		Area.					
Covering of wells in curtains...	26	7·06		1·5	275·34		
„ „ division wall	2	22	7	2	616		
„ „ basin ...	2	105	6	2	2,520		
Deduct Brick-on-edge.							
Lock flooring	2	16	17	1	544		
„	2	16	17·25	1	232		
„	2	16	10·5	1	336		
Flooring of fall	...	213	66	1	14,058		
Tops of drop wall and curtain. .	...	213	8	1	1,704		
Hollow foundations	2	25	1·5	4	300		
						17,174	
Superstructure.							87,000
Water-wings up-stream ...	2	25	3·5	14	2,450		
Abutments of gates up-stream.	2	16·5	6	14	2,772		
„ „ down-stream	2	16·5	9	22·54	6,694·38		
Abutments of bridge	2	3	5	14	390		
Counterforts	2	3	3·5	8	168		
Wing walls of bridge... ...	2	12	9·5	9	2,052		
Side walls down-stream ...	2	50	3·5	14	4,900		
„ of lock	2	112·5	6	22·54	30,429		
Division wall of lock... ...	2	109	7	14	21,364		
„	2	41	7	22·54	12,937·96		
„	2	53	7	14	10,388		
Piers	11	37	3	26·54	32,405·34		
„	11	5	3	14	2,310		
Steps	2	18	7	2	504		
„	2	2	1	2	8		
Backing of arches	12	15	3	1	540		
Carried over ...	...	...	...	...	130,312·68		

Digitized by Google

ESTIMATE No. 22.—TOGLUGHPOOR FALL,—*continued.*

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Brought forward ...	...	...	...	...	130,312·68		
Superstructure,—(contd.)							
Backing of arches	2	18	3	1	108		
Abutment of bridge	2	3	3	9·5	171		
Retaining walls down-stream ...	2	105	3·5	14	10,290	140,881·68	
Deduct—							
Hollow walls	2	90	2	17	6,120		
"	2	28	2	21	2,352		
"	2	50	2	14	2,800		
From piers	11	27	3	13	11,583		
Arches of piers	11	45	3	1·5	2,227·50	25,082·50	115,799
Arch-work.							
Inverts	2	168·5	16·5	1·5	8,340·75	8,341	8,341
Arches over fall	12	16	3	1	576		
" " locks	2	19	3	1	114		
" under piers	11	45	3	1·5	2,227·50	2,917	2,917
Brick-on-edge.							
Lock flooring	2	16	17	1	544		
"	2	16	7·25	1	232		
"	2	16	10·5	1	336		
Flooring of fall	...	213	66	1	14,058		
Tops of drop wall and curtain ...	...	213	8	1	1,704		
Roadway of bridge	...	265	3	·5	397·50	17,271	17,271
Concrete	...	73	213	3	46,647	46,647	46,647
Puddle	...	213	2·5	12	6,390		
	2	75	2	22	6,600		
	2	50	2	13	2,600	15,590	15,590
Kunkur or boulder flooring ...	...	213	15	2	6,390	6,390	6,390
Excavation.							
Basin	...	213	68	4	57,936		
Add foundations	...	...	..	...	104,174	162,110	162,110
Pitching slopes	2	50	24	1	2,400	2,400	2,400
Grating	12	15	31·5	...	5,670	5,670	5,670
Girders	36	17	...	...	612	612	612

Digitized by Google

ESTIMATE No. 22.—TOGLUGHPOOR FALL,—*continued.*

Description of Work.	No.	L.	B.	D.	Quantity	Total.	Grant Total.
Wall-plates	12	15	...	...	180	180	180
Lock gates	4	9·54	...	11 19·5	1,163·88	...	1,164
Chain	4 4	27·5 31·5	... ...	... ...	110 126	236	236

ABSTRACT OF COST OF ESTIMATE No. 22.

Quantity.		Description of Work.	Cost.
			Rs.
Cubic feet	87,000	Masonry in foundations, at Rs. 20 per 100	17,400
„	75,799	„ superstructure, at Rs. 20 per 100 ...	15,159·80
„	40,000	„ „ at Rs. 24 per 100 ...	9,600·00
„	8,341	Arch-work inverts, at Rs. 26 per 100	2,168·66
„	2,917	„ light, at Rs. 25 per 100	729·25
„	17,271	Brick-on-edge, at Rs. 25 per 100	4,317·75
„	46,647	Concrete, at Rs. 14 per 100	6,530·58
„	15,590	Puddle, at Rs. 10 per 1,000	155·90
„	6,390	Boulder flooring "dry," at Rs. 7 per 100	447·30
„	162,110	Excavation, at Rs. 2·5 per 1,000	405·27
„	2,400	Pitching, at Rs. 10 per 100	240·00
Square feet	5,670	Fall grating, at Rs. 1·15 per square foot	6,520·50
Lineal feet	612	Girders, at Rs. 4·25 per foot	2,601
„	180	Wall-plates, at Rs. 6·25 per foot	1,125
	72	Sleepers, at Rs. 11·625 each	837·00
	2	Hooks, at Rs. 7 each	14·00
	1,164	Lock gates, at Rs. 6·5 per foot	7,566
	8	Crabs, at Rs. 135 each	1,080·00
	8	Sluices, at Rs. 125 each...	1,000·00
	8	Pulleys, at Rs. 5 each	40·00
Lineal feet	236	Chain, at Re. 1 per foot...	236·00
		Grand Total	77,174·01

ESTIMATE No. 23.—ALTERATIONS TO NIRGAJNEE FALLS.

Description of Work.	No.	L.	B.	D.	Quantity	Total.	Grand Total.
Excavation.							
Lock Channel	...	1,500	38	12	684,000		
Filling behind side walls ...	2	40	16	8	10,240		
						694,240	694,240
Demolition, old Masonry.							
At head of Lock Channel .. *Vide* Estimate No. 17.	...	...	...	...	22,713·50		
Flooring of falls	4	95	54·5	5	103,550		
" "	3	12·5	4·5	5	843·75		
						127,107·25	127,107
Digging boulders out of cribs	...	350	80	5	140,000		
						140,000	140,000
Masonry.							
Vide Estimate No. 17 ...	...	...	...	...	31,954		
Additional on up stream water-wings	2	30	4·5	1	270		
						32,224	
Deduct—							
Lock bridge *vide* Estimate No. 17	...	...	...	...	...	1,542·52	30,681
Remainder as Estimate No. 17.							

ABSTRACT OF COST OF ESTIMATE No. 23.

Quantity.		Description of Work.	Cost.
			Rs.
Cubic feet	694,240	Excavation, at Rs. 2·25 per 1,000	1,562·04
"	127,107	Demolition, old masonry, at Re. 1 per 100	1,271·07
"	140,000	Excavating boulders, Rs. 7 per 1,000	980·00
"	140,000	Relaying boulders, at Rs. 7 per 1,000	980·00
"	30,681	Brick-work, at Rs. 22 per 100	6,749·82
		Remainder as Estimate No. 17	30,212·56
		Grand Total	41,755·49

Digitized by Google

ESTIMATE No. 24.—ALTERATIONS TO JAOLI FALLS.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Vide Estimate No. 23	...	...	...	...	127,107		
Additional for round ends of walls, *vide* Estimate No. 17 ...	...	...	...	...	8,830		
Widening of flooring differently from Nerzajnee falls, *vide* Estimate No. 23	2	95	5	3·42	3,249	139,186	
Deduct—							
In flooring	4	95	54·5	1·58	32,721		
"	2	12·5	4·5	1·58	177·75	32,898	106,287
Boulder digging	...	177	80	1·21	17,133·60		
"	2	70	37	1·21	6,267·80	23,401	23,401
Remainder as Estimate No. 23.							

ABSTRACT OF COST OF ESTIMATE No. 24.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	106,287	Demolition, old masonry, at Re. 1 per 100	1,062·87
"	23,401	Boulder digging, at Rs. 7 per 1,000	163·80
		Remainder as Estimate No. 23	38,524·42
		Grand Total	39,751·09

Digitized by Google

ESTIMATE No. 25.—ALTERATIONS AT FUTTEYGURH BRANCH HEAD.

DESCRIPTION.	No.	L.	B.	D.	QUANTITY.	TOTAL.	GRAND TOTAL.
Demolition, old Masonry.							
Parapets	13	20	1·5	1·5	585		
"	8	20	1·5	2·25	540		
"	...	180	1·5	2·25	607·5		
Pillars	12	3	3	2·25	243		
Side arches	3	20	18	4·5	4,860		
						6,835	6,835
New Masonry.							
Abutments	3	18	6	11	3,564		
Backing	3	18	4	4	864		
Raising spandrils, &c.	4	100	2	5	4,000		
" "	4	220	2	5	8,800		
Wing-walls	8	20	2·5	5	2,000		
Raising piers	30	6	3	5	2,700		
Raising circular wall	...	180	2	5	1,800		
Raising retaining walls of platform	...	91	2	2	364		
Ditto ditto of pillars ...	4	6·25	6·25	2	312·5		
Ditto ditto of ghat ...	2	125	2·5	2	1,250		
Raising waterwings down-stream	2	17	3	2	204		
New wings and steps ...	6	13·5	3	11	2,673		
" " ...	4	17	3	1·5	306		
Lockwalls	2	127	6	18	27,432		
Curtains	...	16	3	6	288		
"	...	16	2	4	128		
Flooring	...	18	16	1	288		
Backing of inverts	...	16	109	1·75	3,052		
Water-wings of lock	...	27	4	6	648		
" "	...	30	4	6	720		
" "	...	27	2·5	12	810		
" "	...	30	2·5	8	600		
Weir on Futteygurh Branch Head	3	20	4	2	480		
Parapets	13	20	1·5	1·5	585		
"	8	20	1·5	2·25	540		
"	...	180	1·5	2·25	607·5		
Pillars	12	3	3	2·25	243		
Between walls on roadway ...	3	320	3·33	1	3,200		
						68,459	
Deduct—							
Hollows in walls	...	90	2	14	2,520		
						2,520	
							65,939
Arch-work	3	25	18	1·5	2,025		
						2,025	
							2,025
Inverts on lock	...	109	16	1	1,744		
						1,744	
							1,744
Brick-on-edge	...	18	16	1	288		
						288	
							288
Lock gates	2	9·54	...	9 11	381·60		
						382	
							382
Chain	4	23·5	...	...	94		
						94	
							94

Digitized by Google

ESTIMATE No. 25.—ALTERATIONS AT FUTTEYGURH BRANCH HEAD,—*contd.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Upright girders for regulating gear	6	14·5	...	...	87		
	14	16	...	...	224	311	311
Iron gates	2	20·5	...	11	451	451	451
Wooden gates	21	6·66	...	11	1,538·46		
„	9	6·66	...	9	539·46	2,077·92	2,078
Chain, heavy	4	16·5	...	...	66	66	66
„ *light*	60	16·5	...	...	990	990	990
Pitching	2	50	22	1	2,200		
„	2	50	12	1	1,200	3,400	3,400
Metalling	...	584	15	·75	6,570	6,570	6,570

ABSTRACT OF COST OF ESTIMATE No. 25.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	6,835	Demolition of masonry, at Re. 1 per 100	68·35
„	65,939	Brick-work, at Rs. 22 per 100	14,506·58
„	2,025	Arch-work, at Rs. 28 per 100	567·00
„	1,744	Inverts, at Rs. 26 per 100	453·44
„	288	Brick-on-edge, at Rs. 25 per 100	72·00
Square feet	382	Lock gates, at Rs. 6·5 per foot	2,483·00
Number	4	Crabs, at Rs. 135 each	540·00
„	4	Pulleys, at Rs. 5 each	20·00
„	4	Sluices, at Rs. 125 each	500·00
Lineal feet	94	Chain, at Re. 1 per foot	94·00
„	311	Upright girders, at Rs. 9·4 per foot	2,923·40
Square feet	451	Iron drop gates, at Rs. 5 per foot	2,255·00
„	2,078	Wooden „ at Re. 1·25 per foot	2,597·50
Number	30	Windlasses, at Rs. 22 each	660·00
Lineal feet	66	Lifting chain, at Re. 1 per foot	66·00
„	990	„ „ at Rs. 9 „	891·00
Number	28	Axle blocks, small, at Rs. 5 each	140·00
Cubic feet	3,400	Pitching, at Rs. 10 per 100	340·00
„	6,570	Metalling, at Rs. 2 „	131·40
		Grand Total	29,308·67

Digitized by Google

ESTIMATE No. 26.—DUKHERI BRIDGE AND FALL—3·53.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Foundations.							
Water-wings up-steam ...	2	25	5·50	8	2,200		
Curtain	2	16	3	5	480		
Drop walls...	2	16	3	7·53	722·88		
„	2	16	3	4	384		
Curtains under lower gates	4	16	3	3	576		
Sides of wells	2	14	6	4	672		
Abutments of gates up-stream	2	16·50	6·50	8	1,716		
„ „ down-stream	2	16·50	12	2·50	990		
Side walls of locks ...	2	106	9	2·50	4,770		
Abutments of bridge ...	2	3	6	2·50	90		
Side wall down-stream ...	2	50	6	2·50	1,500		
Flooring up-stream ...	2	16	17	3	1,632		
„ well	2	16	7·25	3	696		
„ under gates ...	2	16	10·50	2·50	840		
Backing of inverts ...	2	168·50	16	1·75	9,436		
Division wall of lock ...	2	18	7	8	2,016		
„ „ sides of well	2	14	7	10·53	2,063·88		
„ „ of lock ...	2	80	7	8	8,960		
„ „ „ ...	2	70	7	5·50	5,390		
Drop wall of fall	...	159	5·50	9·03	7,896·73		
Curtain of fall	...	159	3	4	1,908		
„ „	...	159	3	1·50	715·50		
Flooring of fall	...	159	64	1·50	15,264		
Wells in curtain of fall ...	20	14·12	1·50	7	2,965·20		
„ walls of basin ...	28	14·12	1·50	9	5,337·36		
„ division walls ...	4	18·08	2	9	1,353·60		
		Area.					
Covering of wells in curtain	20	7·06		1·50	211·80		
„ „ in division wall	...	18	7	2	252		
„ „ walls of basin	2	95	6	2	2,280		
Flooring of bridge... ...	3	55	21	1	3,465		
						86,783·97	
Deduct, Brick-on-edge.							
Lock flooring	2	16	17	1	544		
„	2	16	7·25	1	232		
„	2	16	10·50	1	336		
Flooring of fall	...	159	64	1	10,176		
Top of drop wall and curtains	...	159	8	1	1,272		
Hollows in water-wings up-stream	2	25	1·50	4	300		
						12,860	
							73,914
Superstructure.							
Water-wings up-stream...	2	25	3·50	13	2,275		
Abutments of gates „ ...	2	16·50	6	13	2,574		
„ down-stream	2	16·50	9	16·53	4,909·41		
Abutments of bridge ...	2	3	5	13	390		
„ „ ...	2	3	3	9·50	171		
Counterforts	2	3	3·50	8	168		
Wing-walls of bridge ...	2	12	2·50	9	540		
Side walls down-stream ...	2	15	3·50	13	4,550		
„ of lock	2	112·50	6	16·53	22,315·50		
Division wall of lock ...	2	112	7	13	20,384		
„ „ ...	2	38	7	16·53	8,793·96		
„ „ ...	2	53	7	13	9,646		
Carried over ...	...	...	...	...	76,716·87		

Digitized by Google

ESTIMATE No. 26.—DUKHERI BRIDGE AND FALL, 3·53—*continued.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Brought forward ...	...	...	...	...	76,716·87		
Superstructure,—contd.							
Piers	8	34	3	20·53	16,752·48		
"	8	5	3	13	1,560		
Steps	2	10	7	2	280		
"	2	3	3	1·50	27		
Backing of arches... ...	9	15	3	1	405		
" "	2	18	3	1	108		
Retaining walls down-stream	2	95	3·50	13	8,645		
						104,494·35	
Deduct—							
Hollows in walls	2	90	2	16	5,760		
" "	2	28	2	16	1,792		
" "	2	50	2	14	2,800		
Piers	8	29	3	7·53	5,240·88		
Arches of piers	8	37	3	1·50	1,332		
						16,924·88	
							87,569
Arch-work.							
Inverts	2	168·50	16·50	1·50	8,340·75		
						8,341	
							8,341
Arches of fall	9	3	16	1	432		
" lock	2	3	19	1	114		
Piers	8	37	3	1·50	1,332		
						1,878	
							1,878
Brick-on-edge.							
Lock flooring	2	16	17	1	544		
" "	2	16	7·25	1	232		
" "	2	16	10·50	1	336		
Flooring of fall	...	159	64	1	10,176		
Top of drop wall and inverts	...	159	8	1	1,272		
Flooring of bridge... ...	3	55	21	1	3,465		
Roadway of bridge ...	...	209	3	·50	313·50		
						16,339·50	
							16,339
Concrete	...	159	70	3	33,390		
						33,390	
							33,390
Puddle	...	159	2·50	8	3,180		
	2	75	2	17	5,100		
	2	50	2	13	2,600		
						10,880	
							10,880
Kunkur flooring	...	159	15	2	4,770		
						4,770	
							4,770
Excavation.							
Basin	...	159	64	4	40,704		
Foundations	...	...	...	...	86,784		
						127,488	
							127,488
Digging out boulders and crib-work	2	179	10	5	17,900		
						17,900	
							17,900

Digitized by Google

ESTIMATE No. 26.—DUKHERI BRIDGE AND FALL, 3·53—*continued.*

DESCRIPTION.	No.	L.	B.	D.	QUANTITY.	TOTAL.	GRAND TOTAL.
Relaying boulder flooring ...	2	179	10	4	14,320		
	2	90	10	4	7,200		
	2	20	10	4	1,600		
						23,120	
							23,120
Pitching on slopes	2	50	24	1	2,400		
						2,400	
							2,400
Demolition, old Masonry.							
Flooring	3	55	21	1·50	5,197·5		
Curtains	6	55	2	2·79	1,841·4		
						7,039	
							7,039
Lock gates	4	9·54		{ 11 / 14·53	974·22	...	974
Chain	4	25·50	...	...	102		
	4	27·50	...	...	110		
						212	
							212
Grating	9	15	31·5	...	4,252·5	...	4,252·5
Girders	27	17	...	...	459	...	459
Wall-plates	9	15	...	...	135	...	135

ABSTRACT OF ESTIMATE No. 26.

QUANTITY.		DESCRIPTION.	TOTAL.
			Rs.
Cubic feet	73,914	Brick-work in foundations, at Rs. 20 per 100	14,782·80
„	57,569	„ „ superstructure, at Rs. 20 per 100 ...	11,513·80
„	30,000	„ „ „ „ 24 „ ...	7,200·00
„	1,878	Arch-work light, at Rs. 25 per 100	469·50
„	8,341	„ inverts, at Rs. 26 per 100	2,168·66
„	16,339	Brick-on-edge, at Rs. 25 per 100	4,084·75
„	33,390	Concrete, at Rs. 14 per 100	4,674·60
„	10,880	Puddle, at Rs. 10 per 1,000	108·80
„	4,770	Kunkur flooring, at Rs. 8 per 100	381·60
Lineal feet	428	Well sinking, at Rs. 5 per foot	2,140·00
Number	52	Curbs, at Rs. 20 each	1,040·00
Cubic feet	127,488	Excavation, at Rs. 2·5 per 1,000	318·72
„	17,900	Boulder digging, at Rs. 7 per 1,000	125·30
„	23,120	Relaying boulder flooring, at Rs. 7 per 1,000	161·84
„	2,400	Pitching slopes, at Rs. 10 per 100	240·00
„	7,039	Demolition, old masonry, at Re. 1 per 100	70·39
		Towing-path 12′ wide	595·60
		Carried over ...	50,076·36

Digitized by Google

ABSTRACT OF ESTIMATE No. 26,—*continued.*

Quantity.		Description.	Total.
			Rs.
		Brought forward ...	50,076·36
		Lock Gear.	
Square feet	974	Lock gates, at Rs. 6·5 per foot	6,331·00
Number	8	Pulleys, at Rs. 5 each	40·00
"	8	Crabs, at Rs. 135 each	1,080·00
"	8	Sluices, at Rs. 125 each	1,000·00
Lineal feet	212	Chain, at Re. 1 per foot	212·00
Number	66	Sleepers $15\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$, at Rs. 11·625 each	767·25
"	2	Hooks, at Rs. 7 each	14·00
		Grating Gear.	
Square feet	4,252	Grating bars, at Re. 1·15 per foot	4,889·80
Lineal feet	459	Girders, at Rs. 4·25 per foot	1,950·75
"	135	Wall-plates, at Rs. 6·25 per foot	843·75
		Grand Total	67,204·91

ESTIMATE No. 27.—NUGLA BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Floor	3	55	23	2	7,590		
Curtains	6	55	2	1·73	1,141·80	8,732	8,732
New masonry	3	55	23	1·5	5,692·5	5,692·5	5,693
Brick-on-edge	3	55	23	·5	1,897·5	1,897·5	1,897

ABSTRACT OF COST OF ESTIMATE No. 27.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	8,732	Demolition, old masonry, at Re. 1 per 100	87·32
"	5,693	Brick-work, at Rs. 22 per 100	1,252·46
"	1,897	Brick-on-edge at Rs. 25 per 100	474·25
		Tow-path 12′ wide	595·60
		Grand Total	2,409·63

Same for Suraiee, Sutheree, and Aternah Bridges.

Digitized by Google

ESTIMATE No. 28.—SIRDHUNNA AND KHUTOWLEE BRIDGES.

Description.	No.	L.	B.	D	Quantity.	Total.	Grand Total.
New Masonry.							
Ghats and water-wings ...	2	160	2	1·5	960		
						960	
							960

ABSTRACT OF COST OF ESTIMATE No. 28.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	960	Brick-work, at Rs. 22 per 100	211·20
		Tow-path 12′ wide	772·80
		Grand Total	984·00

ESTIMATE No. 29.—ALTERATIONS TO CHITOWRA FALLS.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Excavation.							
Lock channel	...	1,500	35	10	525,000		
Filling behind side walls ...	2	40	16	8	10,240		
						535,240	
							535,240
Demolition.							
Old masonry, as Estimate No. 23	...	...	...	...	127,107		
Tail walls, *vide* Estimate No. 17	...	...	...	...	8,830		
						135,937	
							135,937
Masonry.							
As Estimate No. 23	...	...	...	...	30,681		
Raising lock walls	...	120	3	2	720		
„ „	...	314	4·5	2	2,826		
„ „	...	150	9	2	2,700		
						36,927	
Remainder as Estimate No. 23.							36,927

ABSTRACT OF COST OF ESTIMATE No. 29.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	5,35,240	Excavation, at Rs. 2·25 per 1,000	1,204·29
„	1,34,937	Demolition, old masonry, at Re. 1 per 100	1,359·37
„	36,927	Brick-work, at Rs. 22 per 100	8,123·94
		Remainder as Estimate No. 23	32,173·56
		Grand Total	42,861·16

Digitized by Google

ESTIMATE No. 30.—1—KHUTOWLEE ESCAPE; 2—ABOONULLAH; 3—JANNI HEAD.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Flooring	4	24	6	2·5	1,440	1,440	1,440
New Masonry	4	24	6	1·5	864	864	864
Brick-on-edge	4	24	6	·5	288	288	288

ABSTRACT OF COST OF ESTIMATE No. 30.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	1,440	Demolition, old masonry, at Re. 1 per 100	14·40
„	864	Brick-work, at Rs. 20 per 100	1,72·80
„	288	Brick-on-edge, at Rs. 25 per 100	72·00
		Grand Total	259·20

ESTIMATE No. 31.—FALLS AT KHUTOWLEE AND SIRDHUNNA.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Foundation.							
As Estimate No. 26 ...	...	...	...	...	73,914		
Wells under curtain of basin	25	14·12	1·5	9	4,765·50		
		Area.					
Covering of wells	25	7·06		1·5	264·75		
Curtain of basin	...	202	2	2	808	79,752·25	79,752
Brick-on-edge.							
As Estimate No. 26, deducting bridge flooring ...	...	...	...	...	...	...	12,874
Well Sinking.							
As Estimate No. 26 ...	...	...	...	...	428		
Curtain walls	25	9	..	...	225	...	653
Curbs.							
As Estimate No. 26 ...	...	...	...	...	52		
Curtain walls	...	...	..	...	25	...	77
Remainder as Estimate No. 26 (without bridge)							

ABSTRACT OF COST OF ESTIMATE No. 31.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	79,752	Brick-work in foundation, at Rs. 20 per 100	15,950·40
„	12,874	Brick-on-edge, at Rs. 25 per 100	3,218·50
Lineal feet	653	Under-sinking wells, at Rs. 5 per lineal foot	3,265·00
No.	77	Curbs, at Rs. 20 per each	1,540·00
Cubic feet	1,878	Arching light, at Rs. 25 per 100	469·50
„	8,341	Inverts, at Rs. 26 per 100	2,168·66
„	33,390	Concrete, at Rs. 14 per 100	4,674·60
„	10,880	Puddle, at Rs. 10 per 1,000	108·80
„	4,770	Kunkur flooring, at Rs. 8 per 100	381·60
„	127,488	Excavation, at Rs. 2·5 per 1,000	318·72
„	2,400	Pitching slopes, at Rs. 10 per 100	240·00
„	...	Lock and grating gear as Estimate No. 26	17,128·55
		Grand Total	49,464·33

Digitized by Google

ESTIMATE No. 32.—ADDITIONS, &c., TO SALAWUR AND MUSSOORI FALLS.

DESCRIPTION.	No.	L.	B.	D.	QUANTITY.	TOTAL.	GRAND TOTAL.
Excavation.							
New channel from locks ...	...	1,500	36·50	11	602,250		
Filling behind side walls of falls	2	40	16	8	10,240		
						612,490	
							612,490
Demolition, old Masonry.							
At head of lock channel, *vide* Estimate No. 17 ...	...	...	...	...	22,713·50		
Round ends of chamber walls	...	...	...	...	8,830		
Flooring	3	95	54·50	4	62,130		
	2	11·50	4·50	4	414		
	2	95	5	4	3,800		
						97,887	
							97,887
Digging boulders out of cribs	...	132	80	4·51	47,625·60		
	2	70	37	4·51	23,361·80		
						70,987	
							70,987
Boulder Flooring.							
Relaying	...	220	55	3	36,300		
						36,300	
							36,300
Masonry.							
Lock raising lock walls ...	...	120	3	1	360		
„ „ ...	...	314	4·50	1	1,413		
„ „ ...	...	150	9	1	1,350		
Fall up-stream wings ...	2	26	3·50	5	910		
Drop wall of fall ...	3	54·50	5	4	3,270		
Raising side walls	2	46	4·50	8	3,312		
„ chamber walls ...	2	45	4·50	8	3,240		
Lengthening piers ...	3	39	4·50	24·51	12,904·51		
New piers	6	39	3	24·51	17,206·02		
Counterforts	4	3	3	8	288		
Flooring	3	95	54·50	2	31,065		
„	2	11·50	4·50	2	207		
„	2	95	5	2	1,900		
„	3	54·50	50	0·25	2,043·75		
						79,469·28	
Deduct—							
		Area					
Openings and arches of piers	3	427·65	4·50	...	5,773·27		
„ „ „	6	427·65	3	...	7,697·70		
						13,470·97	
							65,998
Arch-work.							
Piers	3	45	4·50	1·50	911·25		
	6	45	3	1·50	1,215		
						2,126	
							2,126
Brick-on-edge	3	45	54·50	1	7,357·5		
	2	45	7	1	630		
	3	11·50	4·50	1	155·25		
						8,143	
							8,143

Digitized by Google

ESTIMATE No. 32.—ADDITIONS, &c., TO SALAWUR & MUSSOORI FALLS,—*contd.*

DESCRIPTION.	No.	L.	B.	D.	QUANTITY.	TOTAL.	GRAND TOTAL.
Stone flooring	3	54·50	50	·75	6,131	6,131	6,131
Grating	12	31·5	11	...	4,158	4,158	4,158
Girders	36	13	...	...	468	468	468
Wall-plates	12	11	...	...	132	132	132
Pitching slopes	2	100	30	1	6,000	6,000	6,000

ABSTRACT OF ESTIMATE No 32.

QUANTITY.		DESCRIPTION.	TOTAL.
			Rs.
Cubic feet	612,490	Excavation, at Rs. 2·25 per 1,000	1,378·10
„	97,887	Demolition, old masonry, at Re. 1 per 100	978·87
„	70,987	Digging boulders out of cribs, at Rs. 7 per 1,000 ...	496·90
„	36,300	Boulder flooring, dry relaying, at Rs. 7 per 1,000 ...	254·10
„	65,998	Brick-work, at Rs. 22 per 100	14,519·56
„	2,126	Arch-work, at Rs. 26 per 100	552·76
„	8,143	Brick-on-edge, at Rs. 25 per 100	2,035·75
„	6,131	Stone flooring at Rs. 2 per foot	12,262·00
		Grating Gear.	
Square feet	4,158	Grating, at Re. 1·15 per square foot	4,781·70
Lineal feet	468	Girders, at Rs. 4·25 per foot	1,989·00
„	132	Wall-plates, at Rs. 6·25 per foot...	825·00
Cubic feet	6,000	Pitching, at Rs. 10 per 100	600·00
		New Rajbuha head	1,410·78
		GRAND TOTAL	41,484·52

Digitized by Google

ESTIMATE No. 33.—ADDITIONS, &c., TO NUNOON AND MORADNUGGUR BRIDGES.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Arches	3	54	28	2·75	12,474		
Backing of arches	2	28	10	2	1,120		
"	2	28	13	4	2,912		
Spandrils	2	163	2·50	2·50	2,037·5		
Parapets	2	235	1·50	2·87	2,023·35		
Pillars	4	3	3	2·87	103·32		
Flooring	3	49	28	1·5	6,174		
						26,844·17	
							26,844
Digging boulders out of Cribs	2	163	10	3·25	10,595		
	4	20	10	3·25	2,600		
						13,195	
							13,195
New Masonry.							
Raising Piers	2	28	6·50	12	4,368		
" Abutments ...	2	28	6·50	1·5	546		
" Wings	4	35	2·50	1·5	525		
" Pillars	4	4	4	1·5	96		
" Parapets	4	36	1·5	2·87	619·92		
Pillars	4	3	3	2·87	103·32		
Parapets on Piers	4	6·5	1·5	2·87	111·93		
Flooring	3	49	28	0·5	2,058		
						8,428·17	
							8,428
Brick-on-edge	3	49	28	·5	2,058		
						2,058	
							2,058
Girder Bridge	3	50	...	...	150		
						150	
							150

ABSTRACT OF ESTIMATE No. 33.

Quantity.		Description.	Total.
			Rs.
Cubic feet	26,844	Demolition, old masonry, at Re. 1 per 100	268·44
"	13,195	Digging boulders out of cribs, at Rs. 7 per 1,000 ...	92·36
"	8,428	Brick-work, at Rs. 22 per 100	1,854·16
"	2,058	Brick-on-edge, at Rs. 25 per 100	514·5
Lineal feet	150	Girder bridge, at Rs. 96·65 per foot	14,497·50
		7′ Tow-path, Estimate No.	501·5
		Grand Total	17,728·46

Digitized by Google

ESTIMATE No. 34.—ALTERATIONS TO { JUTPOORA BRIDGE, NEWAREE „ ABOOPOOR „ NOORPOOR „ }

DESCRIPTION.	No.	L.	B.	D.	QUANTITY.	TOTAL.	GRAND TOTAL.
Demolition, old Masonry.							
Arches	3	54	21	2·75	9,355·50		
Backing of arches	2	21	10	2	840		
„	2	21	13	4	2,184		
Spandrils	2	163	2·5	2·5	2,037·50		
Parapets	2	235	1·5	2·87	2,023·35		
Pillars	4	3	3	2·87	103·32		
Flooring	3	49	21	1·5	4,630·50		
						21,174·17	
							21,174
Digging boulders out of cribs	2	163	10	2·11	6,878·60		
„ „ ...	2	20	10	2·11	844·00		
						7,722·60	
							7,723
New Masonry.							
Raising piers	2	21	6·5	12	3,276		
„ Abutments ...	2	21	6·5	1·5	409·50		
„ Wings	4	35	2·5	1·5	525		
„ Pillars	4	4	4	1·5	96		
Parapets	4	36	1·5	2·87	619·92		
Pillars	4	3	3	2·87	103·32		
Parapets on piers	4	6·5	1·5	2·87	111·93		
Flooring	3	49	21	0·5	1,543·50		
						6,685·17	
							6,685
Brick-on-edge	3	49	21	·5	1,543·5		
						1,543	
							1,543

ABSTRACT OF COST OF ESTIMATE No. 34.

QUANTITY.		DESCRIPTION.	COST.
			Rs.
Cubic feet	21,174	Demolition, old masonry, at Re. 1 per 100	211·74
„	7,723	Digging boulders out of cribs, at Rs. 7 per 1,000 ...	54·06
„	6,685	Masonry, at Rs. 22 per 100	1,470·70
„	1,543	Brick-on-edge, at Rs. 25 per 100	385·75
Lineal feet	150	Girder bridge, at Rs. 90·21 per foot	13,531·50
		7′ towing path	377·30
		GRAND TOTAL	16,031·05

Digitized by Google

ESTIMATE No. 35.—ADDITIONS TO SOUNDA BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Vide Estimate No. 34 ...	...	...	...	...	21,174		
Deduct—							
Flooring	...	...	...	...	4,630·5	16,543	16,543
Masonry.							
Vide Estimate No. 34 ...	...	...	...	...	6,685		
Deduct—							
Flooring	...	...	...	...	1,543·5	5,141	5,141

ABSTRACT OF COST OF ESTIMATE No. 35.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	16,543	Demolition, old masonry, at Re. 1 per 100	165·43
„	5,141	Brick-work, at Rs. 22 per 100	1,131·02
Lineal feet	150	Girder bridge, at Rs. 90·21 per foot	13,531·50
		Towing path	377·30
		Grand Total	15,205·25

Digitized by Google

ESTIMATE No. 36.—ADDITIONS, &c., TO POOTH AND NUGLA BRIDGES.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Arches	3	54	23	2·75	10,246·50		
Backing of arches	2	23	10	2	920		
"	2	23	13	4	2,392		
Spandrils	2	163	2·5	2·5	2,037·5		
Parapets	2	235	1·5	2·87	2,023·35		
Pillars	4	3	3	2·87	103·32		
Flooring	3	49	23	1·5	5,071·50		
						22,794·17	
							22,794
Digging boulders out of cribs	2	163	10	2·23	7,269·80		
	2	20	10	2·23	892·00		
						8,161·80	
New Masonry.							8,162
Raising piers	2	23	6·5	12	3,588		
" Abutments ...	2	23	6·5	1·5	448·5		
" Wings	4	35	2·5	1·5	525		
" Pillars	4	4	4	1·5	96		
Parapets	4	36	1·5	2·87	619·92		
Pillars	4	3	3	2·87	103·32		
Parapets on piers	4	6·5	1·5	2·87	111·93		
Flooring	3	49	23	0·5	1,690·50		
						7,183·17	
							7,183
Brick-on-edge	3	49	23	·5	1,690·5		
						1,690·5	
							1,690
Girder bridge	3	50	...	...	150		
						150	
							150

ABSTRACT OF COST OF ESTIMATE No. 36.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	22,794	Demolition, old masonry, at Re. 1 per 100	227·94
"	8,162	Digging boulders out of cribs, at Rs. 7 per 1,000 ...	57·13
"	7,183	Brick-work, at Rs. 22 per 100	1,580·26
"	1,690	Brick-on-edge, at Rs. 25 per 100	422·5
Lineal feet	150	Girder bridge, at Rs. 92·05 per foot	13,807·50
		7′ towing path	431·00
		Grand Total	16,526·33

Digitized by Google

ESTIMATE No. 37.—ADDITIONS, &c., TO BHOLA FALLS.

DESCRIPTION.	No.	L.	B.	D.	QUANTITY.	TOTAL.	GRAND TOTAL.
Excavation.							
Vide Estimate No. 32 ...	...	...	...	...	...	...	612,490
Demolition, old Masonry.							
At head of lock channel, *vide* Estimate No. 17 ...	...	...	...	...	22,713·50		
Round ends of chamber walls, *vide* Estimate No. 17 ...	...	...	...	...	8,830		
Lock bridge, *vide* Estimate No. 17	...	...	...	...	2,582·99	34,126·49	34,126
Masonry.							
Raising lock walls, *vide* Estimate No. 29	...	...	...	...	6,246		
Lock bridge, *vide* Estimate No. 17	...	...	...	...	1,542·59		
Vide Estimate No. 32 ...	...	...	...	...	41,130·53	48,919·12	
Deduct—							
Openings and arches of piers, *vide* Estimate No. 32 ...	...	...	...	...	...	13,470·97	35,448
Arch-work.							
In fall, *vide* Estimate No. 32	...	...	...	...	2,126		
In lock, *vide* Estimate No. 17	...	...	...	...	504	2,630	2,630
Stone flooring.							
Vide Estimate No. 32 ...	...	...	...	...	6,131	6,131	6,131
Grating girders, wall-plates, pitching, vide Estimate No. 32.							

ABSTRACT OF ESTIMATE No. 37.

QUANTITY.		DESCRIPTION.	TOTAL.
			Rs.
Cubic feet	612,490	Excavation, at Rs. 2·25 per 1,000	1,378·10
"	34,126	Demolition, old masonry, at Re. 1 per 100	341·26
"	35,448	Brick-work, at Rs. 22 per 100	7,798·56
"	2,630	Arch-work, at Rs. 26 per 100	683·8
"	6,131	Stone-flooring, at Rs. 2 per 100...	12,262·00
		Grating girders and wall-plates, *vide* Estimate No. 32 ...	7,595·7
"	6,000	Pitching, ...	600·00
		New rajbuha head	1,410·78
		GRAND TOTAL	32,070·20

Digitized by Google

ESTIMATE No. 38.—ADDITIONS, &c., TO JANEE KHOORD BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Vide Estimate No. 36 ...	...	...	...	...	22,794		
Deduct—							
Flooring	...	...	...	...	5,071·5	17,722	17,722
Masonry.							
Vide Estimate No. 36 ...	...	...	...	...	7,183		
Deduct—							
Flooring	...	...	..	...	1,690·5	5,492	5,492

ABSTRACT OF ESTIMATE No. 38.

Quantity.		Description.	Total.
			Rs.
Cubic feet	17,722	Demolition, old masonry, at Re. 1 per foot	17,722
„	5,492	Brick-work, at Rs. 22 per 100	1,208·24
Lineal feet	150	Girder bridge, at Rs. 92·05 per foot	13,807·50
		7′ towing path	431·00
		Grand Total	15,623·96

Digitized by Google

ESTIMATE No. 39.—ADDITIONS, &c., TO { 1. RAOLI BRIDGE, 2. JARSHA „ 3. PUKKANA „ 4. MAMNIE „ 5. SUHENDA „

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Arches	3	48	21	2·5	7,560		
Backing of arches ...	2	7·5	21	6	630		
Spandrils	4	30	2·5	2	1,800		
„	4	11	2·5	6	660		
Parapets	2	208	1·5	2·875	1,794		
Pillars	4	3	3	2·875	103·50		
Flooring	3	45	21	1·25	3,543·75		
						16,091·25	
New Masonry.							16,091
Raising Piers	2	23	5·5	10·5	2,656·50		
„ Abutments ...	2	23	5·5	1·25	316·25		
„ Wings	4	31	2·5	1·25	387·50		
„ Pillars	4	4	4	1·25	80		
„ Parapets	4	31	1·5	2·875	534·75		
Pillars	4	3	3	2·875	103·50		
Parapets on piers	4	5·5	2·5	2·875	158·12		
Flooring	3	45	21	1·5	4,252·50		
						8,489·12	
							8,489

ABSTRACT OF COST OF ESTIMATE No. 39.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	16,091	Demolition, old masonry, at Re. 1 per 100	160·91
„	8,489	Kunkur masonry, at Rs. 20 per 100	1,697·80
Lineal feet	135	Girder bridge, at Rs. 90·21 per foot	12,178·35
		Towing path	377·30
		Grand Total	14,414·36

ESTIMATE No. 40.—ADDITIONS, &c., TO PEEPULHERA BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Vide Estimate No. 39 ...	...	...	...	...	16,091		
Additional in arches ...	3	48	2	2·5	720		
„ in backing of arches ...	2	7·5	2	2	60		
„ in flooring ...	3	45	2	1·25	337·5	17,208	17,208
Masonry.							
Vide Estimate No. 39 ...	...	...	...	...	8,489		
Additional in piers ...	2	2	5·5	10·5	231		
„ in abutments ...	2	2	5·5	1·5	27·5		
„ in floorings ...	3	45	2	1·5	405	9,152·5	9,153

ABSTRACT OF COST OF ESTIMATE No. 40.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	17,208	Demolition, old masonry, at Re. 1 per 100	172·08
„	9,153	Kunkur masonry, at Rs. 20 per 100	1,830·60
Lineal feet	135	Girder bridge, at Rs. 92·05 per foot	12,426·75
		Towing path	431·00
		Grand Total	14,860·43

ESTIMATE No. 41.—ADDITIONS, &c., TO BOOLUNDSHUHUR BRANCH HEAD.

Main Line.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry.							
Parapets	8	20	1·50	2·25	540		
Pillars	8	3	3	2·25	162		
Side arches...	...	22	18	1·50	594		
"	2	26	18	1·50	1,404		
						2,700	
							2,700
New Masonry.							
Abutments	2	18	6	10	2,160		
"	...	18	6	15	1,620		
Backing of arches	4	18	10	3	2,160		
"	2	18	7·50	3	810		
Raising spandrils, &c. ...	4	140	2	6	6,720		
"	4	43	2	6	2,064		
"	3	183	3·33	1	1,830		
Raising piers	3	22	4	6	1,584		
"	26	6	3	5	2,340		
Raising retaining wall of platform	...	91	2	1·5	273		
" " pillars ...	4	6·25	6·25	1·5	234·37		
" " ghat ...	2	125	2·50	1·5	937·50		
Raising water-wings down-stream	2	30	2	1·5	180		
New wings and steps ...	6	13·50	3	11	2,673		
" "	4	17	3	1·50	306		
Lock walls	2	127	6	17	25,908		
Curtains	...	15	3	6	270		
"	...	15	2	4	120		
Flooring	...	18	16	1	288		
Backing of inverts ...	...	16	109	1·75	3,052		
Water-wings of lock ...	...	27	4	6	648		
"	...	30	4	6	720		
"	...	27	2·50	11	742·5		
"	...	30	2·50	7	525		
Weir in branch head ...	...	35	4	2	280		
Raising wing-walls ...	8	20	2·50	5	2,000		
Parapets	8	20	1·50	2·25	540		
Pillars	8	3	3	2·25	162		
						61,147·37	
Deduct hollow part of wall...	...	90	2	13	2,340		
						2,340	
							58,807
Arch-work	2	29	18	1·50	1,566		
	...	25	18	1·50	675		
						2,241	
							2,241
Inverts	...	109	16	1	1,744		
						1,744	
							1,744
Brick-on-edge	...	18	16	1	288		
						288	
							288
Lock gates	2	9·54		8 10	343·44		
						343·44	
Crabs, pulleys, sluices, chain, vide Estimate No. 25.							344

Digitized by Google

ESTIMATE No. 41.—ADDITIONS, &c., TO BOOLUNDSHUHUR, &c.—*continued.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Upright girders for regulator	3	11·50	...	...	34		
	12	15	...	...	180		
						214	
							214
Iron drop gates	2	20·50	...	10	410		
						410	
							410
Wooden gates	18	6·66	...	10	1,198·80		
	2	7·50	...	8	120		
	3	6·66	...	8	159·84		
						1,478·64	
							1,479
Chain (light)	46	16·50	...	...	759		
						759	
							759
Pitching slopes	2	50	20	1	2,000		
	2	50	10	1	1,000		
						3,000	
Metalling roadway.							3,000
Relaying	...	526	·15	·75	5,917·5		
						5,917	
							5,917

ABSTRACT OF ESTIMATE No. 41.

Quantity.		Description.	Total.
			Rs.
Cubic feet	2,700	Demolition, old masonry, at Re. 1 per 100	27·00
„	19,600	Brick-work, at Rs. 22 per 100	4,312·00
„	39,207	Kunkur masonry, at Rs. 17 per 100	6,665·19
„	2,241	Arch-work, at Rs. 26 per 100	582·66
„	1,744	Inverts, at Rs. 26 per 100	453·44
„	288	Brick-on-edge, at Rs. 25 per 100	72·00
		Lock Gear.	
Square feet	344	Lock gates, at Rs. 6·5 per foot	2,236·00
No.	4	Crabs, at Rs. 135 each	540·00
„	4	Pulleys, at Rs. 5 each	20·00
„	4	Sluices, at Rs. 125 each	500·00
Lineal feet	94	Chain, at Re. 1 per foot	94·00
		Regulating Gear.	
Lineal feet	214	Upright girders, at Rs. 9·4 per foot	2,011·60
Square feet	410	Iron drop gates, at Rs. 5 per foot	2,050·00
„	1,479	Wooden gates, at Re. 1·25 per foot	1,848·75
No.	23	Windlasses (small), at Rs. 22 each	506·00
Lineal feet	759	Chain, at Rs. ·9 per foot	683·10
No.	15	Axle blocks, at Rs. 5 each	372·00
Cubic feet	3,000	Pitching, at Rs. 10 per 100	300·00
„	5,917	Metalling, at Rs. 2 per 100	118·34
		Grand Total	23,392·08

Digitized by Google

ESTIMATE No. 42.—ADDITIONS, &c., TO NIDHOOLI, GESOOPOOR, AND SUNOWTA BRIDGES.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old masonry, vide Estimate No. 39 ...	...	...	...	...	16,091		
Deduct—							
Flooring	...	...	...	...	3,543·75		
						12,547	12,547
New masonry, vide Estimate No. 39	...	...	..	...	8,489		
Raising water-wings ...	2	27	2	1·5	162		
" " ...	2	100	2	1·5	600		
						9,251	
Deduct flooring, *vide* Estimate No. 39	...	...	...	...	...	4,252·5	
							4,998·5

ABSTRACT OF ESTIMATE No. 42.

Quantity.		Description.	Total.
			Rs.
Cubic feet	12,547	Demolition, old masonry, at Re. 1 per 100	125·47
"	4,998	Kunkur masonry, at Rs. 20 per 100	999·6
Lineal feet	135	Girder bridge, at Rs. 90·21 per foot	12,178·35
		Towing-path	377·30
		Grand Total	13,680·72

ESTIMATE No. 43.—ADDITIONS, &c., TO DAMKOURA BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old masonry, vide Estimate No. 42	...	...	...	...	...	...	12,547
Masonry, vide Estimate No. 39	...	...	...	...	8,489		
Raising water-wings	2	175	2	1·5	1,050		
						9,539	
Deduct flooring, *vide* Estimate No. 39	...	...	..	...	...	4,252	
							5,287

ABSTRACT OF ESTIMATE No. 43.

Quantity.		Description.	Total.
			Rs.
Cubic feet	12,547	Demolition, old masonry, at Re. 1 per 100	125·47
"	5,287	Kunkur masonry, at Rs. 20 per 100	1,057·40
Lineal feet	135	Girder bridge, at Rs. 90·21 per foot	12,178·35
		Towing-path	377·30
		Grand Total	13,738·52

Digitized by Google

ESTIMATE No. 44.—ADDITIONS, &c., TO WALLIPOORA BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old masonry, vide Estimate No. 39 ...	...	...	...	...	16,091		
Additional in arches ...	3	48	7	2·50	2,520		
„ Backing in arches	2	7·50	7	2	210		
„ Flooring ...	3	4·5	7	1·25	1,181·25		
						20,002	
							20,002
Masonry, vide Estimate No. 39	...	...	...	...	8,489		
Additional in piers ...	2	7	5·5	10·5	808·5		
„ in abutments ...	2	7	5·5	1·25	96·25		
„ in flooring ...	3	45	7	1·5	1,417·5		
						10,811·25	
							10,811

ABSTRACT OF ESTIMATE No. 44.

Quantity.		Description.	Total.
			Rs.
Cubic feet	20,002	Demolition, old masonry, at Re. 1 per 100	200·02
„	10,811	Kunkur masonry, at Rs. 20 per 100	2,162·20
Lineal feet	135	Girder bridge, at Rs. 96·65 per foot	13,047·75
		Towing-path	501·5
		Grand Total	15,911·47

ESTIMATE No. 45.—FALLS AT WALLIPOORA, NUGLA, ABOOPOOR, JARCHA AND PUKKANA.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Foundations.							
Water-wings up-stream ...	2	25	5·5	8	2,200		
Curtain	2	16	3	5	480		
Drop walls	2	16	3	10·25	984		
„ „	2	16	3	4	384		
Curtains under lower gates	4	16	3	3	576		
Sides of wells	2	14	6	4	672		
Abutments of gates up-stream	2	16·5	6·5	8	1,716		
„ down-stream ...	2	16·5	12	2·5	990		
Side walls of locks ...	2	106	9	2·5	4,770		
Abutments of bridge ...	2	3	6	2·5	90		
Side wall down-stream ...	2	50	6	2·5	1,500		
Flooring up-stream ...	2	16	17	3	1,632		
„ of well	2	16	7·25	3	696		
„ under gates ...	2	16	10·5	2·5	840		
Backing of inverts ...	2	168·5	16	1·75	9,436		
Division wall of lock ...	2	18	7	8	2,016		
„ „ sides of well...	2	14	7	13·25	2,597		
„ „ of lock ...	2	80	7	8	8,960		
„ „ „ ...	2	70	7	5·5	5,390		
Drop wall of fall	...	141	5·5	11·75	9,112·12		
Curtain of fall	...	141	3	4	1,692		
„ „	...	141	3	1·5	634·5		
Flooring of fall	...	141	64	1·5	13,536		
Wells in curtain of fall ...	18	14·12	1·5	7	2,668·68		
„ walls of basin ...	32	14·12	1·5	9	6,099·84		
„ division wall ...	4	18·8	2	9	1,353·60		
		Area.					
Covering of wells in curtain	18	7·06		1·5	190·62		
„ „ division walls	.	18	7	2	252		
„ „ walls of basin	2	106	6	2	2,544		
						84,012·36	
Deduct—							
Brick-on-edge lock flooring	2	16	17	1	544		
„ „ ...	2	16	7·25	1	232		
„ „ ...	2	16	10·5	1	336		
Flooring of fall	...	141	64	1	9,024		
Hollows in water-wings up-stream	2	25	1·5	4	300		
						10,436	
							73,576
Superstructure.							
Water-wings up-stream ...	2	25	3·5	12	2,100		
Abutments of gates up-stream	2	16·5	6	12	2,376		
„ „ down-stream	2	16·5	9	18·25	5,420·25		
Abutment of bridge ...	2	3	5	12	360		
„ „ ...	2	3	3	9·5	171		
Counterforts	2	3	3·5	8	168		
Wing-walls of bridge ...	2	12	2·5	9	540		
Side walls down-stream ...	2	50	3·5	12	4,200		
Carried over ...	...	...	...	...	15,335·25		

Digitized by Google

ESTIMATE No. 45.—FALLS AT WULLIPOORA, NUGLA, ABOOPOOR, JARCHA, AND PUKKANA,—*continued*

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Brought forward ...	...	...	...	...	15,335·25		
Superstructure,—contd.							
Side-walls of lock... ...	2	112·5	6	18·25	24,637·50		
Division wall of lock ...	2	112	7	12	18,816		
" " " ...	2	38	7	18·25	9,709		
" " " ...	2	53	7	12	8,904		
Piers	7	34	3	22·25	15,886·50		
"	7	5	3	12	1,260		
Steps	2	12	7	2	336		
"	2	3	1·5	2	18		
Backing of arches... ...	8	15	3	1	360		
" "	2	18	3	1	108		
Revetment walls down-stream	2	106	3·5	12	8,904		
						104,274·25	
Deduct—							
Hollow parts of walls ...	2	90	2	16	5,760		
" " " ...	2	28	2	16	1,792		
" " " ...	2	50	2	12	2,400		
From piers	7	Area. 286		3	6,006		
						15,958	
							88,316
Arch-work.							
Inverts	2	168·5	16·5	1·5	8,340·75		
						8,341	
							8,341
Arches of fall	8	3	16	1	384		
" lock	2	3	19	1	114		
Under piers	7	36	3	1·5	1,134		
						1,632	
							1,632
Brick-on-edge.							
Lock flooring	2	16	17	1	544		
"	2	16	7·25	1	232		
"	2	16	10·5	1	336		
Flooring of fall	...	141	64	1	9,024		
Bridge over fall	...	197	3	0·5	295·5		
						10,431	
							10,431
Concrete	...	141	70	3	29,610		
						29,610	
							29,610
Puddle	...	141	2·5	10	3,525		
"	2	75	2	19	5,700		
"	2	50	2	12	2,400		
						11,625	
							11,625
Kunkur flooring	...	141	15	2	4,230		
						4,230	
							4,230
Well sinking	18	7	...	...	126		
" "	36	9	...	...	324		
						450	
							450

Digitized by Google

ESTIMATE No. 45.—FALLS AT WULLIPOORA, NUGLA, ABOOPOOR, JARCHA AND PUKKANA,—*continued.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Excavation.							
Basin	...	141	64	4	36,096		
Foundations	...	...	...	...	84,012		
						120,108	120,108
Lock gates	4	9·54	...	10·5	400·68		
	4	9·54	...	16·75	639·18		
						1,039·86	1,040
Chain	4	25·5	...	...	102		
	4	29·5	...	...	118		
						220	220
Grating	8	30	15	...	3,600	3,600	3,600
Girders	24	17	...	...	408	408	408
Wall-plates...	8	15	...	...	120	120	120

ABSTRACT OF COST OF ESTIMATE No. 45.

Quantity.		Description.	Cost.
			Rs.
Cubic feet..	73,576	Kunkur masonry in foundations, at Rs. 17 per 100 ...	12,507·92
"	66,237	" " in superstructure, at Rs. 19 per 100 ...	12,585·03
"	22,079	Brick-work, at Rs. 22 per 100	4,857·38
"	8,341	Arch-work Inverts, at Rs. 26 per 100	2,168·66
"	1,632	" light, at Rs. 26 per 100	424·32
"	10,431	Brick-on-edge, at Rs. 25 per 100	2,607·75
"	29,610	Concrete, at Rs. 14 per 100	4,145·40
"	11,625	Puddle, at Rs. 10 per 1000	116·25
"	4,230	Kunkur flooring, at Rs. 8 per 100	338·40
Lineal feet	450	Well sinking, at Rs. 5 per foot	2,250·00
No.	54	Curbs (small), at Rs. 20 each	1,080·00
Cubic feet	120,108	Excavation, at Rs. 2·5 per 1000	300·27
Square feet	1,040	Lock gates, at Rs. 6·5 per foot	6,760·00
		Pulleys, crabs, and sluices, as Estimate No. 26	2,120·00
Lineal feet	220	Chain, at Re. 1 per foot	220·00
No.	63	Sleepers, at Rs. 11·625 each	732·37
"	2	Hoops, at Rs. 7 each	14·00
Square feet	3,600	Grating, at Re. 1·15 per foot	4,140·00
Lineal feet.	408	Girders, at Rs. 4·25 per foot	1,734·00
"	120	Wall-plates, at Rs. 6·25 per foot	750·00
		Grand Total	59,851·75

Digitized by Google

ESTIMATE No. 46.—FALLS AT MOONDA KHERA.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Masonry.							
In wells of curtain of basin ...	18	14·12	1·5	7	2,668·68		
Covering of ditto	18	7·6	...	1·5	192·62		
Curtain on wells	...	144	3	2	864		
						3,723·3	3,723
Well sinking	18	7	...	...	126		
						126	126

ABSTRACT OF ESTIMATE No. 46.

Quantity.		Description.	Total.
			Rs.
Cubic feet	3,723	Masonry, at Rs. 17 per 100	632·91
"	126	Well sinking, at Rs. 5 per foot	630·00
Number ...	8	Curbs, at Rs. 20 each	160·00
		Remainder, as Estimate No. 45	59,851·75
		Grand Total	61,274·66

ESTIMATE No. 47.—ALTERATIONS TO URROWLI BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand. Total.
Demolition, old masonry, *vide* Estimate No. 44 ...	...	...	...	...	20,002		
Deduct flooring	3	45	28	1·25	4,725		
						15,277	15,277
New masonry.							
Vide Estimate No. 44 ...	...	...	...	...	10,811		
Raising water-wings ...	2	143	2	2·5	1,430		
						12,241	
Deduct flooring	3	45	28	1·5	...	5,670	
							6,571

ABSTRACT OF OF ESTIMATE No. 47.

Quantity.		Description.	Total.
			Rs.
Cubic feet	15,277	Demolition, old masonry, at Re. 1 per 100	152·77
,,	6,571	Kunkur masonry, at Rs. 20 per 100	1,314·2
Lineal feet	135	Girder bridge, at Rs. 96·65 per foot	13,047·75
		Towing-path	501·5
		Grand Total	15,016·22

Digitized by Google

ESTIMATE No. 48.—ALTERATIONS TO MOONDA KHERA BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old masonry, vide Estimate No. 39 ...	...	...	...	...	16,091		
Deduct flooring	...	...	...	...	3,544		
						12,547	12,547
Masonry, vide Estimate No. 39	...	...	...	...	8,489		
Raising water-wings ...	2	410	2	2	3,280		
						11,769	
Deduct flooring, *vide* Estimate No. 39	...	...	...	...	...	4,252	
							7,517

ABSTRACT OF ESTIMATE No. 48.

Quantity.		Description.	Total.
			Rs.
Cubic feet	12,547	Demolition, old masonry, at Re. 1 per 100	125·47
"	7,517	Kunkur masonry, at Rs. 20 per 100	1,503·40
Lineal feet	135	Girder bridge, at Rs. 90·21 per foot	12,178·35
		Towing-path	377·3
		Grand Total	14,184·52

ESTIMATE 49.—ALTERATIONS TO UCHEHJA BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total	Grand Total.
Demolition, old masonry, vide Estimate No. 42 ..	...	..	..	...	...	...	12,547
Masonry, vide Estimate No. 39	...	...	...	...	8,489		
Raising water-wings ...	2	205	2	1·5	1,230		
						9,719	
Deduct flooring, *vide* Estimate No. 39	..	...	..	...	..	4,252	
							5,467

ABSTRACT OF ESTIMATE No. 49.

Quantity.		Description.	Total.
			Rs.
Cubic feet	12,547	Demolition, old masonry, at Re. 1 per 100	125·47
"	5,467	Kunkur masonry, at Rs. 20 per 100	1,093·40
Lineal feet	135	Girder bridge, at Rs. 90·21 per foot	12,178·35
		Towing-path	377·30
		Grand Total	13,774·52

Digitized by Google

ESTIMATE No. 50.—ALTERATIONS TO PULRA FALLS.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Excavation.							
Lock channel	...	1,500	30·5	7	320,250		
Filling behind side wall of falls	2	20	16	5	3,200		
						323,450	
Demolition, old masonry.							323,450
At head of lock channel, *vide* Estimate No. 17 ...	...	...	...	...	22,713·50		
Falls of chamber walls ...	...	...	...	...	8,830		
Lock bridge	...	...	...	...	2,582·99		
Flooring of falls	5	98·50	20	3	29,550		
"	2	98·50	5	3	2,955		
Chamber walls	4	96	4·50	11	19,008		
						85,639·49	
							85,639
Lifting and relaying kunkur flooring, dry	...	136	60	3	24,480		
						24,480	
Masonry.							24,480
Raising lock walls... ...	...	120	3	1	360		
"	...	314	4·5	1	1,413		
"	...	150	9	1	1,350		
Raising water-wing upstream	2	14	4	4·5	504		
" side chamber walls	2	26	4	5	1,040		
Prolongation of piers ...	4	23	4	18·8	6,918·4		
New piers	5	26	3	18·8	7,332		
New drop walls	5	20	5	3·85	1,925		
Flooring	5	98·5	20	2	19,700		
"	2	98·5	5	2	1,970		
Lock bridge, *vide* Estimate No. 17	...	...	...	...	1,542·59		
						44,054·99	
Deduct—							
From piers	4	14	3	4	672		
"	5	14	3	3	630		
		Area					
"	4	113·49	3	...	1,702·35		
"	4	113·49	4	...	1,815·84		
						4,820·19	
							39,235
Arch-work.							
In lock, *vide* Estimate No. 17	...	...	...	...	504		
		Circum					
In piers	4	24·34	4	1·5	584·16		
"	5	24·34	3	1·5	547·65		
						1,635·81	
							1,636
Brick-on-edge	5	78·5	20	1	7,850		
	2	78·5	6	1	942		
						8,792	
							8,792
Stone flooring	5	20	20	·75	1,500		
						1,500	
							1,500

Digitized by Google

ESTIMATE No. 50.—ALTERATIONS TO PULRA FALLS,—*continued.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Pitching slopes	2	50	15	1	1,500	1,500	1,500
Grating	10	18·9	8·5	...	1,606·5	1,606·5	1,607
Girders	20	10·5	...	...	210	210	210
Wall-plates...	10	8.5	...	...	85	85	85

ABSTRACT OF ESTIMATE No. 50.

Quantity.		Description.	Total.
			Rs.
Cubic feet	323,450	Excavation, at Rs. 2·25 per 1,000	727·76
„	85,639	Demolition, old masonry, at Re. 1 per 100	856·39
„	24,480	Lifting and relaying kunkur flooring, at Rs. 7 per 1,000	171·36
„	29,426	Kunkur masonry, at Rs. 17 per 100	5,002·42
„	9,809	Brick-work, at Rs. 22 per 100	2,157·98
„	1,636	Arch-work, at Rs. 26 per 100	425·36
„	8,792	Brick-on-edge, at Rs. 25 per 100	2,198·00
„	1,500	Stone flooring, at Rs. 2 per foot..	3,000·00
„	1,500	Pitching, at Rs. 10 per 100	150·00
Square feet	1,607	Grating, at Rs. 1·15 per foot	1,848·05
Lineal feet	210	Girders, at Rs. 4·25 per foot	892·50
„	85	Wall-plates, at Rs. 6·25 per foot	531·25
		Rajbuha head A. L.	1,410·78
		Grand Total	19,371·85

Digitized by Google

ESTIMATE No. 51.—ALTERATIONS TO KOEL BRANCH HEAD.

DESCRIPTION.	No.	L.	B.	D.	QUANTITY.	TOTAL.	GRAND TOTAL.
Demolition, old masonry, *vide* Estimate No. 41 ...	..	...	...	...	...	...	2,700
New masonry.							
Abutments	2	18	6	10	2,160		
"	...	18	6	15	1,620		
Backing of arches	4	18	10	3	2,160		
" "	2	18	7·5	3	810		
Raising spandrils & roadway	4	92	2	5·5	4,048		
" " ...	4	43	2	5·5	1,892		
" " ...	3	135	3·33	1	1,350		
Raising piers	3	22	4	6	1,584		
"	22	6	3	5	1,980		
Raising retaining walls of platform	...	91	2	3	546		
" pillars ...	4	6·25	6·25	3	468·75		
" wall of ghât ...	2	125	2·50	3	1,875		
Raising water-wings down-stream	2	30	2	3	360		
New wings and steps ...	6	13·50	3	11	2,673		
" " ...	4	17	3	1·50	306		
Lock walls	2	127	6	16·50	25,146		
Curtains	...	15	3	6	270		
"	...	15	2	4	120		
Flooring	...	18	16	1	288		
Backing of inverts ...	...	16	109	1·75	3,052		
Water-wings of lock ...	...	27	4	6	648		
" " ...	...	30	4	6	720		
" " ...	...	27	2·5	10·5	708·75		
" " ...	...	30	2·5	7	525		
Weir in branch head ...	..	35	4	2	280		
Raising wing-walls ...	8	20	2·50	5·5	2,200		
Parapets	8	20	1·5	2·25	540		
Pillars	8	3	3	2·25	162		
						58,492	
Deduct hollow part of walls	...	90	2	12·5	2,250		
						2,250	
							56,242
Arching Inverts, brick-on-edge, same as Estimate No. 41.							
Lock gates	2	9·54	...	{ 7·5 9·5 }	324·36		
						324·36	
							324
Crabs, Pulleys, Sluices, Chain, as Estimate No. 41.							
Upright girders	8	15	...	...	120		
	3	11·50	...	...	34·5		
						154	
							154
Iron drop gates	2	20·50	...	95	389·5		
						389	
							389
Wooden gates	12	6·66	...	9·5	759·24		
	2	7·50	...	7·5	112·50		
	3	6·66	...	7·5	149·85		
						1,021	
							1,021

Digitized by Google

ESTIMATE No. 51.—ALTERATIONS TO KOEL BRANCH HEAD,—*continued.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Chain (light)	34	16·50	...	...	561	561	561
Pitching slopes	2	50	19	1	1,900		
	2	50	10	1	1,000	2,900	2,900
Metalling, Relaying ...	...	478	13	·75	4,660	4,660	4,660

ABSTRACT OF ESTIMATE No. 51.

Quantity.		Description.	Total.
Cubic feet	2,700	Demolition, old masonry, at Re. 1 per 100	27·00
"	14,060	Brick-work, at Rs. 22 per 100	3,003·00
"	42,182	Kunkur masonry, at Rs. 17 per 100	7,170·94
"	2,241	Arch-work, at Rs. 26 per 100	582·66
"	1,744	Inverts, at Rs. 26 per 100	453·44
"	288	Brick-on-edge, at Rs. 25 per 100	72·00
		Lock Gear.	
Square feet	324	Lock gates, at Rs. 6·5 per foot	2,106·00
No.	4	Crabs, at Rs. 135 each	540·00
"	4	Pulleys, at Rs. 5 each	20·00
"	4	Sluices, at Rs. 125 each	500·00
Lineal feet.	94	Chain, at Re. 1 per foot	94·00
"	154	Upright girders, at Rs. 9·4 per foot	1,447·60
Square feet	389	Iron drop gates at Rs. 5 per foot	1,945·00
"	1,021	Wooden gates, at Re. 1·25 per foot	1,276·25
No.	17	Windlasses, small, at Rs. 22 each	374·00
Lineal feet	561	Chain, light, at Rs. ·9 per foot	504·90
No.	11	Axle blocks, at Rs. 5 each	55·00
Cubic feet	2,900	Pitching, at Rs. 10 per 100	290·00
"	4,660	Metalling, at Rs. 6 per 100	279·6
		Grand Total	20,831·59

Digitized by Google

ESTIMATE No 52.—ALTERATIONS TO BURROWLEE, DUBTHULLA, AND CHUNGEYREE BRIDGES.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old masonry.							
Arches	3	43	21	2·50	6,772·50		
Spandrils	6	24	2·50	7	2,520·00		
Parapets	2	190	1·5	2·41	1,373·70		
Pillars	4	3	3	2·41	86·76		
Flooring	3	40	21	1·25	3,150·00		
						13,902·96	
Masonry.							13,903
Raising piers and abutments	4	23	5	9·5	4,370		
Parapets	4	30	1·5	2·41	433·80		
Pillars	4	3	3	2·41	86·76		
Raising wings	4	30	2·5	0·60	180·00		
Parapets on piers	4	5	2·5	2·41	120·50		
Flooring	3	40	21	1·5	3,780·00		
						8,971·06	
							8,971

ABSTRACT OF ESTIMATE No. 52.

Quantity.		Description.	Total.
			Rs.
Cubic feet	13,903	Demolition, old masonry, at Rs. 1 per 100	139·03
„	8,071	Kunkur masonry, at Rs. 20 per 100	1,794·2
Lineal feet	120	Girder bridge, at Rs. 90·21 per foot	10,825·00
		Towing-path	377·3
		Grand Total	13,135·53

Digitized by Google

ESTIMATE No. 53.—FALLS AT BURROWLEE AND CHUNGEYREE.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Foundations.							
Waterings up-stream ...	2	25	5	8	2,000		
Curtain	2	16	3	5	480		
Drop walls	2	16	3	9·14	877·44		
„	2	16	3	4	384		
Curtains under lower gates	4	16	3	3	576		
Sides of wells	2	14	6	4	672		
Abutments of gates up-stream	2	16·5	6·5	8	1,716		
„ „ down-stream	2	16·5	11	2·5	907·50		
Side walls of locks ...	2	106	8	2·5	4,240		
Abutments of bridge ..	2	3	6	2·5	90		
Side walls down-stream ...	2	50	6	2·5	1,500		
Flooring up-stream ...	2	16	17	3	1,632		
„ of well	2	16	7·25	3	696		
„ under gates ...	2	16	10·5	2·5	840		
Backing of inverts ...	2	168·5	16	1·75	9,436		
Division wall of lock ...	2	18	7	8	2,016		
„ „ sides of well	2	14	7	12·14	2,379·44		
„ „ of lock ...	2	83	7	8	9,296		
„ „ „ ...	2	67	7	5·5	5,159		
Drop wall of fall	...	123	5·5	10·64	7,197·96		
Curtain of fall	...	123	3	4	1,476		
„ „	...	123	3	1·5	553·50		
Flooring of fall	...	123	61	1·5	11,254·50		
Wells in curtain of fall ..	15	14·12	1·5	7	2,223·90		
„ walls of basin ...	34	14·12	1·5	9	6,481·08		
„ division walls ...	3	18·8	2	9	1,015·20		
		Area.					
Covering of wells in curtain	15	7·06		1·5	158·85		
„ „ division wall	...	21	7	2	294		
„ „ of basin	2	120	6	2	2,880		
						78,432·37	
Deduct—							
Brick-on-edge.							
Lock flooring	2	16	17	1	544		
„	2	16	7·25	1	232		
„	2	16	10·5	1	336		
Flooring of fall	...	123	61	1	7,503		
Tops of drop wall and curtain	...	123	8	1	984		
Waterings up-stream ...	2	25	1·5	4	300		
						9,899	
							68,533
Superstructure.							
Waterings up-stream ...	2	25	3	11	1,650		
Abutments of gates up-stream	2	16·5	6	11	2,178		
„ „ down-stream	2	16·5	8·5	16·14	4,527·27		
„ of bridges ...	2	3	5	11	330		
„ „ ...	2	3	3	9·5	171		
Counterforts	2	3	3·5	8	168		
Wing-walls of bridge ...	2	12	2·5	9	540		
Side walls down-stream ...	2	50	3	11	3,300		
Carried over ...	...	...	...	...	12,864·27		

Digitized by Google

ESTIMATE No. 53.—FALLS AT BURROWLEE AND CHUNGEYREE,—*continued.*

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Brought forward ...	...	...	...	...	12,864·27		
Superstructure—contd.							
Side walls of locks ...	2	112·5	5·5	16·14	19,973·25		
Division wall of locks ...	2	115	7	11	17,710		
" " " ...	2	35	7	16·14	7,908·60		
" " " ...	2	53	7	11	8,162		
Piers	6	31	3	20·14	11,238·12		
"	6	5	3	11	990		
Steps	2	10	7	2	280		
"	2	3	3	1·5	27		
Backing of arches... ...	7	15	3	1	315		
" "	2	18	3	1	108		
Retaining walls down-stream	2	120	3	11	7,920		
						87,496·24	
Hollow walls	2	90	2	14	5,040		
"	2	28	2	14	1,568		
"	2	50	2	12	2,400		
From piers	6	24	3	9.14	3,948·48		
Arches of piers	6	34	3	1·5	918		
						13,874·48	
							73,622
Arch-work.							
Inverts	2	168·5	16·5	1·5	8,340·75		
						8,341	
							8,341
Arches of fall	7	16	3	1	336		
" " lock	2	19	3	1	114		
" under piers ...	6	34	3	1·5	918		
						1,368	
							1,368
Brick-on-edge.							
Lock flooring	2	16	17	1	544		
" "	2	16	7·25	1	232		
" "	2	16	10·5	1	336		
Flooring of fall	...	123	61	1	7,503		
Tops of drop wall and curtain	...	123	8	1	984		
Roadway of bridge ...	...	173	3	·5	259·50		
						9,858	
							9,858
Concrete	...	123	67	3	24,723		
						24,723	
							24,723
Puddle	...	123	2·5	8	2,460		
"	2	75	2	15	4,500		
"	2	50	2	11	2,200		
						9,160	
							9,160
Kunkur flooring	...	123	15	2	3,690		
						3,690	
							3,690
Well sinking (*small*) ...	...	465	...	...	465		
						465	
							465
Excavation Basin	...	123	61	4	30,012		
Add foundations	...	...	...	...	78,432		
						108,444	
							108,444

Digitized by Google

ESTIMATE No. 53.—FALLS AT BURROWLEE AND CHUNGEYREE,—*continued.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Pitching Slopes	2	50	24	1	2,400	2,400	2,400
Lock gates	4	9·54	{ 9.5 / 14·64 }		921·18	921	921
Pulleys	8	...	...	...	8	8	8
Crabs	8	...	...	...	8	8	8
Sluices	8	...	...	...	8	8	8
Chain	4	25·5	...	...	102		
	4	27·5	...	...	110	212	212
Grating	7	15	27	...	2,835	2,835	2,835
Girders	21	17	...	...	357	357	357
Wall plates...	7	15	...	...	105	105	105

ABSTRACT OF COST OF ESTIMATE No. 53.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	68,533	Kunkur masonry in foundations, at Rs. 17 per 100 ...	11,650·61
„	49,540	„ „ superstructure, at Rs. 19 per 100 ...	9,412·60
„	24,082	Brick-work, at Rs. 22 per 100	5,298·01
„	1,368	Arch-work, light, at Rs. 26 per 100	355·68
„	8,341	„ inverts, at Rs. 26 per 100	2,168·66
„	9,858	Brick-on-edge, at Rs. 25 per 100	2,464·50
„	24,723	Concrete, at Rs. 14 per 100	3,461·22
„	9,160	Puddle, at Rs. 10 per 1000	91·60
„	3,690	Kunkur flooring, "dry," at Rs. 8 per 100	295·50
Lineal feet	465	Well sinking, at Rs. 5 per foot	2,325·00
No.	55	Crabs, at Rs. 20 each	1,100·00
Cubic feet	108,444	Excavation, at Rs. 2·5 per 1000	271·11
„	2,400	Pitching, at Rs. 10 per 100	240·00
Square feet.	921	Lock gates, at Rs. 6·5 per foot	5,986·50
No.	8	Pulleys, at Rs. 5 each	40·00
„	8	Crabs, at Rs. 135 each	1,080·00
„	8	Sluices, at Rs. 125 each	1,000·00
Lineal feet.	212	Chain, at Re. 1 per foot	212·00
No.	57	Sleepers, at Rs. 11,625 each	662·62
Square feet	2,835	Grating, at Rs. 1·15 per foot	3,260·25
Lineal feet	357	Girders, at 4·25 per foot	1,517·25
„	195	Wall-plates, at Rs. 6·25 per foot...	656·25
No.	2	Sleeper hooks, at Rs. 7 each	14·00
		Grand Total	53,563·09

Digitized by Google

ESTIMATE No. 54.—HUSIMPOOR FALLS.

Description.	Cost.
	Rs.
Vide Estimate No. 53	53,563·09
Additional for curtain down-stream, two-thirds of that at Moonda Khan, *vide* Estimate 46·$\frac{2}{3}$ × 1,423 = ...	948·66
Grand Total	54,511·75

ESTIMATE No. 55.—ADDITIONS TO SIMRA FALLS.

Description of Works.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old Masonry,							
At head of lock channel, lock bridge, and tail walls as Estimate No. 50 ...	...	...	...	...	...	...	34,126
Masonry.							
On lock, *vide* Estimate No. 50	...	...	...	...	3,123		
Raising up-stream water-wings	2	14	4	4·5	504		
„ chamber walls ...	6	26	4	5	3,120		
New piers, Drop wall { *vide* Estimate No. 50 ... }	...	...	...	...	9,257		
Lock bridge, *vide* Estimate No. 17	...	...	...	...	1,542·59	17,546·59	
Deduct—							
From piers	5	14	3	3	630		
„	5	Area. 113·49	3	...	1,702·36	2,332·35	15,214
Archwork							
In lock, *vide* Estimate No. 17	...	...	...	...	504		
In piers	5	24·34	3	1·5	547·65	1,052	1,052

ABSTRACT OF COST OF ESTIMATE No. 55.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	34,126	Demolition, old masonry, at Re. 1 per 100	341·26
„	11,414	Kunkur masonry, at Rs. 17 per 100	1,940·38
„	3,800	Brick-work, at Rs. 22 per 100	836·00
„	1,050	Archwork, at Rs. 26 per 100	273·52
		Excavation, as Estimate No. 50	727·76
		Stone flooring „ „	3,000·00
		Pitching slopes „ „	150·00
		Rajbuha head	1,410·78
		Grating, &c.	3,271·80
		Grand Total	11,951·50

Digitized by Google

ESTIMATE No. 56.—ADDITIONS TO KASUNPOOR BRIDGE.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old masonry.							
Vide Estimate No. 58	...	...	...	...	...	...	10,753
Masonry, as Estimate No. 58 ...	...	...	...	...	5,191		
Raising ghats ...	2	416	2	3·6	5,990·4		
						11,181	
							11,181

ABSTRACT OF COST OF ESTIMATE No. 56.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	10,753	Demolition, old masonry, at Re. 1 per 100	107·53
"	11,181	Kunkur masonry, at Rs. 20 per 100	2,236·20
Lineal feet	120	Girder bridge, at Rs. 90·21 per foot	10,825·00
		Towing-path	377·30
		Grand Total	13,546·03

ESTIMATE No. 57.—ADDITIONS TO BAROTHA AND SHEKLA BRIDGES.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old masonry.							
Arches	3	43	25	2·5	8,062·50		
Spandrils ... / Parapets ... / Pillars ... } *vide* Estimate No. 52 ...	...	...	...	...	3,980·46		
Flooring	3	40	25	1·25	3,750		
						15,792·96	
Masonry.							15,793
Raising pier and abutments	4	27	5	9·5	5,130		
Parapets / Pillars / Wings / Parapets on piers } *vide* Estimate No. 52...	...	...	...	...	821·06		
Flooring	3	40	25	1·5	4,500		
						10,451	
							10,451

ABSTRACT OF COST OF ESTIMATE No. 57.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	15,793	Demolition, old masonry, at Re. 1 per 100	157·93
"	10,451	Masonry, at Rs. 20 per 100	2,090·20
Lineal feet	120	Girder bridge, at Rs. 94·35 per foot	11,322·00
		Towing-path	466·25
		Grand Total	14,036·38

Digitized by Google

ESTIMATE No. 58.—ALTERATIONS TO DUOPOOR AND MACHOOA BRIDGES.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, old masonry.							
Vide Estimate No. 52 ...	...	...	...	...	13,903		
Deduct flooring	...	...	...	...	3,150		
						10,753	
Masonry.							10,753
Vide Estimate No. 52 ...	...	...	...	...	3,971		
Deduct flooring	...	...	...	...	8,780		
						5,191	
							5,191

ABSTRACT OF COST OF ESTIMATE No. 58.

Quantity.		Description.	Cost.
			Rs.
Cubic feet.	10,753	Demolition, old masonry, at Rs. 1 per 100	107·53
„	5,191	Kunkur masonry, at Rs. 20 per 100	1,038·20
Lineal feet	120	Girder bridge, at Rs. 90·21 per foot	10,825·00
		Towing-path	377·30
		Grand Total	12,348·03

ESTIMATE No. 59.—ADDITIONS, &c. TO NUNOON REGULATOR.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition.							
Flooring	5	31·56	20	15	4,734		
						4,734	
Masonry.							4,734
Flooring ...	5	31·56	20	2	6,312·0		
„ ...	3	20	2	2	240·0		
Lock walls ...	3	150	6	15·75	42,525·0		
„ ...	...	127·5	4	5·75	2,932·5		
„ ...	...	127·5	3	10	3,825·0		
Thickening of wall at gates	...	14	3	15·75	661·5		
Lock walls under bridge ...	3	14	2	10	840·0		
„ on ghats ...	2	80	3	10	4,800·0		
Flooring of lock	3	150	17	2	15,300·0		
Curtains	3	16	2	3·75	360·0		
Drop walls of locks ...	2	16	2	6	384·0		
„ ...	2	16	2	4	256·0		
Piers	7	17	2·5	10	2,975·0		
Water-wings	...	18	4	5·75	414·0		
„	...	18	2	10	360·0		
Deduct—					82,185		
Hollow parts of lock ...	3	100	11	2	6,600		
						75,585	
							75,585

Digitized by Google

ESTIMATE [illegible] TO NUNOON REGULATOR,—*continued.*

[illegible]	No.	L.	B.	D.	QUANTITY.	TOTAL.	GRAND TOTAL.
Stone grooves	[illegible]	[illegible]	...	...	140	140	140
Lock gates	2	9·54	...	[illegible]	400·68		
	4	9·54	...	9·5	362·52	763·20	763
Sál Timber. Grating supports	14	10·75	·75	·75	84·65	85	85
Grating	14	8·75	12	...	1,470	1,470	1,470
Gates, wooden	8	92·5	9·5	...	703	703	703

ABSTRACT OF ESTIMATE No. 59.

QUANTITY.		DESCRIPTION.	TOTAL.
			Rs.
Cubic feet	4,734	Demolition, at Re. 1 per 100	47·34
„	50,390	Kunkur masonry, at Rs. 17 per 100	8,566·30
„	25,195	Brick masonry, at Rs. 20 per 100	5,039·00
		Regulating Gear.	
Lineal feet	140	Stone grooves, at Re. 1 per foot...	140·00
Cubic feet	85	Sál Timber, at Rs. 3 per foot	255·00
Square feet	1,470	Grating, at Re. 1·15 per foot	1,690·50
„	703	Gates, at Re. 1·25 per foot	878·50
Number	14	Windlasses, at Rs. 22 each	308·00
„	3	Axle blocks, at Rs. 5 each	15·00
		Lock Gear.	
Square feet	763	Lock gates, at Rs. 6·5 per foot	4,959·50
Number	12	Sluices, at Rs. 125 each	1,500·00
„	12	Pulleys, at Rs. 5 each	60·00
„	12	Crabs, at Rs. 135 each	1,620·00
Lineal feet	318	Chain, at Re. 1 per foot	318·00
			25,397·39

Digitized by Google

ESTIMATE No. 60.—ALTERATIONS, &c., TO KEYLUMPOOR BRIDGE.

CAWNPOOR BRANCH.

DESCRIPTION.	No.	L.	B.	D.	QUANTITY.	TOTAL.	GRAND TOTAL.
Demolition.							
Arches	3	35	21	2·5	5,512·5		
Spandrils	12	18·75	2·5	2·5	1,406·25		
Parapets	2	108	15	3	972		
Ogees	3	33	5	3	1,485		
						9,375·75	
Masonry.							9,376
Raising piers and abutments	4	21	4·5	6·5	2,457		
Parapets on piers	4	45	1·5	3	81		
Flooring	3	33	8	0·5	396		
						2,934	
							2,934

ABSTRACT OF ESTIMATE No. 60.

QUANTITY.		DESCRIPTION.	TOTAL.
			Rs.
Cubic feet	9,376	Demolitions, at Re. 1 per 100	93·76
"	2,934	Kunkur masonry, at Rs. 19 per 100	557·46
Lineal feet	99	Girder bridge, at Rs. 74·14 per foot	7,339·86
		Towing-path	327·30
		GRAND TOTAL	8,318·38

ESTIMATE No. 61.—ALTERATIONS, BRIDGES, 3 ARCHES OF 33′—18′ ROAD-WAY.

DESCRIPTION.	No.	L.	B.	D.	QUANTITY.	TOTAL.	GRAND TOTAL.
Demolitions, vide Estimate, No. 60, deduct Ogee ...	...	...	...	...	...	...	7,891
Masonry, vide Estimate, No. 60, deduct Flooring...	...	...	...	...	...	...	2,538

ABSTRACT OF ESTIMATE No. 61.

QUANTITY.		DESCRIPTION.	TOTAL.
			Rs.
Cubic feet	7,891	Demolitions, at Re. 1 per 100	78·91
"	2,538	Kunkur masonry, at Rs. 19 per 100	482·22
Lineal feet	99	Girder Bridge, at Rs. 74·14 per foot	7,339·86
		Towing-path	327·30
		GRAND TOTAL	8,228·29

ESTIMATE No. 62.—ALTERATIONS, BRIDGES OF 3 ARCHES OF 33′—20′ ROAD-WAY.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, Arches	3	35	23	2·5	6,037·50		
Spandrils ... Parapets ...	*vide* Estimate, No. 60 ...				2,378·25		
						8,415·75	8,416
Masonry, Raising piers and abutments ...	4	23	4·5	6·5	2,691		
Parapets on piers, *vide* Estimate, No. 60 ...	...	...	...	...	81		
						2,772	2,772

ABSTRACT OF ESTIMATE No. 62.

Quantity.		Description.	Total.
			Rs.
Cubic feet	8,416	Demolitions, at Re. 1 per 100	84·16
"	2,772	Kunkur masonry, at Rs. 19 per 100	526·68
Lineal feet	99	Girder bridge, at Rs. 75·98 per foot	7,522·02
		Towing-path	368·50
		Grand Total	8,501·36

ESTIMATE No. 63.—ALTERATIONS, BRIDGES, 3 ARCHES OF 32′—18′ ROAD-WAY.

Quantity.		Description.	Total.
			Rs.
		Demolition and masonry, *vide* Estimate, No. 61 ...	561·13
Lineal feet	96	Girder bridge, at Rs. 74·14 per foot	7,117·44
		Towing-path	327·30
		Grand Total	8,005·87

ESTIMATE No. 64.—ALTERATIONS, BRIDGE, 3 ARCHES OF 31′—18′ ROAD-WAY.

Quantity.		Description.	Total.
			Rs.
		Demolitions and masonry, *vide* Estimate No. 61 ...	561·13
Lineal feet	93	Girder bridge, at Rs. 74·14 per foot	6,895·02
		Towing-path	327·30
		Grand Total	7,783·45

Digitized by Google

ESTIMATE No. 65.—1 BRIDGE, 3 OF 30′—18′ ROAD-WAY.

Quantity.		Description.	Cost.
Lineal feet	90	Demolition, masonry *Vide* Estimate No. 61 ... ... Girder bridge, at Rs. 74·14 per foot ... ... Towing-path	561·13 6,672·60 377·30
		Grand Total	7,611·03

ESTIMATE No. 66.—1 BRIDGE, 3 OF 30′—20′ ROAD-WAY.

Quantity.		Description.	Cost.
Lineal feet	90	Demolition, masonry, *Vide* Estimate No. 62 ... ... Girder bridge, at Rs. 75·98 per foot ... ... Towing-path	610·84 6,838·20 368·50
		Grand Total	7,817·54

ESTIMATE No. 67.—1 BRIDGE 3 OF 29′—18′ ROAD-WAY.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, Arches ..	3	29	21	2·5	4,567·5		
Spandrils ...	12	16·75	2·5	2·5	1,256·25		
Parapets ..	2	96	1·5	3	864		
						6,687·75	
							6,688

ABSTRACT OF COST, ESTIMATE No. 67.

Quantity.		Description.	Cost.
Cubic feet	6,688	Demolition, at Re. 1 per 100	66·88
		Masonry, *vide* Estimate No. 61	482·22
Lineal feet	87	Girder bridge, at Rs. 74·14 per foot	6,450·18
		Towing-path	327·30
		Grand Total	7,326·58

ESTIMATE No. 68.—1 BRIDGE, 3 OF 29′—20′ ROAD-WAY.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolitions. Arces ...	3	29	23	2·5	5,002·5		
Spandrils } *vide* Estimate } Parapets } No. 67 }	...	...	...	...	2,120·25		
						7,123	
							7,123

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 68.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	7,123	Demolition, at Re. 1 per 100	71·23
"	...	Masonry, *vide* Estimate No. 62	526·68
Lineal feet	87	Girder bridge, at Rs. 75·98 per foot	6,610·26
		Towing-path	368·50
		Grand Total	7,576·67

ESTIMATE No. 69.—2 BRIDGES, 3 OF 28′—18′ ROAD-WAY.

Quantity.		Description.	Cost.
			Rs.
		Demolition, Masonry, } *vide* Estimate No. 67	549·10
Lineal feet	84	Girder bridge, at Rs. 74·14 per foot	6,227·76
		Towing-path	327·30
		Grand Total	7,104·16

ESTIMATE No. 70.—1 BRIDGE, 3 OF 28′—20′ ROAD-WAY.

Quantity.		Description.	Cost.
			Rs.
		Demolition, Masonry, } *vide* Estimate No. 68	597·91
Lineal feet	84	Girder bridge, at Rs. 75·98 per foot	6,382·32
		Towing-path	368·50
		Grand Total	7,348·73

ESTIMATE No. 71.—1 BRIDGE, 3 OF 27′—18′ ROAD-WAY.

Quantity.		Description.	Cost.
			Rs.
		Demolition masonry, *vide* Estimate No. 67	549·10
Lineal feet	81	Girder bridge, at Rs. 74·14 per foot	6,005·34
		Towing-path	327·30
		Grand Total	6,881·74

Digitized by Google

ESTIMATE No. 72.—1 BRIDGE, 3 OF 17′—20′ ROAD-WAY.

Quantity.		Description.	Cost.
			Rs.
Lineal feet	81	Demolition, masonry, *vide* Estimate No. 68	597·91
		Girder bridge, at Rs. 75·98 per foot	6,154·38
		Towing-path	368·50
		Grand Total	7,120·79

ESTIMATE No. 73.—2 BRIDGES, 3 OF 26′—20′ ROAD-WAY.

Quantity.		Description.	Cost.
			Rs.
Lineal feet	78	Demolition, masonry, *vide* Estimate No. 68	597·91
		Girder bridge, at Rs. 75·98 per foot	5,926·44
		Towing-path	368·50
		Grand Total	6,892·85

ESTIMATE No. 74.—1 BRIDGE 3 OF 26′—25′ ROAD-WAY.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition, Arches	3	29	28	2·5	6,090		
Spandrils, Parapets } *vide* Estimate No. 67			...	...	2,120·25	8,210	8,210
Masonry.							
Raising Piers and Abutments	4	28	4·5	6·5	3,276		
Parapets on Piers, *vide* Estimate No. 60 ...			...	...	81	3,357	3,357

ABSTRACT OF COST OF ESTIMATE No. 74.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	8,210	Demolition, at Re. 1 per 100	82·10
"	3,357	Kunker masonry, at Rs. 19 per 100	637·83
Lineal feet	78	Girder bridge, at Rs. 80·58 per foot	6,285·24
		Towing-path	426·50
		Grand Total	7,431·67

Digitized by Google

ESTIMATE No. 75.—1 BRIDGE, 2 OF 35′—18′ ROAD-WAY.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolitions, Arches ...	2	35	21	2·5	3,675		
Spandrils ...	8	19·75	2·5	2·5	987·5		
Parapets ...	2	74·5	1·5	3	670·5		
						5,333	5,333
Masonry.							
Raising piers and abutments	3	21	4·5	6·5	1,842·75		
Parapets on piers	1	4·5	1·5	3	40·50		
						1,883	1,883

ABSTRACT OF COST OF ESTIMATE No. 75.

Quantity.		Description.	Grand Total.
			Rs.
Cubic feet	5,333	Demolition, at Re. 1 per 100	53·33
"	1,883	Kunker masonry, at Rs. 19 per foot	357·77
Lineal feet	70	Girder bridge at Rs. 74·14 per foot	5,189·80
		Towing-path	327·30
		Grand Total	5,928·20

ESTIMATE No. 76.—1 BRIDGE, 2 OF 35′—20′ ROAD-WAY,

Description of work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolitions Arches	2	35	23	2·5	4,025		
Spandrils, Parapets } *vide* Estimate No. 75			...	...	1,658		
						5,683	5,683
Masonry.							
Raising piers and abutments	3	23	4·5	6·5	2,018·25		
Parapets on piers *vide* Estimate No. 75 ...			...	...	40·50		
						2,059	2,059

ABSTRACT OF COST OF ESTIMATE No. 76.

Quantity.		Description.	Grand Total.
			Rs.
Cubic feet	5,683	Demolition, at Re. 1 per 100...	56·83
	2,059	Masonry, at Rs. 19 per foot	391·21
Lineal feet	70	Girder bridge, at Rs. 75·98 per foot	5,318·60
		Towing-path	368·50
		Grand Total	6,135·14

Digitized by Google

ESTIMATE No. 77.—3 BRIDGES, 2 OF 33′—18′ ROAD-WAY.

Quantity.		Description.	Cost.
			Rs.
		Demolition, Masonry, } *vide* Estimate No. 75	411·10
Lineal feet	66	Girder bridge, at Rs. 74·14 per foot	4,893·24
		Towing-path	327·30
		Grand Total	5,631·64

ESTIMATE No. 78.—2 BRIDGES, 2 OF 32′—18′ ROAD-WAY.

Quantity.		Description.	Cost.
			Rs.
		Demolition, Masonry, } *vide* Estimate No. 75	411·10
Lineal feet	64	Girder bridge, at Rs. 74·14 per foot	4,744·96
		Towing-path	327·30
		Grand Total	5,483·36

ESTIMATE No. 79.—1 BRIDGE, 2 OF 32′—20′ ROAD-WAY.

Quantity.		Description.	Cost.
			Rs.
		Demolition, Masonry, } *vide* Estimate No. 76	448·04
Lineal feet	64	Girder bridge, at Rs. 75·98 per foot	4,862·72
		Towing-path	368·50
		Grand Total	5,679·26

ESTIMATE No. 80.—5 BRIDGES, 2 OF 30′—18′ ROAD-WAY.

Quantity.		Description.	Cost.
			Rs.
		Demolition, Masonry, } *vide* Estimate No. 75	411·10
Lineal feet	60	Girder bridge, at Rs. 74·14 per foot	4,448·40
		Towing-path	327·30
		Grand Total	5,186·80

Digitized by Google

ESTIMATE No. 81.—3 BRIDGES, 2 OF 30′—20′ ROAD-WAY.

QUANTITY.		DESCRIPTION.	COST.
			Rs.
		Demolition, Masonry, } *vide* Estimate No. 76	448·04
Lineal feet	60	Girder bridge, at Rs. 75·98 per foot	4,558·80
		Towing-path	368·50
		GRAND TOTAL	5,375·34

ESTIMATE No. 82.—5 BRIDGES, 2 OF 25′—18′ ROAD-WAY.

QUANTITY.		DESCRIPTION.	COST.
			Rs.
		Demolition, Masonry, } *vide* Estimate No. 75	411·10
Lineal feet	50	Girder bridge, at Rs. 74·14 per foot	3,707·00
		Towing-path	327·30
		GRAND TOTAL	4,445·40

ESTIMATE No. 83.—1 BRIDGE, 2 OF 25′—20′ ROAD-WAY.

QUANTITY.		DESCRIPTION.	COST.
			Rs.
		Demolition, Masonry, } *vide* Estimate No. 76	448·04
Lineal feet	50	Girder Bridge, at Rs. 75·98 per foot	3,799·00
		Towing-path	368·50
		GRAND TOTAL	4,615·54

ESTIMATE No. 84.—ALTERATIONS, 4 BRIDGES, 2 ARCHES OF 25′—15′ ROAD-WAY.

DESCRIPTION.	No.	L.	B.	D.	QUANTITY.	TOTAL.	GRAND TOTAL.
Demolitions.							
Arches	2	2·5	18	2·5	2,250·0		
Spandrils	8	14·75	2·5	2·5	737·5		
Parapets	2	54·5	1·5	3	490·5		
						3,478	3,478
Masonry.							
Raising piers and abutments	3	18	4·5	6·5	1,579·5		
Parapets on piers, *vide* Estimate No. 75	...	...	...	...	40·5		
						1,620	1,620

ABSTRACT OF ESTIMATE No. 84.

Quantity.		Description.	Total.
			Rs.
Cubic feet	3,478	Demolition, at Re. 1 per 100	34·78
„	1,620	Masonry kunkur, at Rs. 19 per 100	307·80
Lineal feet	50	Girder bridge, at Rs. 71·38 per foot	3,569·00
		Towing-path	310·50
		Grand Total	4,222·08

ESTIMATE No. 85.—ALTERATIONS, 5 BRIDGES, 1 ARCH OF 30′, 18′ ROADWAY.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition.							
Arch	...	30	21	2·5	1,575		
Parapets	2	30	1·5	3	270		
						1,845	1,845
Masonry.							
Raising abutments ...	2	21	4·5	6·5	1,228·5		
						1,228	1,228

ABSTRACT OF ESTIMATE No. 85.

Quantity.		Description.	Total.
			Rs.
Cubic feet	1,845	Demolition, at Re. 1 per 100	18·45
„	1,228	Kunkur masonry, at Rs. 19 per 100	233·32
Lineal feet	30	Girder Bridge, at Rs. 74·14 per foot	2,224·20
		Towing-path	327·30
		Grand Total	2,803·27

ESTIMATE No. 86.—ALTERATIONS, BRIDGES 1 ARCH OF 30′, 20′ ROADWAY.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition.							
Arch	...	30	23	2·5	1,725		
Parapets	2	30	1·5	3	270		
						1,995	1,995
Masonry.							
Raising abutments... ...	2	21	4·5	6·5	1,345		
						1,345	1,345

Digitized by Google

ABSTRACT OF ESTIMATE No. 86.

Quantity.		Description.	Total.
			Rs.
Cubic feet	1,995	Demolition, at Re. 1 per 100	19·95
"	1,345	Kunkur masonry, at Rs. 19 per 100	255.55
Lineal feet	30	Girder bridge, at Rs. 75·98 per foot	2,279·40
		Towing-path	368·50
		Grand Total	2,923·40

ESTIMATE No. 87.—ALTERATIONS, BRIDGES, 1 ARCH OF 25′, 15′ ROADWAY.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition.							
Arch	...	25	18	2·5	1,125		
Parapets	2	25	1·5	3	225		
						1,350	
Masonry.							1,350
Raising abutments ...	2	18	4·5	6·5	1,053		
						1,053	
							1,053

ABSTRACT OF ESTIMATE No. 87.

Quantity.		Description.	Total.
			Rs.
Cubic feet	1,350	Demolition, at Re. 1 per 100	13·50
"	1,053	Kunkur masonry, at Rs. 19 per 100	200·07
Lineal feet	25	Girder bridge, at Rs. 71·38 per foot	1,784·50
		Towing-path	310·50
		Grand Total	2,308·57

ESTIMATE No. 88.—ALTERATIONS, 1 BRIDGE, 1 ARCH OF 25′,20′ ROADWAY.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolitions.							
Arch	...	25	23	2·5	1,437·5		
Parapets	2	25	1·5	3	225·0		
						1,662	
Masonry.							1,662
Raising abutments ...	2	23	4·5	6·5	1,345·5		
						1,345	
							1,345

Digitized by Google

ABSTRACT OF ESTIMATE No. 88.

Quantity.		Description.	Total.
			Rs.
Cubic feet	1,662	Demolition, at Re. 1 per 100	16·62
"	1,345	Kunkur masonry, at Rs. 19 per 100	255·55
Lineal feet	25	Girder Bridge, at Rs. 75·98 per foot	1,899·50
		Towing-path	368·50
		Grand Total	2,540·17

ESTIMATE No. 89.—ALTERATIONS AIMA BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Masonry	2	15	4·5	2·5	337	337	337

ABSTRACT OF ESTIMATE No. 89.

Quantity.		Description.	Total.
			Rs.
Cubic feet	337	Kunkur masonry, at Rs. 19 per 100	64·03
		Towing-path	310·50
		Grand Total	374·53

ESTIMATE No. 90.—ALTERATIONS UPPER RAILWAY BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Masonry.							
Raising abutments	2	33	4	2	528	528	528

ABSTRACT OF ESTIMATE No. 90.

Quantity.		Description.	Total.
			Rs.
Cubic feet	528	Kunkur masonry, at Rs. 19 per 100	100·32
		Towing-path for 25 feet roadway	426·50
Square feet	56	Add planking, 8 × 7, at Rs. 8 per foot	44·80
		Grand Total	571·62

Digitized by Google

ESTIMATE No. 91.—ALTERATIONS, DUBOWLEE BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolitions.							
Arch	...	22	21	1·5	693		
Parapet	2	72	2	1·5	432		
Abutments	2	23	5	8·5	1,955		
Pillars	4	3	3	2	72		
						3,152	
							3,152
Masonry.							
Filling passages	2	21	4	7	1,176		
Raising wing-walls ...	4	21	2·5	2	420		
„ Pillars	4	4	4	2	128		
Parapets	2	72	1·5	2	432		
Pillars	4	3	3	2	72		
						2,228	
							2,228
Arch-work	...	32	21	2	1,344		
						1,344	
							1,344

ABSTRACT OF ESTIMATE No. 91.

Quantity.		Description.	Total.
			Rs.
Cubic feet	3,152	Demolition, at Re. 1 per 100	31·52
„	2,228	Kunkur masonry, at Rs. 19 per 100	423·32
„	1,344	Arch-work, at Rs. 26 per foot	349·44
		Grand Total	804·28

ESTIMATE No. 92.—ALTERATIONS DUBOWLEE LOCKS.

Quantity.		Description.	Cost.
			Rs.
Vide Estimat	e No. 149	Navigable Line	22,175·19
		Grand Total	22,175·19

ESTIMATE No. 93.—ALTERATIONS, DAKNAPOOR BRIDGE AND OTHERS.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolitions.							
Flooring	...	20	20	1	400		
Curtains	2	20	2	2	160		
Part of waterwings ...	2	10	4	2	160		
						720	
							720
Masonry.							
Flooring	...	20	20	1	400		
Curtains	2	20	2	2	160		
Underpinning abutments...	2	20	3	3	360		
„ „ ...	2	20	1·5	1·38	82·80		
Underpinning waterwings...		28	2	2	448		
						1.451	
							1,451

Digitized by Google

ABSTRACT OF ESTIMATE No. 93.

Quantity.		Description.	Total.
			Rs.
Cubic feet	720	Demolitions, at Re. 1 per 100	7·20
„	1,451	Kunkur masonry, at Rs. 19 per 100	275·69
		Tow-path.	
Number	4	Iron uprights, at Rs. 8 each	32·00
Square feet	56	Planking, at Rs. 8 per foot	44·80
		Grand Total	359·69

ESTIMATE No. 94.—ALTERATIONS, GHATS AT CAWNPOOR.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total
Masonry.							
Underpinning Ghats ...	2	285	2	2	2,280		
	2	410	2	2	3,280		
						5,560	
							5,560

ABSTRACT OF ESTIMATE No. 94.

Quantity.		Description.	Total.
			Rs.
Cubic feet	5,560	Masonry, at Rs. 19 per 100	1,056·4
		Grand Total	1,056·4

ESTIMATE No. 95.—No. 1 LOCK.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolitions.							
Upper flooring of lock ...	...	22	32	1·5	1,056		
Drop-wall	...	32	3	3·5	336		
Curtain	...	45	2	4·5	405		
Counterforts ...	2	7	4	3·5	196		
						1,993	
Masonry.							1,993
Curtain	...	45	3	2	270		
Flooring	...	22	32	1	704		
						974	
							974
Brick-on-edge.	...	22	32	0·5	352		
						352	
							352

ABSTRACT OF COST OF ESTIMATE No. 95.

Quantity.		Description of Work.	Cost.
			Rs.
Cubic feet.	1,993	Demolitions, at Re. 1 per 100	19·93
„	974	Kunkur masonry, at Rs. 19 per 100	185·06
„	352	Brick-on-edge, at Rs. 25 per 100	88·00
		Grand Total	292·99

Digitized by Google

ESTIMATE No. 96.—GENERAL GUNJ BRIDGE.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition.							
Arch	...	22	23	1·5	759		
Parapets	2	80	1·5	2·5	600		
						1,359	1,359
Masonry.							
Raising abutments... ...	2	25	4	2	400		
„ wings	4	26	2·5	2	520		
Parapets	4	30	1·5	2·5	450		
						1,370	1,370

ABSTRACT OF COST OF ESTIMATE No. 96.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	1,359	Demolitions, at Re. 1 per 100	13·59
	1,370	Kunkur masonry, at Rs. 19 per 100	260·30
Lineal feet	20	Girder bridge, at Rs. 75·98 per foot	1,519·60
		Tow-path	76·80
		Grand Total	1,870·29

ESTIMATE No. 97.—LOCK No. 3.

Description of Work.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolitions.							
Arches	2	16	20	1	640		
Parapets	4	18	1·5	2	216		
„	...	19·5	1·5	2	58·5		
						914	914
Masonry.							
Abutments	2	20	4·5	2	360		
Centre walls	...	20	13	2	520		
Parapets	4	18	1·5	2	216		
„	...	19·5	1·5	2	58·5		
						1,154	1,154
Arch-work	2	16	20	1	640		
						640	640

ABSTRACT OF COST OF ESTIMATE No. 97.

Quantity.		Description of Work.	Cost.
			Rs.
Cubic feet	914	Demolitions, at Re. 1 per 100	9·14
„	1,154	Kunkur masonry, at Rs. 19 per 100	219·26
„	640	Arch-work, at Rs. 26 per 100	166·40
		Grand Total	394·80

J. CROFTON, *Captain, R. E.*

Digitized by Google

GANGES CANAL.

ALTERNATIVE LINE.

ABSTRACT OF COST OF ESTIMATE No. 98.—EXCAVATION, &c.

Quantity.		Description.	Costs.
		1st Section.	Rs.
Cubic feet	455,134,834	Excavation canal channel, at Rs. 2·75 per 1,000 ...	12,51,620·79
,,	53,525,227	Embankment Kalee Nuddee, upper and lower crossings, at Rs. 8 per 1,000	4,28,201·81
,,	32,314,880	Excavation on junction, at Rs. 2·5 per 1,000 ...	80,787·20
,,	8,717,457	,, Kalee Nuddee escape, at Rs. 2·5 per 1,000	21,793·64
,,	4,200,000	Extra excavation, widening at bridges, &c., at Rs. 2·5 per 1,000	9,240·00
,,	125,292	Rubble masonry wall in embankment, upper Kalee Nuddee crossing, at Rs. 14 per 100	17,540·88
,,	705,516	Ditto ditto ditto	98,772·24
		2nd Section.	
,,	173,548,968	Excavation canal channel, at Rs. 2·5 per 1,000 ...	4,33,872·42
,,	25,881,232	Escape into the Hindun Nuddee, at Rs. 2·5 per 1,000	64,703·08
,,	1,305,000	Widening at bridges, falls, &c., at Rs. 2·2 per 1,000 ...	2,871·00
		3rd Section.	
,,	151,288,356	Excavation canal channel, at Rs. 2·5 per 1,000 ...	378,220·89
,,	1,252,800	Widening at bridges, falls, &c., at Rs. 2·2 per 1,000	2,756·16
		4th Section.	
,,	84,886,493	Excavation canal channel, at Rs. 2·5 per 1,000 ...	212,216·23
,,	584,400	Widening at bridges, falls, &c., at Rs. 2·2 per 1,000...	1,285·68
		Grand Total	30,03,882·02

ABSTRACT OF COST OF ESTIMATE No. 99.—REGULATOR AT ROORKEE.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	96,344	Brick-work in lime cement, at Rs. 20 per 100 ...	19,268·80
,,	59,927	,, in superstructure, at Rs. 20 per 100 ...	11,985·40
,,	81.958	,, ,, at Rs. 24 per 100 ...	19,669·92
,,	16,011	Arching, at Rs. 28 per 100	4,483·08
,,	7,587	Inverts, at Rs. 26 per 100	1,972·62
,,	7,680	Boulder floorings (dry), at Rs. 7 per 100	537·60
,,	8,100	Metalling roadway, at Rs. 6 per 100	486·00
,,	129,032	Excavation foundations, at Rs. 3·25 per 1,000 ...	419·35
,,	1,800,000	,, drainage cut, at Rs. 2·2 per 1,000 ...	3,960·00
,,	9,648	Stone flooring, at Rs. 2 per foot	19,296·00
Lineal feet	1,008	Stone grooves, at Re. 1 per foot	1,008·00
		Lock Apparatus.	
Square feet	992·16	Lock gates, at Rs. 6·5 per foot	6,449·04
Number	8	Sluices in gates, at Rs. 125 each	1,000·00
,,	8	Pulleys, &c., at Rs. 5 each	40·00
,,	8	Crabs, at Rs. 135 each	1,080·00
Lineal feet	214	Chains, at Re. 1 per foot	214·00
		Regulating Bridge Apparatus.	
Square feet	2,279	Gates, at Re. 1·25 per foot	2,848·75
Number	47	Axle blocks, at Rs. 5 each	235·00
,,	45	Windlasses, at Rs. 22 each	990·00
Lineal feet	765	Chains, at Re. 0·9 per foot	688·50
		Grand Total	96,632·06

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 100.—JUNCTION REGULATOR.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	98,972	Brick-work in foundations, at Rs. 20 per 100 ...	19,794·40
"	32,515	" in superstructure, at Rs. 20 per 100 ...	6,503·00
"	62,436	" " at Rs. 24 per 100 ...	14,984·64
"	16,257	Kunkur masonry " at Rs. 17 per 100 ...	2,763·69
"	31,218	" " at Rs. 20 per 100 ...	6,243·60
"	685	Arch-work, light, at Rs. 28 per 100	191·80
"	21,042	" heavy, at Rs. 32 per 100	6,733·44
"	2,760	" inverts, at Rs. 26 per 100	717·60
"	16,402	Brick-on-edge, at Rs. 25 per 100	4,123·00
"	1,027	Stone capping, at Rs. 2 per foot	2,054·00
"	48,825	Concrete, at Rs. 14 per 100	6,835·50
Lineal feet	456	Stone grooving, at Re. 1 per foot	456·00
Cubic feet	8,550	Kunkur flooring (dry), at Rs. 8 per 100	684·00
"	7,920	Metalling, at Rs. 6 per 100	475·20
"	21,373	Puddle, at Rs. 10 per 1,000	213·73
"	180,797	Earth-work, at Rs. 3·25 per 1,000	587·59
Square feet	443·8	Lock-gates, at Rs. 6·5 per foot	2,884·70
Number	4	Sluices, at Rs. 125 each	500·00
"	4	Pulleys, at Rs. 5 each	20·00
"	4	Crabs, at Rs. 135 each	540·00
Lineal feet	106	Chain, at Re. 1 per foot	106·00
Number	144	Sleepers, at Rs. 5·55 each	799·20
"	4	Hooks, at Rs. 7 each	28·00
Square feet	5,415	Grating, at Rs. 11·5 per foot...	6,227·25
Lineal feet	684	Girders, at Rs. 4·25 per foot	2,907·00
"	190	Wall plates, at Rs. 6·25 per foot	187·50
		Grand Total	88,560·84

ABSTRACT OF COST OF ESTIMATE No. 101.—FALLS 6′, 11 BAYS OF 15′, ROADWAY 18′.

Quantity.		Description.		Cost.
				Rs.
Cubic feet	100·999	Brick-work in foundations, at Rs. 20 per 100 ...		20,199·80
"	50,193	" in superstructure, at Rs. 20 per 100 ...		10,038·60
"	85,958	" " at Rs. 24 per 100 ...		20,629·92
"	13,734	Arch-work, heavy, at Rs. 32 per 100		4,394·88
"	645	" light, at Rs. 28 per 100		180·60
"	11,946	Inverts, at Rs. 26 per 100		3,105·96
"	14,632	Brick-on-edge, at Rs. 25 per 100		3,658·00
"	799	Stone capping, at Rs. 2 per foot		1,598·00
"	39,900	Concrete, at Rs. 14 per 100		5,586·00
Lineal feet	264	Stone grooving, at Re. 1 per foot		264·00
"	7,600	Kunkur flooring (dry), at Rs. 8 per foot		608·00
"	23,903	Puddle, at Rs. 10 per 1,000		239·03
"	153,496	Earth-work, at Rs. 3·25 per 1000		498·86
"	5,400	Metalling, at Rs. 6 per 100		324·00
Square Feet	992·16	Lock Gates, at Rs. 6·5 per foot	Lock Apparatus.	6,449·04
Number	8	Sluices, at Rs. 125 each	Lock Apparatus.	1,000·00
"	8	Pulleys, at Rs. 5 each	Lock Apparatus.	40·00
"	8	Crabs, at Rs. 135 each	Lock Apparatus.	1,080·00
Lineal feet	220	Chain, at Re. 1 per foot		220·00
Number	60	Sleepers 15′ × 5′ × ·5, at Rs. 11·625 each		697·50
"	2	Hooks for lifting sleepers, at Rs. 7 each ...	Fall.	14·00
Square feet	4,762·5	Grating, at Re. 1·15 per foot	Fall.	5,607·87
Lineal feet	561	Girders, at Rs. 4·25 per foot	Fall.	2,384·25
"	165	Wall-plates, at 6·25 per foot	Fall.	1,031·25
		Grand Total		89,649·56

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 101.—GRATING OF FALLS ON 1st SECTION.

Quantity.		Description.	Cost.
		Gratings for falls.—Bay 15 *feet wide ; depth of water* 10 *feet ; Kurries* 0·2 *apart (average)*	Rs.
Number	22	Sal kurries 30′ × ·5 × ·5, at Rs. 22·5 each ...	495·00
		Horizontal area of grating ; 28·5 × 15=4 27·5 or 1·5 per superficial foot of grating.	
	37 × 30=	1,110 lineal feet iron bars ·15 apart (average) ·875 lineal feet=Rs. 2·27 per superficial foot, horizontal...	971·25

ABSTRACT OF COST OF ESTIMATE No. 102.—FALLS 6′, 11 BAYS OF 15′, ROADWAY 20′.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	101,407	Brick-work in foundations, at Rs. 20 per 100 ...	20,281·40
„	50,193	„ „ superstructure, at Rs. 20 per 100 ...	10,038·60
„	88·429	„ „ „ at Rs. 24 per 100 ...	21,222·96
„	15,042	Arch-work, heavy, at Rs. 32 per 100	4,813·44
„	645	„ light, at Rs. 28 per 100	180·60
„	12,558	Inverts, at Rs. 26 per 100	3,265·08
„	14,632	Brick-on-edge, as Estimate No. 101, at Rs. 25 per 100	3,658·00
„	799	Stone capping, as Estimate No. 101, at Rs. 2 per foot	1,598·00
„	39,900	Concrete, as Estimate No. 101, at Rs. 14 per 100 ...	5,586·00
Lineal feet	264	Stone grooving, as Estimate No. 101, at Re. 1 per foot	264·00
Cubic feet	7,600	Kunkur flooring, dry, as Estimate No. 101, at Rs. 8 per 100	608·00
„	6,075	Metalling, at Rs 6 per 100	364·50
„	23,903	Puddle, as Estimate No. 101, at Rs. 10 per 1,000 ...	239·03
„	153·496	Earth-work, as Estimate No. 101, at Rs. 3·25 per 1,000	498·86
		Lock apparatus, gratings, &c. ... } as per Estimate No. 101	8,789·04 9,534·87
		Grand Total	90,942·38

ABSTRACT OF COST OF ESTIMATE No. 103.—FALL 6′, 6 BAYS OF 14′ (ON JUNCTION).

Quantity.		Description.	Cost.
			Rs.
Cubic feet	86,380	Kunkur masonry in foundations, at Rs. 17 per 100...	14,684·60
„	6,555	„ „ superstructure, at Rs. 17 per 100...	1,114·35
„	19,617	„ „ at Rs. 20 per 100	3,933·40
„	13,112	Brick-work, at Rs. 20 per 100	2,622·40
„	39·336	„ at Rs. 24 per 100	9,440·64
„	5,616	Arch-work, heavy, at Rs. 32 per 100	1,797·12
„	387	„ light, at Rs. 28 per 100	108·36
„	5,520	„ inverts, at Rs. 26 per 100	1,435·20
„	10,794	Brick-on-edge, at Rs. 25 per 100	2,698·5
„	406	Stone capping, at Rs. 2 per foot	812·00
„	20,265	Concrete, at Rs. 14 per 100	2,837·10
		Carried over ...	41,483·67

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 103,—*continued.*

Quantity.		Description.	Cost.
			Rs.
		Brought forward ...	41,483·67
Lineal feet	108	Stone grooving, at Re. 1 per foot	108·00
Cubic feet	3,860	Kunkur flooring, dry, at Rs. 8 per 100	308·80
„	5,400	Metalling, at Rs. 6 per 100	324·00
„	16,610	Puddle, at Rs. 10 per 1,000	166·10
„	126,607	Earth-work, at Rs. 3·25 per 1,000	411·47
Square feet	763·2	Wall gates, at Rs. 6·5 per foot	4,960·80
Number	8	Sluices, at Rs. 125 each	1,000·00
„	8	Pulleys, at Rs. 5 each...	40·00
„	8	Crabs, at Rs. 135 each	1,080·00
Lineal feet	220	Chain, at Re. 1 per foot	220·00
Number	28	Sleepers, at Rs. 10·875 each	304·50
„	2	Hooks, at Rs. 7 each	14·00
Square feet	1,638	Grating, at Re. 1·15 per foot...	1,883·70
Lineal feet	192	Girders, at Rs. 45 per foot	864·00
„	84	Wall-plates, at Rs. 6·5 per foot	546·00
		Grand Total	53,715·04

ABSTRACT OF COST OF ESTIMATE No. 104.—FALL, ESCAPE, AND DAM BRIDGE AT THE 51st MILE.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	172,480	Brick-work in foundation, at Rs. 20 per 100 ...	34,496·00
„	43,501	„ „ superstructure, at Rs. 20 per 100 ...	8,700·20
„	117,511	„ „ „ at Rs. 24 per 100 ...	28,202·64
„	13	Arch-work, large, at Rs. 32 per 100	4,164·48
„	3,187	„ small, at Rs. 28 per 100	892·36
„	5,520	„ inverts, at Rs. 26 per 100	1,435·20
„	32,059	Brick-on-edge, at Rs. 25 per 100	8,014·75
„	799	Stone capping, at Rs. 2 per foot	1,598·00
„	39,900	Concrete flooring, at Rs. 14 per 100	5,586·00
Lineal feet	1,272	Stone grooves, at Re. 1 per foot	1,272·00
Cubic feet	23,760	Kunkur (dry), at Rs. 8 per 100	1,900·80
„	7,800	Metalling, at Rs. 6 per 100	468·00
„	25,463	Puddle, at Rs. 10 per 1,000	254·63
„	260,120	Earth-work, at Rs. 3·25 per 1,000	845·39
Lineal feet	94	Iron grooves, at Rs. 5 per foot	470·00
		Lock gear, as Estimate No. 101	8,789·04
		Gratings, &c., „ „	9,534·87
Square feet	2,658·6	Regulating gates, wooden, at Rs. 1·25 per foot ...	3,323·20
Number	42	Axle blocks, small, at Rs. 5 each	210·00
„	4	„ large, at Rs. 12 each	48·00
Lineal feet	840	Lifting chains, small, at Rs. 0·9 per foot	756·00
Number	42	Windlasses, small, at Rs. 22 each	924·00
„	2	„ large, at Rs. 66 each	132·00
Square feet	406·6	Regulating gates, large, at Rs. 5 each	2,033·00
Lineal feet	132	Lifting chains large, at Re. 1 per foot	132·00
		Grand Total	124,182·56

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 104½.—FALL ON ESCAPE INTO WEST KALLEE NUDDEE.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	70,000	Excavation in foundations, at Rs. 3·25 per 1,000 ...	227·50
„	90,159	Brick-work in foundations, at Rs. 20 per 100 ...	18,031·80
Lineal feet	210	Sinking large wells, at Rs. 7 per foot ...	1,470·00
„	750	„ small „ at Rs 5 per foot ...	3,750·00
Cubic feet	18,662	Filling in wells, at Rs. 12 per 1,000	2,239·44
„	52,773	Brick-work in superstructure, at Rs. 20 per 100 ...	10,554·60
„	5,265	„ „ „ at Rs. 24 per 100 ...	1,263·60
„	1,074	Arch-work, light, at Rs. 28 per 100	300·72
„	4,325	Brick-on-edge, at Rs. 25 per 100	1,081·25
Lineal feet	132	Stone grooving, at Re. 1 per foot	132·00
Cubic feet	13,876	Puddle, at Rs. 10 per 1,000	138·76
Number	14	Curbs, large, at Rs. 90 each	1,260·00
„	15	„ small, at Rs. 20 each	1,000·00
„	160	Piles, at Rs. 3 each	480·00
„	60	Sleepers, at Rs. 11·625 each	697·50
Square feet	2,565	Grating, at Re. 1·15 per foot	2,949·75
Lineal feet	306	Girders, at Rs. 4·25 per foot	1,300·50
„	90	Wall-plates, at Rs. 6·25 per foot	562·50
Number	2	Hooks, at Rs. 7 each	14·00
		Grand Total	47,453·92

ABSTRACT OF COST OF ESTIMATE No. 105.—AQUEDUCT ON THE KALLEE NUDDEE, UPPER CROSSING.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	86,675	Brick-work in foundations, at Rs. 20 per 100 ...	17,335·00
„	243,713	„ „ superstructure, at Rs. 20 per 100 ...	48,742·60
„	85,432	„ „ „ at Rs. 24 per 100 ...	20,503·68
„	4,031	Arch-work, small, at Rs. 28 per 100	1,128·68
„	55,281	„ large, at Rs. 32 per 100	17,689·92
„	12,060	Brick-on-edge, at Rs. 25 per 100	3,015·00
„	64,160	Kunkur flooring, dry, at Rs. 8 per 100... ...	5,132·80
„	7,200	Pitching slopes with boulders, at Rs. 10 per 100 ...	720·00
„	102,300	Puddle, at Rs. 10 per 1,000	1,023·00
Lineal feet	336	Well-sinking, large, at Rs. 7 per foot	2,352·00
„	900	„ small, at Rs. 5 per foot	4,500·00
Cubic feet	31,411	Filling in wells, at Rs. 12 per 100	3,769·32
		Grand Total	125,912·00

ABSTRACT OF COST OF ESTIMATE No. 106.—AQUEDUCT OVER KALLEE NUDDEE, LOWER CROSSING.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	117,694	Brick-work in foundations, at Rs. 20 per 100 ...	23,538·80
„	359,771	„ „ superstructure, at Rs. 20 per 100 ...	71,954·20
„	178,058	„ „ „ at Rs. 24 per 100 ...	42,733·92
„	179,885	Kunkur masonry „ at Rs. 17 per 100 ...	30,580·45
„	89,028	„ „ „ at Rs. 20 per 100 ...	17,805·60
		Carried over ...	186,612·97

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 106,—*continued.*

Quantity.		Description.	Cost.
			Rs.
		Brought forward ...	186,612·97
Cubic feet	4,398	Arch-work, light, at Rs. 28 per 100	1,231·44
„	181,472	„ heavy, at Rs. 32 per 100	58,071·04
„	25,725	Brick-on-edge, at Rs. 25 per 100	6,431·25
„	126,800	Kunkur flooring, dry, at Rs. 8 per 100.	10,144·00
„	7,200	Pitching of slopes, at Rs. 10 per 100	720·00
„	148,575	Puddle, at Rs. 10 per 1,000	1,485·75
Lineal feet	360	Sinking wells, large, at Rs. 7 per foot	2,520·00
„	960	„ small, at Rs. 5 per foot	4,800·00
Cubic feet	54,209	Filling in wells, at Rs. 12 per 100	6,505·80
		Grand Total	278,521·53

ABSTRACT OF COST OF ESTIMATE NO. 107.—BRIDGE 4 ARCHES OF 51′ SPAN, 18′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	16,160	Brick-work in foundations, at Rs. 20 per 100 ...	3,232·00
„	32,260	„ in superstructure, at Rs. 20 per 100 ...	6,452·00
„	26,333	„ ditto, at Rs. 24 per 100	6,319·92
„	13,734	Arch-work, large, at Rs. 32 per 100	4,394·88
„	6,426	ditto inverts, at Rs. 26 per 100	1,670·76
„	5,400	Metalling, at Rs. 6 per 100...	324·00
„	16,160	Earth-work, at Rs. 3·25 1,000	52·52
		Grand Total	22,446·08

ABSTRACT OF COST OF ESTIMATE No. 108.——BRIDGE, 4 ARCHES OF 51′ SPAN, 20′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	16,568	Brick-work in foundations, at Rs. 20 per 100 ...	3,313·60
„	32,235	„ superstructure, at Rs. 20 per 100 ...	6,447·00
„	28,830	„ „ at Rs. 24 per 100 ...	6,919·20
„	15,042	Arch-work, large, at Rs. 32 per 100	4,813·44
„	7,038	„ inverts, at Rs. 26 per 100	1,829·88
„	6,075	Metalling, at Rs. 6 per 100	364·50
„	16,568	Earth-work, at Rs. 3·25 per 100	53·84
		Grand Total	23,741·46

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 109.—BRIDGE, 4 ARCHES OF 51' SPAN, ROADWAY 25'.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	17,588	Brick-work in foundations, at Rs. 20 per 100 ...	3,517·60
"	34,652	" superstructure, at Rs. 20 per 100 ...	6,930·40
"	32,591	" " at Rs. 24 per 100 ...	7,821·84
"	18,312	Arch-work, large, at Rs. 32 per 100	5,859·84
"	8,568	" inverts, at Rs. 26 per 100 ...	2,227·68
"	7,762	Metalling, at Rs. 6 per 100	465·72
"	17,588	Earth-work, at Rs. 3·25 per 1,000	57·16
		Grand Total	26,880·24

ABSTRACT OF COST OF ESTIMATE No. 110.—BRIDGE ON JUNCTION, 3' ARCHES OF 40' SPAN, ROADWAY 18'.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	14,394	Kunkur masonry in foundations, at Rs. 17 per 100 ..	2,446·98
"	5,224	" in superstructure, at Rs. 17 per 100 ..	888·08
"	3,977	" " at Rs. 20 per 100	795·40
"	10,450	Brick-work in superstructure, at Rs. 20 per 100 ...	2,090·00
"	7,955	" " at Rs. 24 per 100	1,909·20
"	9,072	Arch-work, heavy, at Rs. 32 per 100	2,903·04
"	2,520	Brick-on-edge, at Rs. 25 per 100	630·00
"	3,480	Metalling, at Rs. 6 per 100	208·80
"	14,394	Earth-work, at Rs. 3·25 per 1,000	46·78
		Grand Total	11,918·28

ABSTRACT OF COST OF ESTIMATE No. 111.—CULVERT UNDER CHANNEL, 2 ARCHES 20'.

Quantity.		Description.	Cost.
			Rs.
Cubic feet.	39,504	Masonry in foundations, at Rs. 17 per 100 ...	6,715·68
"	86,106	Superstructure, at Rs. 17 per 100	14,638·02
"	24,048	Arch-work, light, at Rs. 28 per 100	6,733·44
"	21,042	" inverts, at Rs. 26 per 100	5,470·92
"	2,880	Kunker flooring, dry, at Rs. 8 per 100	230·40
"	5,460	Puddle, at Rs. 10 per 1,000	54·60
"	61,104	Excavation, at Rs. 3·25 per 1,000	198·58
		Grand Total	34,041·64

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 112.—CULVERT UNDER CHANNEL, 1 ARCH OF 18′.

Quantity.		Description.	Cost.
			Rs.
Cubic feet.	10,896	Masonry in foundations, at Rs. 17 per 100 ...	1,852·32
„	43,455	„ in superstructure, at Rs. 17 per 100 ...	7,387·35
„	4,128	Arch-work, at Rs. 28 per 100	1,155·84
„	3,612	Invert, at Rs. 26 per 100	939·12
„	960	Kunkur flooring, dry, at Rs. 8 per 100	76·80
„	1,470	Puddle, at Rs. 10 per 1,000	14·70
„	14,336	Excavation, at Rs. 3·25 per 1,000	46·59
		Grand Total	11,472·72

ABSTRACT OF COST OF ESTIMATE No. 113.—INLET FOR DRAINAGES, SECTION No. 1.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	3,822	Masonry in foundations, at Rs. 17 per 100 ...	649·74
„	6,390	„ in superstructure, at Rs. 17 per 100 ...	1,086·30
„	253	Arch-work, light, at Rs. 28 per 100	70·84
„	220	Kunkur flooring, dry, at Rs. 8 per 100... ...	17·60
		Grand Total	1,828·48

ABSTRACT OF COST OF ESTIMATE No. 114.—RAJBUHA OUTLET 6′ WIDE, SECTION No. 1.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	2,816	Masonry in foundations, at Rs. 17 per 100 ...	478·72
„	4,325	„ in superstructure, at Rs. 17 per 100 ...	735·25
„	196	Arch-work, at Rs. 28 per 1,000	54·88
„	2,658	Puddle, at Rs. 10 per 100	26·58
Number	1	Windlasses, at Rs. 20 each	20·00
„	1	Sluice gate 6·5 × 8, at Rs. 50 per 100	50·00
Lineal feet	18	Chain, at Rs. 9 per foot	16·20
„	20	Stone grooves, at Re. 1 per foot	20.00
Cubic feet	2,816	Excavation, at Rs. 3·25 per 1,000	9·15
		Grand Total	1,410·78

ABSTRACT OF COST OF ESTIMATE No. 115.—3rd CLASS CHOWKIES.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	186	Masonry in fo undations, at Rs. 17 per 100 ...	31·62
„	1,276	„ superstructure, at Rs. 18 per 100 ...	229·68
„	188	Arch-work, light, at Rs. 28 per 100	52·64
„	96	Brick-on-edge, at Rs. 25 per 100	24·00
„	186	Excavation, at Rs. 2 per 1,000	0·37
Number	1	Door, at Rs. 25	25·00
		Grand Total	363·31

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 116.—6′ FALLS, 7 BAYS OF 15′, ROADWAY 18′.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	11,482	Kunkur masonry in foundations, at Rs. 17 per 100 ...	1,951·94
„	22,964	Brick-work „ at Rs. 20 per 100...	4,592·80
„	8,000	Kunkur masonry in superstructure, at Rs. 17 per 100	1,360·00
„	16,000	Brick-work „ at Rs. 20 per 100 ...	3,200·00
„	9,762	Kunkur masonry „ at Rs. 20 per 100 ...	1,952·40
„	19,525	Brick-work „ at Rs. 24 per 100 ...	4,686·00
„	336	Arch-work, light, at Rs. 28 per 100	94·08
„	8,190	„ heavy, at Rs. 32 per 100	2,620·80
„	3,780	„ inverts, at Rs. 26 per 100	982·80
„	7,789	Brick-on-edge, at Rs. 25 per 100	1,947·25
„	551	Stone capping, at Rs. 2 per foot	1,102·00
„	25,200	Concrete, at Rs. 14 per 100	3,528·00
Lineal feet	140	Stone grooves, at Rs. 1 per foot	140·00
Cubic feet	5,920	Kunkur flooring, dry, at Rs. 8 per 100... ...	473·60
„	3,480	Metalling, at Rs. 6 per 100	208·80
„	9,687	Puddle, at Rs. 10 per 1,000	96·87
„	80,212	Excavation, at Rs. 3·25 per 100	260·69
Number	60	Sleepers, at Rs. 11·625 each	697·50
Square feet	2,362·5	Grating, at Rs. 1·15 per foot	2,716·87
Lineal feet	238	Girders, at Rs. 4·25 per foot	1,011·50
„	105	Wall-plates, at Rs. 6·25 per foot	655·75
Number	2	Hooks, at Rs. 7 each	14·00
		Grand Total	34,293·65

ABSTRACT OF COST OF ESTIMATE No. 117.—FALL REGULATOR AND ESCAPE AT BOOLUNDSHUHUR BRANCH HEAD.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	62,949	Masonry in foundation, at Rs. 17 per 100 ...	10,700·65
„	51,612	„ superstructure, at Rs. 17 per 100 ...	8,774·04
„	41,717	„ „ at Rs. 20 per 100 ...	8,343·40
„	4,529	Brick-work, at Rs. 24 per 100	1,086·96
„	1,236	Arch work, light, at Rs. 28 per 100	346·08
„	7,875	„ heavy, at Rs. 32 per 100	2,520·00
„	17,246	Brick-on-edge, at Rs. 25 per 100	4,311·50
„	506	Stone capping, at Rs. 2 per foot	1,012·00
„	25,200	Concrete, at Rs. 14 per 100	3,528·00
Lineal feet	740	Stone grooves, at Re. 1 per foot	740·00
Cubic feet	14,800	Kunkur flooring, dry, at Rs. 8 per 100	1,184·00
„	7,313	Metalling, at Rs. 6 per 100	438·78
„	3,780	Pitching, at Rs. 10 per 100	378·00
„	9,687	Puddle, at Rs. 10 per 1,000	96·87
„	87,413	Excavation, at Rs. 3·25 per 100	284·09
		Grating, as per Estimate No. 116	5,095·62
Square feet	1,519	Gates, at Rs. 1·25 per foot	1,898·75
„	33	Axle blocks, small, at Rs. 5 each	165·00
„	30	Windlasses, at Rs. 22 each	660·00
Lineal feet	510	Feet of chain, at Rs. 0·9 per foot	459.00
		Grand Total	52,022·74

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 118.—BRIDGE, 3 ARCHES OF 40′, ROADWAY 25′.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	13,288	Kunkur masonry in foundation, at Rs. 17 per 100 ...	2,258·96
„	4,831	„ „ superstructure, at Rs. 17 per 100	821·27
„	5,321	„ „ „ at Rs. 20 per 100	1,064·20
„	9,661	Brick-work in superstructure, at Rs. 20 per 100 ...	1,932·20
„	10,641	„ „ „ at Rs. 24 per 100 ...	2,553·84
„	10,920	Arch-work, heavy, at Rs. 32 per 100	3,494·40
„	5,040	„ inverts, at Rs. 26 per 100	1,310·40
„	5,003	Metalling, at Rs. 6 per 100	300·18
„	13,288	Earth-work, at Rs. 3·25 per 1,000	43·18
		Grand Total	13,778·63

ABSTRACT OF COST OF ESTIMATE No. 119.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	11,998	Kunkur masonry in foundations, at Rs. 17 per 100 ...	2,039·66
„	4,331	„ „ in superstructure, at Rs. 17 per 100	736·27
„	4,697	„ „ „ at Rs. 20 per 100	939·40
„	8,661	Brick-work „ „ at Rs. 20 per 100	1,732·20
„	9,396	„ „ „ at Rs. 24 per 100	2,255·04
„	8,970	Arch-work, heavy, at Rs. 32 per 100	2,870·40
„	4,140	„ inverts, at Rs. 26 per 100	4,076·40
„	3,915	Metalling, at Rs. 6 per 100	2,34·90
„	11,998	Earth-work, at Rs. 3·25 per 1,000	38·99
		Grand Total	11,923·26

ABSTRACT OF COST OF ESTIMATE NO. 120.—BRIDGES, 3 ARCHES OF 40′, ROADWAY 18′.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	11,482	Kunkur masonry in foundations, at Rs. 17 per 100 ...	1,951·94
„	4,131	„ „ in superstructure, at Rs. 17 per 100 ...	702·27
„	4,448	„ „ ditto, at Rs. 20 per 100 ...	889·60
„	8,261	Brick-work „ in ditto, at Rs. 20 per 100 ...	1,652·20
„	8,898	„ „ ditto, at Rs. 24 per 100 ...	2,135·52
„	8,190	Arch-work, he avy, at Rs. 32 per 100	2,620·80
„	3,780	„ inverts, at Rs. 26 per 100	982·80
„	3,480	Metalling, at Rs. 6 per 100	208·80
„	11,482	Earth-work, at Rs. 3·25 per 1,000	37·31
		Grand Total	11,181·24

Digitized by Google

ABSTRACT OF COST OF ESTIMATE NO. 121.—SYPHON FOR DRAINAGE, 2 ARCHES OF 10′.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	13,035	Masonry in foundations, at Rs. 17 per 100 ...	2,215·95
„	12,916	„ in superstructure, at Rs. 17 per 100 ...	2,195·72
„	5,856	Arch-work, light, at Rs. 28 per 100	1,639·68
„	5,124	„ inverts, at Rs. 26 per 100	1,332·24
„	1,040	Kunkur flooring, dry, at Rs. 8 per 100	83·20
„	1,872	Puddle, at Rs. 10 per 1,000	18·72
„	58,176	Excavation, at Rs. 3·25 per 1,000	189·07
		Grand Total	7,674·58

ABSTRACT OF COST OF ESTIMATE No. 122.—CULVERT, 1 ARCH OF 15′.

Quantity.		Description.	Cost.
			Rs.
Cubic feet..	17,971	Masonry in foundations, at Rs. 17 per 100 ...	3,055·07
„	35,266	„ „ superstructure, at Rs. 17 per 100 ...	5,995·22
„	3,760	Arch-work, light, at Rs. 28 per 100	1,052·80
„	3,642	„ inverts, at Rs. 26 per 100	946·92
„	900	Kunkur flooring, dry, at Rs. 8 per 100	72·00
„	1,656	Puddle, at Rs. 10 per 1,000	16·56
„	23,259	Excavation, at Rs. 3·25 per 1,000	75·59
		Grand Total	11,214·16

ABSTRACT OF COST OF ESTIMATE No. 123.—BRIDGE ON ESCAPE, 2 ARCHES OF 30′, ROADWAY 25′. SPAN.

Quantity.		Description.	Cost.
			Rs.
Cubic feet..	6,952	Kunkur masonry in foundations, at Rs. 17 per 100 ...	1,181·84
„	5,100	„ „ in superstructure, at Rs. 17 per 100...	867·00
„	10,208	„ „ „ at Rs. 20 per 100...	2,041·60
„	4,158	Arch-work, heavy, at Rs. 32 per 100	1,330·56
„	2,520	Travests, at Rs. 26 per 100	655·20
„	2,933	Metalling, at Rs. 6 per 100	175·98
„	7,000	Earth-work, at Rs. 3·25 per 1,000	22·75
		Grand Total	6,274·93

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 124.—BRIDGE ON ESCAPE, 2 ARCHES OF 30', ROADWAY 30'.

Quantity.		Description.	Cost.
			Rs.
Cubic feet..	7,602	Kunkur masonry in foundation, at Rs. 17 per 100 ...	1,292·34
"	5,500	" " superstructure, at Rs. 17 per 100..	935·00
"	11,148	" " " at Rs. 20 per 100...	2,229·60
"	4,960	Arch-work, heavy, at Rs. 32 per 100	1,568·00
"	2,970	Inverts, at Rs. 26 per 100	772·20
"	2,250	Metalling, at Rs. 6 per 100	135·00
"	8,000	Earth-work, at Rs. 3·25 per 1,000	26·00
		Grand Total	6,958·14

ABSTRACT OF COST OF ESTIMATE No. 125.—FALL ON ESCAPE INTO HINDUN FROM 100th MILE.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	50,000	Excavation for foundations, at Rs. 3·25 per 1,000 ...	162·50
"	69,658	Brick-work in ditto, at Rs. 20 per 100	13,931·60
"	180	Sinking large wells, at Rs. 7 per foot	1,260·00
"	600	Ditto small ditto, at Rs. 5 per foot	3,000·00
"	17,468	Filling in wells, at Rs. 12 per 100	2,096·16
"	49,497	Brick-work in superstructure, at Rs. 20 per 100 ...	9,899·40
"	3,159	Ditto ditto, at Rs. 24 per 100	758·16
"	670	Arch-work, light, at Rs. 28 per 100	187·60
"	2,849	Brick-on-edge, at Rs. 25 per 100	712·25
Lineal feet	88	Stone grooving, at Re. 1 per foot	88·00
Cubic feet	12,418	Puddle, at Rs. 10 per 100	124·18
Number	12	Curbs, large, at Rs. 90 each	1,080·00
"	40	Ditto small, at Rs. 20 each	800·00
"	110	Piles, at Rs. 3 each	330·00
"	40	Sleepers, at Rs. 11·625 each	465·00
Square feet	1,710	Grating, at Rs. 1·15 per foot	1,966·50
Lineal feet	204	Girders, at Rs. 4·25 per foot	867·00
"	60	Wall plates, at Rs. 6·25 per foot	375·00
Number	2	Hooks, at Rs. 7 each	14·00
		Grand Total	38,117·35

ABSTRACT OF COST OF ESTIMATE No. 126.—RAJBUHA OUTLET, SECTION No. 2.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	2,798	Masonry in foundations, at Rs. 17 per 100 ...	475·66
"	3,942	Ditto in superstructure, at Rs. 17 per 100 ...	670·14
"	196	Arch-work, light, at Rs. 28 per 100	54·88
"	2,403	Puddle, at Rs. 10 per 1,000	24·03
"	2,798	Excavation, at Rs. 3·25 per 1,000	9·09
Number	1	Gate, 6·5 × 6, at Rs. 40 each	40·00
"	1	Windlass, at Rs. 20 each	20·00
Lineal feet	15	Chain, small, at Rs. 0·9 per foot	13·50
"	16	Stone grooves, at Re. 1 per foot	16·00
		Grand Total	1,323·30

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 127.—6' FALLS, 6 BAYS OF 15', ROADWAY 18'.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	31,498	Kunkur masonry in foundation, at Rs. 17 per 100 ...	5,354·66
„	22,809	„ „ „ superstructure, at Rs. 17 per 100	3,877·53
„	25,954	„ „ „ „ 20 per 100	5,190·80
„	7,245	Arch-work, heavy, at Rs. 32 per 100	2,318·40
„	288	„ light, at Rs. 28 per 100	80·64
„	6,646	Brick-on-edge, at Rs. 25 per 100	1,661·50
„	3,307	Arch-work, inverts, at Rs. 26 per 100	859·82
„	478	Stone capping, at Rs. 2 per foot	956·00
„	21,525	Concrete, at Rs. 14 per 100	3,013·50
Lineal feet	108	Stone grooves, at Re. 1 per foot	108·00
„	5,200	Kunkur flooring, dry, at Rs. 8 per 100... ...	416·00
„	3,300	Metalling, at Rs. 6 per 100	198·00
„	8,515	Puddle, at Rs. 10 per 1,000	85·15
„	71,314	Excavation, at Rs. 3·25 per 1,000	231·77
„	60	Sleepers, at Rs. 11·625 each ...	697·50
Square feet	1,755	Grating, at Rs. 1·15 per foot ...	2,018·25
Lineal feet	204	Girders, at Rs. 4·25 per foot ... grating, &c.	867·00
„	90	Wall plates, at Rs. 6·25 per foot ...	562·50
Number	2	Hooks, at Rs. 7 per each ...	14·00
		Grand Total	28,511·02

ABSTRACT OF COST OF ESTIMATE No. 128.—5' FALLS, 6 BAYS OF 15', ROADWAY 20'.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	23,510	Kunkur masonry in foundation, at Rs. 17 per 100 ..	3,996·70
„	22,929	„ „ superstructure, at Rs. 17 per 100	3,897·93
„	27,107	„ „ „ at Rs. 20 per 100	5,421·40
„	7,935	Arching, heavy, at Rs. 32 per 100	2,539·20
„	288	„ light, at Rs. 28 per 100	80·64
„	6,646	Brick-on-edge, at Rs. 25 per 100	1,661·50
„	478	Stone capping, at Rs. 2 per foot	956·00
„	21,525	Concrete, at Rs. 14 per foot	3,013·50
Lineal feet	108	Stone grooves, as estimate No. 127, at Re. 1 per foot ...	108·00
Cubic feet	3,712	Metalling roadway, at Rs. 6 per 100	222·72
„	8,515	Puddle, at Rs. 10 per 1,000	85·15
„	70,880	Excavation, at Rs. 3·25 per 1,000	230·36
„	12,340	Kunkur flooring, at Rs. 8 per 100	987·20
Square feet	2,616	Well foundations, at Rs. 301 per 100	7,874·16
Number	72	Piles, at Rs. 3 each	216·00
		Gratings, &c., as estimate No. 127	4,159·25
		Grand Total	35,449·71

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 129.—COEL BRANCH HEAD.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	20,166	Kunker masonry in foundations, at Rs. 17 per 100 ...	3,428·22
„	20,333	Brick work, „ „ at Rs. 20 per 100 ...	4,066·60
„	33,314	Kunker masonry in superstructure, at Rs. 17 per 100	5,663·38
„	34,020	„ „ „ at Rs. 20 per 100	6,804·00
„	4,878	Arch-work, light, at Rs. 28 per 100	1,365·84
„	12,271	Brick-on-edge, at Rs. 25 per 100	3,067·75
		Stone capping, as estimate No. 127	956·00
„	21,525	Concrete, at Rs. 14 per 100	3,013·50
Lineal feet	396	Stone grooves, Re. 1 per foot	396·00
Cubic feet	10,830	Kunkur flooring, dry, at Rs. 8 per 100 ...	866·40
„	5,265	Road metalling, at Rs. 6 per 100	315·90
„	2,400	Pitching with boulders, at Rs. 10 per 100 ...	240·00
„	10,161	Puddle, at Rs. 10 per 1,000	101·61
„	6,778	Filling in wells, at Rs. 12 per 100	813·36
	240	Piles, at Rs. 3 each	720·00
	120	Curbs, small, at Rs. 20 each	2,400·00
	960	Undersinking wells, 120 × 8, at Rs. 5 per foot ...	4,800·00
		Gratings, as estimate No. 127	4,159·25
Square feet	798	Regulating gates, at Rs. 1·25 per foot ...	997·50
Number	20	Axle blocks, at Rs. 5 each	100·00
	18	Windlasses, at Rs. 22 each	396·00
Lineal feet	288	Chain, at Re. 0·9 per foot	259·20
		Grand Total	44,930·51

ABSTRACT OF COST OF ESTIMATE No. 130.—BRIDGES, 3 ARCHES OF 35′ SPAN, 18′ ROADWAY.

Quantity.		Description	Cost.
			Rs.
Cubic feet	10,848	Kunkur masonry in foundations, at Rs. 17 per 100 ...	1,844·16
„	11,604	„ „ in superstructure, at Rs. 17 per 100	1,972·68
„	13,076	„ „ „ at Rs. 20 per 100	2,615·20
„	7,245	Arch-work, heavy, at Rs. 32 per 100	2,318·40
„	3,307	„ inverts, at Rs. 26 per 100	859·82
„	3,300	Metalling, at Rs. 6 per 100	198·00
„	10,848	Earth-work, at Rs. 3·25 per 1,000	35·25
		Grand Total	9,843·51

ABSTRACT OF COST OF ESTIMATE No. 130A.—BRIDGE, AS ESTIMATE No. 130A, BUT WITH WELL FOUNDATIONS.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	2,346	Kunkur masonry in foundation, at Rs. 17 per 100 ...	398·82
	as Estimate		
„	No. 130	„ „ in superstructure at	4,587·88
„	ditto	Arch-work, heavy	2,318·40
„	ditto	Metalling	198·00
„	ditto	Earth-work	35·25
„	6,720	Kunkur flooring, at Rs. 8 per 100	537·60
Square feet	1,173	Well foundations, at Rs. 301 per 100	3,530·73
		Grand Total	11,606·68

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 130A.—WELL FOUNDATIONS FOR ESTIMATE No. 130 A, WELL SUNK 8′.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	3,505	Brick-work, at Rs. 20 per 100	701·00
„	1,796	Filling wells, at Rs. 12 per 100	215·52
Number	10	Curbs, at Rs. 20 each	200
„	4	ditto, at Rs. 60 each	240
Lineal feet	80	Under-sinking, at Rs. 5 per foot	400
„	32	ditto, at Rs. 7 per foot	224
			1,980·52

Area of pier foundations, 2 × 176 = 352
„ abutments „ 2 × 168 = 336

1,980·52 ÷ 688 = Rs. 301 per 100 superficial foot.

ABSTRACT OF COST OF ESTIMATE No. 131.—BRIDGES, 3 ARCHES 35′ SPAN, 20′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	11,326	Kunkur masonry in foundations, at Rs. 17 per 100 ...	1,925·42
„	12,129	„ „ superstructure, at Rs. 17 per 100	2,061·93
„	13,823	„ „ „ at Rs. 20 per 100	2,764·60
„	7,935	Arch-work, heavy, at Rs. 32 per 100	2,539·20
„	3,622	„ inverts, at Rs. 26 per 100	941·72
„	3,712	Metalling, at Rs. 6 per 100	222·72
„	11,320	Earth-work, at Rs. 3·25 per 1,000	36·80
		Grand Total	10,492·39

ABSTRACT OF COST OF ESTIMATE No. 131 A.—BRIDGE AS BEFORE, BUT WITH WELL FOUNDATIONS.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	2,454·00	Kunkur masonry in foundations, at Rs. 17 per 100...	417·18
„	as before	„ „ in superstructure	4,826·53
„	„	Arch-work, heavy	2,539·20
„	„	Metalling	222·72
„	„	Earth-work	36·80
„	7,140	Kunkur flooring, dry, at Rs. 8 per 100... ...	571·20
Square feet	1,227	Well foundations, at Rs. 301 per 100	3,693·27
		Grand Total	12,306·90

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 132.—BRIDGES, 3 ARCHES OF 35′ SPAN, 25′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	12,523	Kunkur masonry in foundations, at Rs. 17 per 100 ..	2,128·91
„	13,442	„ „ superstructure, at Rs. 17 per 100...	2,285·14
„	15,692	„ „ „ at Rs. 20 per 100...	3,138·40
„	9,660	Arch-work, heavy, at Rs. 32 per 100	3,091·20
„	4,410	„ inverts, at Rs. 26 per 100	1,146·60
„	4,744	Metalling, at Rs. 6 per 100..	284·64
„	12,523	Earth-work, at Rs. 3·25 per 1000	40·69
		Grand Total	12,115·58

ABSTRACT OF COST OF ESTIMATE No. 132 A.—BRIDGE AS IN ESTIMATE No. 132, BUT WITH WELL FOUNDATIONS.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	2,724	Kunkur masonry in foundations, at Rs. 17 per 100...	463·08
	as Estimate	„ in Superstructure	5,423·54
	No. 132	Arching, heavy	3,091·20
	„	Metalling	284·64
	„	Earth-work	40·69
cubic feet	8,190	Kunkur flooring under arches, at Rs. 8 per 100 ...	655·20
Square feet	1,362	Well foundations, at Rs. 301 per 100	4,099·62
		Grand Total	14,057·97

ABSTRACT OF COST OF ESTIMATE No. 133.—SYPHON FOR DRAINAGE, 2 ARCHES OF 10′ ON 3rd SECTION.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	11,910	Masonry in foundations, at Rs. 17 per 100 ...	2,024·70
„	11,866	„ in superstructure, at Rs. 17 per 100 ...	2,017·22
„	5,256	Arch-work, light, at Rs. 28 per 100 ...	1,471·68
„	4,599	„ inverts, at Rs. 26 per 100 ...	1,195.74
„	1,040	Kunkur flooring, dry, at Rs. 8 per 100 ...	83·20
„	1,547	Puddle, at Rs. 10 per 1,000	15·47
„	52,976	Excavation, at Rs. 3·25 per 1,000 ...	172·17
		Grand Total	6,980·18

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 134.—SYPHON DRAINAGE, 1 ARCH 10′ (ON 3RD SECTION.)

Quantity.		Description.	Cost.
			Rs.
Cubic feet	6,833	Masonry in foundations, at Rs. 17 per 100 ...	1,161·61
„	7,696	„ in superstructure, at Rs. 17 per 100 ...	1,308·32
„	2,628	Arch-work, light, at Rs. 28 per 100	735·84
„	2,299	„ inverts, at Rs. 26 per 100	597·74
„	520	Kunkur flooring, dry, at Rs. 8 per 100... ...	41·60
„	833	Puddle, at Rs. 10 per 1,000	8·33
„	28,000	Excavation, at Rs. 3·25 per 1,000	91·00
		Grand Total	3,944·44

ABSTRACT OF COST OF ESTIMATE No. 135.—RAJBUHA OUTSETS, 6′ WIDE. (ON 3RD SECTION.)

Quantity.		Description.	Cost.
			Rs.
Cubic feet	2,780	Masonry in foundations, at Rs. 17 per 100 ...	472·60
„	3,560	„ in superstructure, at Rs. 17 per 100 ...	605·20
„	196	Arch-work, at Rs. 28 per 100	54·88
„	2,148	Puddle, at Rs. 10 per 1,000	21·48
„	2,780	Excavation, at Rs. 3·25 per 1,000	9·03
Number	1	Gate, at Rs. 32 each	32·00
„	1	Windlass, at Rs. 20 each	20·00
Lineal feet	13	Chain, small, at Rs. ·9 per foot	11·70
„	14	Stone grooving, at Re. 1 per foot	14·00
		Grand Total	1,240·89

ABSTRACT OF COST OF ESTIMATE No. 136.—4′ FALL, 5 BAYS OF 15,′ ROADWAY 18′ (ON 4TH SECTION).

Quantity.		Description.	Cost.
			Rs.
Cubic feet	12,954	Kunkur masonry in foundation, at Rs. 17 per 100 ...	2,202·18
„	16,087	„ „ in superstructure, at Rs. 17 per 100	2,734·79
„	20,091	„ „ „ at Rs. 20 per 100	4,018·10
„	4,677	Arch-work heavy, at Rs. 32 per 100	1,496·64
„	240	„ light, at Rs. 28 per 100	67·20
„	5,397	Brick-on-edge, at Rs. 25 per 100	1,349·25
„	382·5	Stone capping, at Rs. 2 per cubic foot	765·00
„	17,850	Concrete, at Rs. 14 per 100	2,499·00
Lineal feet	80	Stone grooves, at Re. 1 per foot	80·00
Cubic feet	9,220	Kunkur flooring, at Rs. 8 per 100	737·60
„	2,400	Metalling roadway, at Rs. 6 per 100	144·00
„	55,872	Excavation, at Rs. 3·25 per 1,000	181·58
„	6,530	Puddle, at Rs. 10 per 1,000	653·00
		Caried over ...	16,928·34

ABSTRACT OF COST OF ESTIMATE No. 136, &c.,—*continued.*

Quantity.		Description.	Cost.
			Rs.
		Brought forward ...	16,928·34
Square feet	2,623	Well foundations, at Rs. 30, per 100	7,895·23
Number	68	Piles, at Rs. 3 each	204·00
"	24	Sleepers, at Rs. 11·625 each	279·00
Supl. feet	1,237·5	Grating, at Rs. 1·15 per foot	1,423·25
Lineal feet	170	Girders, at Rs. 4·25 per foot	722·50
"	75	Wall-plates, at Rs. 6·25 per foot	468·75
Number	2	Hooks, at Rs. 7·0 each	14·00
		Grand Total.	27,935·07

ABSTRACT OF COST OF ESTIMATE No. 137.—BRIDGE 3 ARCHES OF 30′, ROADWAY 20′.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	1,936	Kunkur masonry in foundations, at Rs. 17 per 100...	329·12
"	6,102	" " in superstructure, at Rs. 17 per 100	1,037·34
"	10,642	" " " at Rs. 20 per 100	2,128·40
"	5,123	Arch-work heavy, at Rs. 32 per 100	1,639·36
"	2,700	Metalling, at Rs. 6 per 100	162·00
"	8,000	Earth-work at Rs. 3·25 per 1,000	26·00
"	5,580	Kunkur flooring, dry, at Rs. 8 per 100 ...	446·4
Square feet	1,227	Well foundations, as Estimate No. 131 A ...	3,693·27
		Grand Total	9,461·89

ABSTRACT OF COST OF ESTIMATE No. 138.—BRIDGE 3 ARCHES OF 30′, ROADWAY 18′.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	1,840	Kunkur masonry in foundations, at Rs. 17 per 100 ..	312·80
"	5,934	" " in superstructure, at Rs. 17 per 100	1,008·78
"	10,112	" " " at Rs. 20 per 100	2,022·40
"	4,677	Arch-work, heavy, at Rs. 32 per 100	1,496·64
"	2,400	Metalling, at Rs. 6 per 100	144·00
"	7,326	Earth-work, at Rs. 3·25 per 100	23·80
"	5,220	Kunkur flooring, at Rs. 8 per 100	417·60
		Well foundations, as Estimate No. 130 A ...	3,530·73
		Grand Total	8,956·75

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 139.—SYPHON FOR DRAINAGE, 2 ARCHES OF 10′ (ON 4TH SECTION.)

Quantity.		Description.	Cost.
			Rs.
Cubic feet	11,280	Masonry in foundations, at Rs. 17 per 100 ...	1,917·60
„	11,278	„ in superstructure, at Rs. 17 per 100 ...	1,917·26
„	4,920	Arch-work, at Rs. 28 per 100	1,377·60
„	4.305	„ invert, at Rs. 26 per 100	1,119·30
„	1,040	Kunkur flooring, dry, at Rs. 8 per 100 ...	83·20
„	1,365	Puddle, at Rs. 10 per 1,000	13·65
„	50,064	Excavation, at Rs. 3·25 per 1,000	162·70
		Grand Total	6,591·31

ABSTRACT OF COST OF ESTIMATE No. 140.—SYPHON FOR DRAINAGE, 1 ARCH OF 3′ (ON 4TH SECTION.)

Quantity.		Description.	Cost.
			Rs.
Cubic feet	2,970	Masonry in foundations, at Rs. 17 per 100 ...	504·90
„	4,563	„ in superstructure, at Rs. 17 per 100 ..	775·71
„	615	Arch-work light, at Rs. 28 per 100	172·20
„	307	„ inverts, at Rs. 26 per 100	79·82
„	320	Kunkur flooring, at Rs. 8 per 100	25·60
„	367	Puddle, at Rs. 10 per 1,000	3·67
„	8,928	Excavation, at Rs. 3·25 per 1,000	29·01
		Grand Total	1,590·91

ABSTRACT OF COST OF ESTIMATE No. 141.—RAJBUHA OUTLET (ON 4TH SECTION.)

Quantity.		Description.	Cost.
			Rs.
Cubic feet	2,780	Masonry in foundations, at Rs. 17 per 100 ...	472·60
„	2,683	„ in superstructure, at Rs. 17 per 100 ...	456·11
„	196	Arch-work light, at Rs. 28 per 100	54·88
„	1,545	Puddle, at Rs. 10 per 1,000	15·45
„	2,780	Excavation, at Rs. 3·25 per 1,000	9·03
Number	1	Gate 6′ 5″ × 5′, at Rs. 32 each	32·00
„	1	Windlass, at Rs. 20 each	20·00
Lineal feet	13	Chain small, at Re. 0-9 per foot	11·70
„	14	Stone grooves, at Re. 1 per foot	14·00
		Grand Total	1,085·77

ABSTRACT OF COST OF ESTIMATE No. 142.—REPAIRS TO MAIN LINE, GANGES CANAL.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	3,102,912	Earth-work, at Rs. 2·5 per 100	7,757·28
Miles	131	Repairing tow-path from Roorkee to Futteguhr branch head and from Julpoori Bridge to Nanoon Regulator, at Rs. 100 per mile	13,100·00
		Grand Total	20,857·28

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 143.—ALTERATIONS TO FALLS ON PRESENT LINE, 200′ WATERWAY.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	34,880	Demolition, at Re. 1 per 100	348·8
„	8,705	Masonry, at Rs. 22 per 100	1,915·1
„	8,720	Brick-on-edge, at Rs. 25 per 100	2,180·0
		Grand Total	4,443·9

ABSTRACT OF COST OF ESTIMATE No. 144.—ALTERATIONS TO FALLS ON PRESENT LINE, 150′ WATERWAY.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	26,160	Demolition, at Re. 1 per 100	261·6
„	6,610	Masonry, at Rs. 22 per 100	14,54·2
„	6,540	Brick-on-edge, at Rs. 25 per 100	1,635·0
		Grand Total	3,350·8

ABSTRACT COST OF ESTIMATE No. 145.—REGULATING BRIDGES, FUTTEGURH BRANCH, HEAD MAIN LINE.

Quantity.		Description.	Cost.
			Rs.
Lineal Feet	102	Girders, at Rs. 9·4 per foot	958·8
Square feet	82	Iron drop gates, at Rs. 5 per foot	410·0
„	240	Wooden gates, at Re. 1·25 per foot	300·0
Number ...	9	Small windlasses, at Rs. 22 each	198·0
		Grand Total	1,866·8

ESTIMATE, No. 146.—71′ TOW-PATHS UNDER BRIDGES, MAIN LINE.

	Items of Work.	Total.
		Rs.
32	Tow-paths, 18′ Roadway, *vide* Estimate No. 174, at Rs. 327·30 each	10,473·6
7	Ditto 20′ ditto at „ 368·50 „	2,579·5
3	Ditto 25′ ditto at „ 426·50 „	1279·5
	Grand Total	14,332·6

J. CROFTON, *Captain, R. E.*

Digitized by Google

GANGES CANAL.

NAVIGABLE LINE.

ABSTRACT OF COST OF ESTIMATE No. 147.—EXCAVATION.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	217,460,025	Excavation, at Rs. 2·25 per 1,000	4,89,285·05
„	50,429,030	Embankment, at Rs. 6 per 1,000	3,02,574·18
		Grand Total	7,91,859·23

ABSTRACT OF COST OF ESTIMATE No. 148.—DOUBLE LOCK CHAMBER AT EXIT FROM GANGES CANAL.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	30,396	Brick-work in foundations, at Rs. 20 per 100 ...	6,079·20
„	54,932	„ in superstructure, at Rs. 20 per 100 ...	10,986·40
„	814	Brick-on-edge, at Rs. 25 per 100	202·75
„	1,020	Arch-work, light, at Rs. 28 per 100	285·60
„	6,528	„ inverts, at Rs. 26 per 100	1,697·28
„	780	Kunkur flooring, dry, at Rs. 8 per 100... ...	62·40
„	7,639	Puddle, at Rs. 10 per 1,000	76·39
„	40,147	Excavation, at Rs. 3·25 per 1,000	130·47
Square feet	992·16	Lock gates, at Rs. 6·5 per foot	6,449·04
Lineal feet	220	Chain, at Re. 1 per foot	220·00
Number	8	Pulleys, at Rs. 5 each	40·00
„	8	Crabs, at Rs. 135 each	1,080·00
„	8	Sluices, at Rs. 125 each	1,000·00
		Excavation drainage cut as Estimate No. 99 ...	3,960·00
		Grand Total	32,269·53

Same as above, but with deep foundations above and below chambers on wells—	
As Estimate No. 148, deducting drainage cut	28,309·53
Additional for well foundations, *vide* Estimate No. 149, 2 × 560·74 = ...	1,121·48
Grand Total	29,431·01

ABSTRACT OF COST OF ESTIMATE No. 149.—DOUBLE LOCK, 6′ DROP, 18′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	35,403	Masonry in foundations, at Rs. 17 per 100 ...	6,018·51
„	45,548	„ in superstructure, at Rs. 20 per 100 ...	9,109·60
„	1,479	Brick-on-edge, at Rs. 25 per 100	369·75
„	1,837	Arch-work, light, at Rs. 28 per 100	514·36
„	6,783	„ inverts, at Rs. 26 per 100	1,763·58
„	1,152	Kunkur flooring, dry, at Rs. 8 per 100... ...	92·16
„	2,796	Metalling roadway, at Rs. 6 per 100	167·76
„	8,316	Puddle, at Rs. 10 per 1,000	83·16
„	49,002	Excavation, at Rs. 3·25 per 1,000	159·25
Square feet	610·56	Lock gates, at Rs. 6·5 per foot	3,968·64
Number	8	Pulleys, at Rs. 5 each	40·00
„	8	Crabs, at Rs. 135 each	1,080·00
„	8	Sluices, at Rs. 125 each	1,000·00
Lineal feet	188	Chains, at Re. 1 per foot	188·00
		Grand Total	24,554·77

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 149.—WITH WELL FOUNDATIONS.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	34,489	Brick-work in foundations, at Rs. 17 per 100 ...	5,863·13
"	551	Filling in wells, at Rs. 12 per foot	66·12
Lineal feet	78	Undersinking, at Rs. 5 per foot	390·00
Number	13	Curbs, at Rs. 20 each	260·00
		Remainder as Estimate No. 149	18,536·26
		Grand Total	25,115·51

ABSTRACT OF COST OF ESTIMATE No. 149A.—DOUBLE LOCK, 6′ WITHOUT BRIDGE.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	32,043	Masonry in foundations, at Rs. 17 per 100 ...	5,447·31
"	39,794	" in superstructure, at Rs. 20 per 100 ...	7,958·80
"	5,712	Inverts, at Rs. 26 per 100	1,485·12
"	483	Arch-work, at Rs. 28 per 100	135·24
		Grand Total	15,026·47
		Foundations, superstructure, arches, and inverts, as Estimate No. 149	17,406·05
		Difference of cost without bridge	2,379·58
		Vide Estimate No. 149	24,554·77
		Total Cost without Bridge	22,175·19

ABSTRACT OF COST OF ESTIMATE No. 150.—DOUBLE LOCK, 12′ DROP, 18′ ROADWAY.

Quantity.		Description.	Total.
			Rs.
Cubic feet	37,737	Masonry in foundations, at Rs. 17 per 100 ...	6,415·29
"	62,833	" in superstructure, at Rs. 20 per 100 ...	12,566·60
"	1,479	Brick-on-edge, at Rs. 25 per 100	369·75
"	1,676	Arch-work, light, at Rs. 28 per 100	469·28
"	6,783	" inverts, at Rs. 26 per 100	1,763·58
"	1,152	Kunkur flooring, at Rs. 8 per 100	92·16
"	2,796	Metalling roadway, at Rs. 6 per 100	167·76
"	11,250	Puddle, at Rs. 10 per 1,000	112·50
"	49,002	Excavation, at Rs. 3·25 per 1,000	159·25
Square feet	839·52	Lock gates, at Rs. 6·5 per foot	5,456·88
Lineal feet	204	Chain, at Re. 1 per foot	204·00
Number	8	Pulleys, at Rs. 5 each	40·00
"	8	Crabs, at Rs. 135 each	1,080·00
"	8	Sluices, at Rs. 125 each	1,000·00
		Grand Total	29,897·05

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 151.—DOUBLE LOCK, 6′ DROP, 25′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	36,595	Masonry in foundations, at Rs. 17 per 100 ...	6,221·15
„	47,847	„ in superstructure, at Rs. 20 per 100 ...	9,569·40
„	1,658	Brick-on-edge, at Rs. 25 per 100	414·50
„	2,288	Arch-work, light, at Rs. 28 per 100	640·64
„	7,140	„ inverts, at Rs. 26 per 100	1,856·40
		Kunkur flooring, dry, as Estimate No. 149 ...	92·16
„	3,389	Metalling roadway, at Rs. 6 per 100	203·34
„	8,578	Puddle, at Rs. 10 per 1,000	85·78
„	50,532	Excavation, at Rs. 3·25 per 1,000	164·24
		Lock apparatus as Estimate No. 149	6,276·64
		Grand Total	25,524·25

Same as above, but with deep foundation on wells—

Estimate as above	25,524·25
Additional for well foundations, *vide* Estimate No. 149 ...	560·74
Grand Total	26,085·09

ABSTRACT OF COST OF ESTIMATE No. 152.—DOUBLE LOCK, 8′ DROP, 20′ ROADWAY.

Quantity.		Description.	Total.
			Rs.
Cubic feet	35,927	Masonry in foundations, at Rs. 17 per 100 ...	6,107·59
„	50,681	„ in superstructure, at Rs. 20 per 100 ...	10,136·20
„	1,530	Brick-on-edge, at Rs. 25 per 100	382·50
„	1,966	Arch-work, light, at Rs. 28 per 100	550·48
„	6,885	„ inverts, at Rs. 26 per 100	1,790·10
„	3,146	Metalling roadway at Rs. 6 per 100	188·76
„	1,152	Kunkur flooring, at Rs. 8 per 100	92·16
„	9,381	Puddle, at Rs. 10 per 1,000	93·81
„	49,442	Excavation, at Rs. 325 per 1,000	160·98
Square feet	687	Lock gates, at Rs. 6·5 per foot	4,465·50
Lineal feet	196	Chains, at Re. 1 per foot	196·00
Number	8	Pulleys, at Rs. 5 each	40·00
„	8	Crabs, at Rs. 135 each	1,080·00
„	8	Sluices, at Rs. 125 each	1,000·00
		Grand Total	26,284·08

ABSTRACT OF COST OF ESTIMATE No. 153—DOUBLE LOCK, 5′ DROP, 10′ ROADWAY.

Quantity.		Description.	Total.
			Rs.
Cubic feet	34,021	Masonry in foundations, at Rs. 17 per 100 ...	5,783·57
„	39,603	„ in superstructure, at Rs. 20 per 100 ...	7,920·60
„	1,160	Arch-work, light, at Rs. 28 per 100	324·80
„	6,375	„ inverts, at Rs. 26 per 100	1,657·50
		Carried over ...	15,686·47

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 153.—*continued.*

Quantity.		Description.	Total.
			Rs.
		Brought forward ...	15,686·47
Cubic feet	1,275	Brick-on-edge, at Rs. 25 per 100	318·75
„	1,398	Metalling roadway, at Rs. 6 per 100	83·88
„	...	Kunkur flooring, dry, as Estimate No. 149 ...	92·16
„	7,827	Puddle, at Rs. 10 per 1,000	78·27
„	47,242	Excavation, at Rs. 3·25 per 1,000	153·53
Square feet	572·4	Lock gates, at Rs. 6·5 per foot	3,720·60
Lineal feet	188	Chain, at Re. 1 per foot	188·00
Number	8	Pulleys, at Rs. 5 each	40·00
„	8	Crabs, at Rs. 135 each	1,080·00
„	8	Sluices, at Rs. 125 each	1,000·00
		Additional for well foundations, as Estimate No. 149 A	560·74
		Grand Total	23,002·40

ABSTRACT OF COST OF ESTIMATE No. 154.—DOUBLE LOCK, 9·73 FALL, 10′ ROADWAY.

Quantity.		Description.	Total.
			Rs.
Cubic feet	34,504	Masonry in foundations, at Rs. 17 per 100 ...	5,865·68
„	53,256	„ in superstructure, at Rs. 20 per 100 ...	10,651·20
		Brick-on-edge, as Estimate No. 153	318·75
		Arch-work, light, as Estimate No. 153	324·80
		„ inverts, as Estimate No. 153 ...	1,657·50
		Metalling roadway, as Estimate No. 153 ...	83·88
		Kunkur flooring, dry	92·16
„	9,783	Puddle, at Rs. 10 per 1,000	97·83
		Excavations, as Estimate No. 153	153·50
Square feet	752·89	Lock gates, at Rs. 6·5 per foot	4,893·78
Lineal feet	196	Chain, at Re. 1 per foot	196·00
Number	8	Pulleys, at Rs. 5 each	40·00
„	8	Crabs, at Rs. 135 each	1,080·00
„	8	Sluices, at Rs. 125 each	1,000·00
		Additional for well foundations	560·74
		Grand Total	27,015·82

ABSTRACT OF COST OF ESTIMATE No. 155.—AQUEDUCT OVER KALEE NUDDEE, UPPER CROSSING, 2 ARCHES OF 40′ SPAN.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	18,469	Brick-work in well foundations, at Rs. 20 per 100 ...	3,693·80
Lineal feet	96	Sinking wells, large, at Rs. 7 per foot	672·00
„	264	„ „ small, at Rs. 5 per foot	1,320·00
Cubic feet	8,278	Filling in wells, at Rs. 12 per 100	993·36
„	91,076	Brick-work in superstructure, at Rs. 20 per 100 ...	18,215·20
„	10,395	Arch-work, heavy, at Rs. 32 per 100	3,326·40
„	1,627	Brick-on-edge, at Rs. 25 per 100	406·75
„	13,350	Puddle, at Rs. 10 per 1,000	133·50
„	15,760	Kunkur flooring, dry, at Rs. 8 per 1,000 ...	1,260·80
Number	8	Curbs, large at Rs. 90 each...	720·00
„	22	„ small, at Rs. 20 each	440·00
		Grand Total	31,181·81

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 156.—AQUEDUCT OVER KALEE NUDDEE, LOWER CROSSING, 3 ARCHES OF 40′ SPAN.

Quantity.		Description.	Total.
			Rs.
Cubic feet	21,871	Brick-work in well foundations, at Rs. 20 per 100 ...	4,374·20
Lineal feet	96	Sinking wells, large, at Rs. 7 per foot	672·00
„	336	„ „ small, at Rs. 5 per foot	1,680·00
Cubic feet	9,456	Filling in wells, at Rs. 12 per 100	1,134·72
„	143,947	Brick-work in superstructure, at Rs. 20 per 100 ...	28,789·80
„	19,305	Arch-work, heavy, at Rs. 32 per 100	6,177·60
„	2,450	Brick-on-edge, at Rs. 25 per 100	612·50
„	23,120	Kunkur flooring, dry, at Rs. 8 per 100... ...	1,849·60
„	18,174	Puddle, at Rs. 10 per 1,000	181·74
Number	8	Curbs, large, at Rs. 90 each	720·00
„	28	„ small, at Rs. 20 each	560·00
		Grand Total	46,752·16

ABSTRACT OF COST OF ESTIMATE No. 157.—AQUEDUCT OVER CHOYA NULLA, 3 ARCHES OF 30′ SPAN.

Quantity.		Description.	Cost.
			Rs.
		Well foundation and sinking, as Estimate No. 156 ...	7,860·92
Cubic feet	81,994	Masonry in superstructure, at Rs. 20 per 100 ...	16,398·80
„	12,994	Arch-work, heavy, at Rs. 32 per 100	4,158·08
„	1,925	Brick-on-edge, at Rs. 25 per 100	481·25
„	18,820	Kunkur flooring, dry, at Rs. 8 per 100... ...	1,505·60
„	10,885	Puddle, at Rs. 10 per 1,000	108·85
		Grand Total	30,513·50

ABSTRACT OF COST OF ESTIMATE No. 158.—BRIDGE ON WELL FOUNDATIONS, 10′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	4,447	Brick-work in foundations, at Rs. 17 per 100 ...	755·99
„	16,263	„ in superstructure, at Rs. 20 per 100 ...	3,252·60
„	260	Brick-on-edge, at Rs. 25 per 100	65·00
„	1,345	Arching, heavy, at Rs. 32 per 100	430·40
„	104	„ light, at Rs. 26 per 100	27·04
„	1,357	Filling in, at Rs. 12 per 100	162·84
„	1,005	Puddle, at Rs. 10 per 1,000	10·05
„	1,356	Metalling, at Rs. 6 per 100	81·36
„	4,315	Excavation, at Rs. 3·25 per 1,000	14·02
		Undersinking wells, as per Estimate No. 159A ...	240·00
		Number of curbs	240·00
		Grand Total	5,279·30

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 159.—BRIDGE, 18′ ROADWAY.

Quantity.		Description.	Total.
			Rs.
Cubic feet	4,686	Masonry in foundations, at Rs. 17 per 100 ...	796·62
„	18,295	„ in superstructure, at Rs. 20 per 100 ...	3,659·00
„	468	Brick-on-edge, at Rs. 25 per 100	117·00
„	2,173	Arch-work, heavy, at Rs. 32 per 100	695·36
„	1,270	„ invert and light, at Rs. 26 per 100 ...	330·20
„	2,712	Metalling roadway, at Rs. 6 per 100	162·72
„	1,125	Puddle, at Rs. 10 per 1,000	11·25
„	5,320	Excavation, at Rs. 3·25 per 1,000	17·29
		Grand Total	5,789·44

ABSTRACT OF COST OF ESTIMATE No. 159 A.—BRIDGE, 18′ ROADWAY WITH WELL FOUNDATIONS.

Quantity.		Description.	Total.
			Rs.
Cubic feet	4,708	Brick-work in foundations, at Rs. 17 per 100 ...	800·36
„	168	Arching, light, at Rs. 26 per 100	43·68
„	2,173	„ heavy, at Rs. 32 per 100	695·36
		Remainder, as Estimate No. 159	3,967·26
„	1,357	Filling in wells, at Rs. 12 per 100	162·84
Lineal feet	48	Undersinking wells, at Rs. 5 per foot	240·00
Number	8	Curbs, at Rs. 30 each	240·00
		Grand Total	6,149·50

ABSTRACT OF COST OF ESTIMATE No. 160.—BRIDGE, 20′ ROADWAY.

Quantity.		Description.	Total.
			Rs.
Cubic feet	4,900	Masonry in foundations, at Rs. 17 per 100 ...	833·00
„	18,803	„ in superstructure, at Rs. 20 per 100 ...	3,760·60
„	508	Brick-on-edge, at Rs. 25 per 100	127·00
„	2,380	Arch-work, heavy, at Rs. 32 per 100	761·60
„	1,391	„ inverts and light, at Rs. 26 per 100 ...	361·66
„	3,051	Metalling roadway, at Rs. 6 per 100	183·06
„	1,155	Puddle, at Rs. 10 per 1,000	11·55
„	5,670	Excavation, at Rs, 3·25 per 1,000	18·43
		Grand Total	6,056·90

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 160A.—BRIDGE, 20′ ROADWAY WITH WELL FOUNDATIONS.

Quantity.		Description.	Total.
			Rs.
Cubic feet	4,772	Brick-work in foundations, at Rs. 17 per 100 ...	811·24
"	184	Arching, light, at Rs. 26 per 100	47·84
"	2,380	" heavy, at Rs. 32 per 100	761·60
		Remainder, as Estimate No. 160	4,100·64
		Undersinking, &c., as Estimate No. 159A ...	642·84
		Grand Total	6,364·16

ABSTRACT OF COST OF ESTIMATE No. 161.—BRIDGE, 25′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	5,435	Masonry in foundations, at Rs. 17 per 100 ...	923·95
"	20,073	" in superstructure, at Rs. 20 per 100 ...	4,014·60
"	608	Brick-on-edge, at Rs. 25 per 100	152·00
"	2,898	Arch-work, heavy, at Rs. 32 per 100	927·36
"	1,694	" inverts and light, at Rs. 26 per 100 ...	440·44
"	3,898	Metalling roadway, at Rs. 6 per 100	233·88
"	1,230	Puddle, at Rs. 10 per 1,000	12·30
"	6,545	Excavation, at Rs. 3·25 per 1,000	21·27
		Grand Total	6,725·80

ABSTRACT OF COST OF ESTIMATE No. 161A.—BRIDGE, 25′ ROAD WAY, BUT WITH WELL FOUNDATIONS.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	5,535	Brick-work in foundations, at Rs. 17 per 100 ...	940·95
"	224	Arching, light, at Rs. 26 per 100	58·24
"	2,898	" heavy, at Rs. 32 per 100	927·36
		Remainder, as Estimate No. 161	4,434·05
"	1,696	Filling in wells, at Rs. 12 per 100	203·52
Lineal feet	60	Under-sinking wells, at Rs. 5 per foot	300·00
Number	10	Curbs, at Rs. 30 each	300·00
		Grand Total	7,164·12

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 162.—CULVERT FOR DRAINAGE, 2 ARCHES OF 20′ SPAN.

QUANTITY.		DESCRIPTION.	COST.
			Rs.
Cubic feet	17,568	Masonry in foundations, at Rs. 17 per 100 ...	2,986·56
„	32,180	„ superstructure, at Rs. 20 per 100 ...	6,436·00
„	7,596	Arch-work, light, at Rs. 28 per 100	2,126·88
„	6,646	„ invert, at Rs. 26 per 100	1,727·96
„	2,880	Kunkur flooring, dry, at Rs. 8 per 100 ...	230·40
„	1,456	Puddle, at Rs. 10 per 1,000	14·56
„	23,898	Excavation, at Rs. 3·25 per 1,000	77·67
		GRAND TOTAL	13,600·03

ABSTRACT OF COST OF ESTIMATE No. 163—CULVERT FOR DRAINAGE, 2 ARCHES OF 10′ SPAN.

QUANTITY.		DESCRIPTION.	TOTAL.
			Rs.
Cubic feet	7,283	Masonry in foundation, at Rs. 17 per 100 ...	1,238·11
„	22,300	„ in superstructure, at Rs. 20 per 100 ...	4,460·00
„	2,532	Arch-work, light, at Rs. 28 per 100	708·96
„	2,215	„ inverts, at Rs. 26 per 100	575·90
„	1,680	Kunkur flooring, dry, at Rs. 8 per 100	134·40
„	728	Puddle, at Rs. 10 per 1,000	7·28
„	8,385	Excavation, at Rs. 3·25 per 1,000	27·25
		GRAND TOTAL	7,151·90

ABSTRACT OF COST OF ESTIMATE No. 164.—SYPHONS FOR DRAINAGE, 1 ARCH OF 10′ SPAN.

QUANTITY.		DESCRIPTION.	TOTAL.
			Rs.
Cubic feet	3,996	Masonry in foundations, at Rs. 17 per 100 ...	679·32
„	4,802	„ in superstructure, at Rs. 20 per 100 ...	960·40
„	1,266	Arch-work, light, at Rs. 28 per 100	354·48
„	1,108	„ invert, at Rs. 26 per 100	288·08
„	520	Kunkur flooring, dry, at Rs. 8 per 100... ...	41·60
„	322	Puddle, at Rs. 10 per 1,000	3·22
„	15,288	Excavation, at Rs. 3·25 per 1,000	49·68
		GRAND TOTAL	2,376·78

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 165.—SYPHON FOR DRAINAGE, 1 ARCH OF 6′ SPAN.

Quantity.		Description.	Total.
			Rs.
Cubic feet	3,192	Masonry in foundations, at Rs. 17 per 100 ...	542·64
„	4,264	„ in superstructure, at Rs. 20 per 100 ...	852·80
„	738	Arch-work, light, at Rs. 28 per 100	206·64
„	686	„ inverts, at Rs. 26 per 100	178·36
„	360	Kunkur flooring, dry, at Rs. 8 per 100... ...	28·80
„	230	Puddle, at Rs. 10 per 1,000	2·30
„	11,171	Excavation, at Rs. 3·25 per 1,000	36·30
		Grand Total	1,847·84

ABSTRACT OF COST OF ESTIMATE No. 166.—SYPHON FOR DRAINAGE, 1 ARCH OF 3′ SPAN.

Quantity.		Description.	Total.
			Rs.
Cubic feet	2,075	Masonry in foundations, at Rs. 17 per 100 ...	352·75
„	3,220	„ in superstructure, at Rs. 20 per 100 ...	644·00
„	369	Arch-work, light, at Rs. 28 per 100	103·32
„	158	„ invert, at Rs. 26 per 100	41·08
„	320	Kunkur masonry, at Rs. 8 per 100	25·60
„	161	Puddle, at Rs. 10 per 1,000	1·61
„	5,794	Excavation, at Rs. 3·25 per 1,000	18·83
		Grand Total	1,187·19

ABSTRACT OF COST OF ESTIMATE No. 167.—SYPHON FOR DRAINAGE, 2 ARCHES OF 6′ SPAN.

Quantity.		Description.	Total.
			Rs.
Cubic feet	5,006	Masonry in foundations, at Rs. 17 per 100 ...	851·02
„	6,022	„ in superstructure at Rs. 20 per 100 ...	1,204·40
„	1,477	Arch-work, light, at Rs. 28 per 100	413·56
„	1,372	„ inverts, at Rs. 26 per 100	356·72
„	520	Kunkur flooring, dry, at Rs. 8 per 100... ...	41·60
„	414	Puddle, at Rs. 10 per 1,000	4·14
„	18,638	Excavations, at Rs. 3·25 per 1,000	60·57
		Grand Total	2,932·01

Digitized by Google

ABSTRACT OF COST OF ESTIMATE No. 168.—SYPHON FOR DRAINAGE, 2 ARCHES OF 10′ SPAN.

Quantity.		Description.	Total.
			Rs.
Cubic feet	6,802	Masonry in foundations, at Rs. 17 per 100 ...	1,156·34
„	7,098	„ in superstructure, at Rs. 20 per 100 ...	1,419·60
„	2,532	Arch-work, light, at Rs. 28 per 100	708·96
„	2,216	„ inverts, at Rs. 26 per 100	576·16
„	1,040	Kunkur flooring, dry, at Rs. 8 per 100... ...	83·20
„	598	Puddle, at Rs. 10 per 1,000	5·98
„	29,368	Excavation, at Rs. 3·25 per 1,000	95·44
		Grand Total	4,045·68

ABSTRACT OF COST OF ESTIMATE No. 169.—RAJBUHA SYPHON, 1 ARCH OF 6′ SPAN.

Quantity.		Description.	Cost.
			Rs.
Cubic fect	2,517	Masonry in foundations, at Rs. 17 per 100 ...	427·89
„	2,891	„ in superstructure, at Rs. 20 per 100 ...	578·20
„	997	Arch-work, light, at Rs. 28 per 100	274·12
„	200	Kunkur flooring, dry, at Rs.8 per 100 ...	16·00
„	230	Puddle, at Rs. 10 per 1,000	2·30
„	8,904	Excavation, at Rs. 3·25 per 1,000	28·93
		Grand Total	1,327·44

ABSTRACT OF COST OF ESTIMATE No. 170.—WATERCOURSE SYPHON, 1 ARCH OF 3′ SPAN.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	2,030	Masonry in foundations, at Rs. 17 per 100 ...	345·10
„	2,468	„ insuperstructure, at Rs. 20 per 100 ...	493·60
„	489	Arch-work, light, at Rs. 28 per 100	136·92
„	140	Kunkur flooring, dry, at Rs. 8 per 100 ...	11·20
„	161	Puddle, at Rs. 10 per 1,000	1·61
„	6,231	Excavation, at Rs. 3·25 per 1,000	20·25
		Grand Total	1,008·68

J. CROFTON, *Captain, R. E.*

Digitized by Google

GANGES CANAL.

MISCELLANEOUS ESTIMATES.

ESTIMATE No. 171.—GIRDER BRIDGE 55′ SPAN,

18′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
		Longitudinal and cross girders, rail, and fixing ...	4,000·00
Cubic feet	1,045	Iron plates between girders 55 × 19 = 1,045, at Rs. ·875 per foot	914·37
„	784	Kunkur, 55 × 19 × ·75 = 783·75, at Rs. 6 per 100 ...	47·04
		Grand Total	4,961·41
		4,961·41 ÷ 55 = 90·21 per foot.	

20′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
		Longitudinal and cross girders, rail, and fixing... ...	4,000·00
Cubic feet	1,155	Iron plates between girders, 55 × 21 = 1,155, at Rs. ·875 per foot	1,010·62
„	866	Kunkur, 55 × 21 × ·75 = 866, at Rs. 6 per 100	51·96
		Grand Total	5,062·58
		5,062·58 ÷ 55 = 92·65 per foot.	

25′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
		Longitudinal and cross girders, rail, and fixing... ...	4,000·00
Cubic feet	1,430	Iron plates between girders, 26 × 55 = 1,430, at Rs. ·875 per foot	1,251·25
„	1,072	Kunkur, 55 × 26 × ·75 = 1,072, at Rs. 6 per 100 ...	64·32
		Grand Total	5,315·57
		5,315·57 ÷ 55 = 96·65 per foot.	
		Rs.	
		2 Main girders, at Rs. 1,200 2,400	
		Hand-rail and fixing 520	
		18 Cross girders, at Rs. 60 each 1,080	
		4,000	

Digitized by Google

ESTIMATE No. 172.—GIRDER BRIDGE 30′ SPAN, 18′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
		Longitudinal and cross girders, rail, and fixing ...	1,700·00
Cubic feet	570	Iron plates between girders, 30 × 19 = 570, at Rs. ·875 per foot	498·75
„	427	Kunkur, 30 × 19 × ·75 = 427, at Rs. 6 per 100 ...	25·62
		Grand Total	2,224·37
		2,224·37 ÷ 30 = 74·14 per foot.	

20′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
		Longitudinal and cross girders, rail, and fixing ...	1,700·00
Cubic feet	630	Iron plates between girders, 30 × 21 = 630, at Rs. ·875 per foot	551·25
„	472	Kunkur, 30 × 21 × ·75 = 472, at Rs. 6 per 100 ...	28·32
		Grand Total	2,279·57
		2,279·57 ÷ 30 = 75·98 per foot.	

25′ ROADWAY.

Quantity.		Description.	Cost.
			Rs.
		Longitudinal and cross girders, rail, and fixing ...	1,700·00
Cubic feet	780	Iron plates between girders, 30 × 26 = 780, at Rs. ·875 per foot	682·50
„	585	Kunkur, 30 × 26 × 75 = 585, at Rs. 6 per 100 ...	35·10
		Grand Total	2,417·60
		Rs.	
		2,417·60 ÷ 30 = 80·58 per foot.	
		N. B.—2 Main girders, at Rs. 476 952	
		9 Cross „ „ Rs. 60 540	
		Iron-rail and fixing 200	
		1,692	say 1,700

Digitized by Google

ESTIMATE No. 173.—TOWING-PATHS UNDER BRIDGES 12′ WIDE.

ROADWAY 18′ WIDE.

Quantity.		Description.	Cost.
			Rs.
Number	4	Iron uprights, at Rs. 25 each	100·0
"	4	Girders, at Rs. 30 each	120·0
Lineal feet	40	T Iron, at Rs. 0·75 per foot	30·0
Square feet	432	Wooden flooring, 36 x 12, at Rs. 0·8 per foot	345·6
		Grand Total	595·6

ROADWAY 20′ WIDE.

Quantity.		Description.	Cost.
			Rs.
Number	5	Iron uprights, at Rs. 25 each	125·0
"	5	Girders, at Rs. 30 each	150·0
Lineal feet	40	T Iron, at Rs. 0·75 per foot	30·0
Square feet	456	Wooden flooring, 38 x 12, at Rs. 0·8 per foot	364·8
		Grand Total	669·8

ROADWAY 25′ WIDE.

Quantity.		Description.	Cost.
			Rs.
Number	6	Iron uprights, at Rs. 25 each	150·0
"	6	Girders, at Rs. 30 each	180·0
Lineal feet	40	T Iron, at Rs. 0·76 per foot	30·0
Square feet	516	Wooden flooring, 43 x 12, at Rs. 0·8 per foot	412·8
		Grand Total	772·8

Digitized by Google

ESTIMATE No. 174.—TOWING-PATH UNDER BRIDGES 7′ WIDE.

ROADWAY 18′ WIDE.

Quantity.		Description.	Cost.
			Rs.
Number	4	Iron uprights, at Rs. 25 each	100·0
"	4	Girders, at Rs. 17·5 each	70·0
Lineal feet	30	T Iron, at Rs. 0·75 per foot	22·5
Square feet	231	Wooden flooring, 33 × 7, at Rs. 0·8 per foot	184·8
		Grand Total	377·3

ROADWAY 20′ WIDE.

Quantity.		Description.	Cost.
			Rs.
Number	5	Iron uprights, at Rs. 25 each	125·0
"	5	Girders, at Rs. 17·5 each	87·5
Lineal feet	30	T Iron, at Rs. 0·75 per foot	22·5
Square feet	245	Wooden flooring, 35 × 7, at Rs. 0·8 per foot	196·0
		Grand Total	431·0

ROADWAY 25′ WIDE.

Quantity.		Description.	Cost.
			Rs.
Number	6	Iron uprights, at Rs. 25 each	150·0
"	6	Girders, at Rs. 17·5 each	105·0
Lineal feet	30	T Iron, at Rs. 0·75 per foot	22·5
Square feet	280	Wooden flooring, 40 × 7, at Rs. 0·80 per foot	224·0
		Grand Total	501·5

ESTIMATE No. 175.—TOWING-PATH ON CAWNPOOR BRANCH.

	Rs.
18 feet Roadway, *vide* Estimate No. 174	377·30
Deduct from uprights	50·00
Grand Total	327·30
20 feet Roadway, *vide* Estimate No. 174	431·00
Deduct from uprights	62·50
Grand Total	368·50
25 feet Roadway, *vide* Estimate No. 174	501·50
Deduct from uprights	75·00
Grand Total	426·50

Digitized by Google

ESTIMATE No. 176.—MUMHOODPOOR FALLS, WITH WOOD AND IRON GRATING.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Masonry, vide Estimate No. 17	...	...	...	..	...	...	29,061
Arch-work	...	...	...	...	...	...	2,520

ABSTRACT OF COST OF ESTIMATE No. 176.—WITH WOOD AND IRON GRATING.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	29,061	Masonry, at Rs. 22 per 100	6,393·42
„	2,520	Arch-work, at Rs. 28 per 100	705·60
		Grating, &c., *vide* Estimate No. 17	8,332·80
		Grand Total	15,431·82

ESTIMATE No. 176.—WITH STONE GRATING.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Masonry.							
Drop wall, *vide* Estimate No. 17	...	...	...	..	4,905·00		
Raising side chamber walls „ centre „ „	*Vide* Estimate No. 17			...	8,272·12		
Lengthening piers	4	38	4·5	19·35	13,235·40		
„ „	4	14	4·5	15	3,780·00		
Counterforts, *vide* Estimate No. 17	...	...	...	...	264·60		
Backing on bridge ...	8	25	5	3·67	3,760·00		
						34,127·12	
Deduct—		Area.					
Arch-ways in piers ...	4	427		4·5	7,686		
						7,686·00	
							26,441
Arch-work of bridge ...	8	26	5	1	1,040		
„ under piers ...	4	49	4·5	1·5	1,323		
„ in grating ...	8	21·4	30	1·5	7,704		
						10,067	
							10,067
Stone-work	8	21·4	30	·5	2,568	2,568	2,568

ABSTRACT OF COST OF ESTIMATE No. 176.—WITH MASONRY GRATING.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	26,441	Masonry, at Rs. 22 per 100	5,817·02
„	10,067	Arch-work, at Rs. 28 per 100	2,818·76
„	2,568	Stone-work, at Rs. 2 per foot	5,136·00
		Total cost with masonry grating	13,771·78
		Total cost with grating of wood and iron ...	15,431·82
		Difference of Cost	1,660·04

Digitized by Google

ESTIMATE No. 177.—FALLS ON 1st SECTION ALTERNATIVE LINE, 11 BAYS OF 15′ ROADWAY, 18′ WITHOUT LOCKS.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Foundations.							
Water-wings, up-stream ...	2	42	5	8·5	3,570·0		
Drop wall of fall ..	...	190	5·5	11·5	12,017·5		
Curtain wall, down-stream ..	...	190	4·5	5·5	4,072·5		
„ „ „ ...	...	190	4	4·5	3,420·0		
Flooring of fall ...	...	190	62	1·5	17,670·0		
Revetments below fall ...	2	158	5	10	15,800·0		
Foundations of 1 bridge, 4 of 51—18′ roadway ...	*Vide* Estimate No. 107				16,160·0		
						73,340	
Deduct—							
Hollows, up-stream water-wings	2	42	2	4	672		
Hollows, down-stream revetments	2	156	2	6·5	4,108		
Hollows, up-stream water-wings of bridge ...	2	52	4	8	3 328		
						8,108	
							65,232
Superstructure.							
Water-wings, up-stream ...	2	42	3·25	12	3,276·0		
Side walls of fall ..	2	35	5	11	3,850·0		
„ „	2	35	3·5	12·5	3,062·5		
Sloping portion of wall ...	2	12	2	3	144·0		
Side walls of fall ...	2	35	5	5	1,750·0		
„ „ ...	2	35	3·5	12·5	3,062·5		
Piers of fall	10	31	2·5	22	17,050·0		
„ „	10	3	2·5	12	900·0		
Backing of arches over fall	22	7·5	3	1·5	742·5		
Counterforts of foot-path bridge	2	3	3·5	7	147·0		
Retaining walls of foot-path bridge	2	15	8	2·5	600·0		
Retaining walls below fall...	2	158	3	12	11,376·0		
Counterforts of revetments	10	2	2	10	400·0		
Superstructure of 1 bridge, 4 of 51—18′ roadway ...	*Vide* Estimate No. 107				58,593·37		
						104,953·87	
Deduct—							
Up-stream water-wings of bridge	2	52	2·5	12	3,120·0		
Brick-on-edge 5″ thick ...	...	190	3	·5	285·0		
„ 1′ „ ...	...	...	...	...	12,920·0		
Difference between bridge with and without Tow-path, &c. — Parapets...	...	14	·75	2	21·0		
„ „ ...	...	14	1·5	1·5	31·5		
„ „ ...	...	14	2	1	28·0		
„ Piers ...	3	21	6·5	3	1,228·5		
„ Tow-path walls ...	2	21	2·5	12	1,260·0		
						18,894	
							86,059·87
Carried over ...	...	...	...	...	...	...	151,291·87

Digitized by Google

ESTIMATE No. 177.—FALLS ON 1st SECTION ALTERNATIVE LINE, 11 BAYS OF 15′, ROADWAY 18′ WITHOUT LOCKS,—*continued.*

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Brought forward ...	...	...	...	...	...	...	151,291·87
Arching.							
Over fall	11	16	3	1	528		
						528	
As Estimate No. 107, inverts	...	...	...	...	6,426		
Deduct	...	14	21	1·5	441		
						5,985	
As Estimate No. 107, bridge Arches	...	...	...	...	13,734		
Deduct	...	14	21	3	882		
						12,852	
							19,365
Brick-on-edge 3′ bridge ...	...	190	3	·5	285		
Flooring of fall 1′ thick ...	...	190	68	1	12,920		
						13,205	
Deduct stone capping, as Estimate No. 101	...	...	...	...	...	799	
							12,406
				Grand Total, Brick-work			183,062·87
Concrete bed	...	190	70	3	39,900		
						39,900	
							39,900
Kunkur flooring	...	190	20	2	7,600		
						7,600	
							7,600
Puddle.							
Abutments	2	70	20·5	1·5	4,305		
Drop-wall of fall	...	190	20	2	7,600		
" "	...	190	4	9·5	7,220		
						19,125	
Earth-work.							19,125
Basin of fall	..	190	65	4	49,400		
Foundations	...	...	..	...	73,340		
						122,740	
							122,740
Metalling	...	...	...	...	5,400		
						...	5,400

ABSTRACT OF COST OF ESTIMATE No. 177.

Quantity.		Description.	Cost.
			Rs.
Cubic feet	65,232	Brick-work in foundations, at Rs. 20 per 100 ...	13,046·40
"	47,140	" in superstructure, at Rs. 20 per 100 ...	9,428·00
"	38,920	" " at Rs. 24 per 100 ...	9,340·80
"	12,852	Arch-work, heavy, at Rs. 32 per 100	4,112·64
"	528	" light, at Rs. 28 per 100	147·84
"	5,985	" inverts, at Rs. 26 per 100	1,556·10
"	12,406	Brick-on-edge, at Rs. 25 per 100	3,101·50
Lineal feet	799	Stone capping, as Estimate No. 101, at Rs. 2 per foot	1,598·00
Cubic feet	39,900	Concrete, at Rs. 14 per 100	5,586·00
Lineal feet	264	Stone grooving, as Estimate No. 101, at Re. 1 per foot	264·00
Cubic feet	7,600	Kunkur flooring, dry, at Rs. 8 per 100	608·00
"	5,400	Metalling, at Rs. 6 per 100	324·00
"	19,125	Puddle, at Rs. 10 per 1,000	191·25
"	122,740	Earth-work, at Rs. 3·25 per 1,000	398 90
		Gratings, &c., as Estimate No. 101	9,534 87
		Grand Total	59,238·30

Digitized by Google

ESTIMATE No. 178.—LOCK ON MUHOODPOOR FALLS.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Demolition.							
Arches	2	25	2	18	1,800		
Parapets	4	25	1·5	3	450		
						2,250	
							2,250
Masonry.							
Wells	8	20·41	1·5	10	2,449·20		
„ in curtains	4	14·12	1·5	8	677·76		
		Area.					
Covering of wells	8	19·63	1·5	...	235·56		
Flooring	2	20	16	2	1,280·00		
Walls of locks	2	26	7	14	5,096·00		
„ „	2	119	7	21·56	35,918·96		
„ „	2	24	6	21·56	6,209·28		
„ „	2	3	3·5	21·56	452·76		
„ „	2	5	6	21·56	1,293·60		
„ „	2	104	4·5	7	6,552·00		
Counterforts	5	3	3	11	495·00		
						60,660·12	
Deduct,—Hollows in walls	2	100	2	19	7,600		
						7,600	
							53,060
Lock gates	4	9·54	9·3	...	354·88		
	4	9·54	19·86	...	757·85		
						1,112·73	
							1,113

ABSTRACT OF ESTIMATE No. 178.

Quantity.		Description.	Total.
			Rs.
Cubic feet	2,250	Demolition, at Re. 1 per 100	22·50
„	53,060	Masonry, at Rs. 22 per 100	11,673·20
Square feet	1,113	Lock gates, at Rs. 6·5 per foot	7,234·50
Number	4	Crabs, at Rs. 135 each	540·00
„	4	Sluices, at Rs. 125 each	500·00
„	4	Pulleys, at Rs. 5 each	20·00
Lineal feet	104	Chain, at Re. 1 per foot	104·00
„	36	Draw-bridges, at Rs. 60 per foot	2,160·00
		Grand Total	22,254·20

Digitized by Google

ESTIMATE No ——(?)————————————(?)

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Excavation, vide Estimate No. 17	...	...	...	...	...	...	966,490
Masonry, vide Estimate No. 17	...	...	...	...	1,542		
Piers	2	34	3	19·35	3,947·4		
						5,489	
		Area.					
Deduct from piers ...	2	286	3	...	1,716		
						1,716	
							3,773
Grating	4	11	27	...	1,188		
						1,188	
							1,188
Girders	8	13	...	...	104		
						104	
							104
Wall-plates	4	11	...	...	44		
						44	
							44
Stone-flooring ...	2	12	50	·75	900		
						900	
							900

ABSTRACT OF ESTIMATE No.——(?)

Quantity.		Description.	Total.
			Rs.
Cubic feet	966,490	Excavation, at Rs. 2·25 per 100	2,174·60
„	3,773	Masonry, at Rs. 22 per 100	830·06
Square feet	1,188	Grating, at Re. 1·15 per foot	1,366·20
Lineal feet	104	Girders, at Rs. 4·25 per foot	442·00
„	44	Wall-plate, at Rs. 6·25 per foot	275·00
Cubic feet	900	Stone, at Rs. 2 per foot	1,800·00
		Grand Total	6,887·86

Digitized by Google

ESTIMATE No. 179.—SOONDA BRIDGE.

Description.	No.	L.	B.	D.	Quantity.	Total	Grand Total.
Demolition, vide Estimate No. 35	...	...	...	...	...	...	16,543
Masonry.							
Raising piers	2	21	6·5	5	1,365·00		
Filling spaces in abutments	2	21	6	4·75	1,197·00		
Raising wings	4	35	2·5	5	1,750·00		
„ pillars	4	4	4	5	320·00		
Backing of arches, *vide* Estimate No. 34	...	...	...	...	3,024·00		
Spandrils, *vide* Estimate No. 34	...	...	...	...	2,037·50		
Parapets	2	235	1·5	2·87	2,023·35		
Pillars	4	3	3	2·87	103·32	11,820	11,820
Embankment	2	450	35	2·5	78,750	78,750	78,750
Lifting and relaying metal...	...	500	15	·75	5,625	5,625	5,625
Arch-work	3	54	21	2·25	7,654·5	7,654	7,654

ABSTRACT OF ESTIMATE No. 179.

Quantity.		Description.	Total.
			Rs.
Cubic feet	16,543	Demolition, at Re. 1 per 100	165·43
„	11,820	Brick-work, at Rs. 22 per 100	2,600·40
„	7,654	Arch-work, at Rs. 32 per 100	2,449·28
		Tow-path, 12 feet wide	595·60
„	78,750	Embankment, at Rs. 2·25 per 1,000	177·18
„	5,625	Metalling, at Re. 1 per 100	56·25
			6,044·14
		Amount of estimate with girders ...	15,205·25
		Difference of cost	9,161·11

Digitized by Google

ESTIMATE No. 180.—TEMPORARY OVER-FALL ON DIVERSION, 200′ WATERWAY.

Description.	No.	L.	B.	D.	Quantity.	Total.	Grand Total.
Abutments.							
Piling	372	18	0·75	0·75	3,766		
Walling pieces	2	140	0·5	0·75	105		
						3,871	
							3,871
Weir.							
Cribs	40	...	...	...	40		
						40	
							40
Piles	533	18	0·75	0·75	5,396		
"	266	14	0·75	0·75	2,088		
Covering of timber ...	...	200	22	0·75	3,300		
Walling pieces	3	200	0·50	0·75	225		
						11,009	
							11,009
Boulders	...	200	20	8	32,000		
		200	40	2	16,000		
		200	10	5	10,000		
						58,000	
							58,000

ABSTRACT OF ESTIMATE No. 180.

Quantity.		Description.	Total.
			Rs.
Cubic feet.	3,871	Timber in abutments, at Rs. 0·62 per foot	2,400·02
"	11,009	" " Weir, at Rs. 0·62 per foot	6,825·58
Number	40	Cribs, at Rs. 20 each	800·00
Cubic feet..	58,000	Boulders, at Rs. 7 per 100	4,040·00
		Grand Total	14,085·60
		Cost of Weir = Rs. 11,685·58 ÷ 200 = 58·85 per foot, say Rs. 59.	

ESTIMATE No. 181.—DIVERSIONS OF MAIN CHANNEL ABOVE FUTTEGURH BRANCH HEAD.

DESCRIPTION.	No.	L.	B.	D.	CONTENTS.	TOTAL.	GRAND TOTAL.
Excavation and filling ...	...	500	150	10	750,000	750,000	750,000
Bridge-of-boats							

ABSTRACT OF COST OF ESTIMATE No. 181.

QUANTITY.		DESCRIPTION.	COST.
			Rs.
Cubic feet	750,000	Excavation and filling, at Rs. 4 per 1,000	3,000
Lineal feet	150	Piling to protect slopes, at Rs. 5·0 per foot	750
		Bridge-of-boats	500
		GRAND TOTAL	4,250

No.——(?)—FROM FUTTEGURH BRANCH HEAD TO NANOON.

DESCRIPTION.	No.	L.	B.	D.	CONTENTS.	TOTAL.	GRAND TOTAL.
Excavation and filling ...	...	500	115	10	575,000	575,000	575,000
Bridge-of-boats							

ABSTRACT OF COST OF ESTIMATE No.——(?)

QUANTITY.		DESCRIPTION.	COST.
			Rs.
Cubic feet	575,000	Excavation and filling, at Rs. 4 per 1,000 ...	2,300
Lineal feet	150	Piling to protect slopes, at Rs. 5 per foot ...	750
		Bridge-of-boats	800
		GRAND TOTAL	3,850

J. CROFTON, *Captain, R. E.*

Digitized by Google

REPORT

OF THE

GANGES CANAL COMMITTEE,

CONVENED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA IN COUNCIL (No. 20,410c., OF GOVERNMENT OF INDIA, PUBLIC WORKS DEPARTMENT, DATED 24TH FEBRUARY, 1866), TO DECIDE UPON THE PROPRIETY OF PROCEEDING, AS PREVIOUSLY DETERMINED WITH

MAJOR CROFTON'S PROJECT FOR REMODELLING THE GANGES CANAL,

OR

OF STOPPING ITS PROGRESS, PENDING THE PREPARATION OF A DETAILED PROJECT

ACCORDING TO THE VIEWS OF MAJOR-GENL. SIR ARTHUR COTTON, R.E., K.S.I.

WITH A COMPARISON OF THE COST AND ADVANTAGES OF THE TWO PLANS.

ROORKEE:
PRINTED AT THE THOMASON CIVIL ENGINEERING COLLEGE PRESS.
MDCCCLXVI.

Digitized by Google

JAMES JOHNSTON, SUPERINTENDENT.

Digitized by Google

CONTENTS.

	PAGE
PROPOSED HEADS FOR THE GANGES CANAL.	
Preliminary Observations, ...	3
Head Works near Sookertal, ...	6
Head Works on the Ganges below Sookertal:—Gurmuktesur, ...	16
„ „ „ „ Rajghat, ...	*ib.*
Head Works on the Jumna, near Agra, ...	20
„ „ „ Delhi, ...	*ib.*
Remarks on the present condition of the Ganges Canal, ...	27
Remarks on Major Crofton's Project, ...	31
Proposed Weir across the Ganges at Hurdwar, ...	36
Stone from the Sewalik Hills and Himalayas for the Canal works, ...	38
Extension of the Canal from Cawnpore to Allahabad, ...	41
Financial state of Canal, ...	42
Comparison of the Financial Results of Madras Irrigation Works with those of the Ganges Canal, ...	47
Acknowledgments, ...	48
Dissent, ...	49
Appendix A., ...	i
„ B., ...	x
„ C., ...	xiii
„ D., ...	xxii
„ E., ...	xxiv
„ F., ...	xxv

Digitized by Google

Digitized by Google

Report of a Committee convened by Order of His Excellency the Governor General of India in Council (No. 20,410c., of Government of India, Public Works Department, dated 24th February, 1866), to decide upon the propriety of proceeding, as previously determined, with Major Crofton's project for remodelling the Ganges Canal, or of stopping its progress, pending the preparation of a detailed project according to the views of Major-General Sir Arthur Cotton, R.E., with a comparison of the cost and advantages of the two plans.

President.

COLONEL COMMANDANT EDWARD LAWFORD, R.E.

Members.

LT.-COL. J. C. ANDERSON, R.E.	GEORGE SIBLEY, C.E.
LT.-COL. J. G. FIFE, R.E.	HUGH LEONARD, M.I.C.E., F.G.S.

Proceedings of the Committee.

The Committee having met at Cawnpore on the 31st March, proceeded, accompanied by Major J. Crofton, R.E., to examine the Canal Works from the river Ganges up to near the Dubowli Falls, and also the river itself in the vicinity of the town. They then went to Agra and examined the river Jumna at that place, and for a few miles lower down.

The Ganges was examined near Rajghat, opposite Allygurh, and the Committee proceeded for about eight miles along the canal above Nanoon, after inspecting the Regulating Works at that place. The river Jumna was examined at the confluence of the Hindun, and afterwards at Alee, a small village near the ruins of Toghlukabad, about ten miles below Delhi.

The Committee then returned to the Ganges at Gurmuktesur, and from thence marched along the edge of the high land, to the confluence of the Solani torrent with the Ganges, examining its junction with the strip of low ground along the margin of the river nearly the whole way, and more carefully in the vicinity of the Solani. Crossing the high land to the canal, the Committee then proceeded along its banks from the Jaoli Falls to the head at Hurdwar, examining each important work as closely as circumstances permitted, and termina-

Digitized by Google

ting their inspections with the temporary bunds in the river and the head works of the canal.

The Committee also saw some of the places near Hurdwar from whence stone has been obtained for the canal works.

Conclusions arrived at.

After much discussion and careful consideration of every point bearing on the subject, the Committee have arrived at the following conclusions, on grounds explained in the subsequent detailed reports.

Weir across the Ganges near the Solani.

£1,128,631.

I. That the construction of a weir across the Ganges below the confluence of the Solani with other necessary works for supplying water to the canal, at an estimated cost of Rs. 1,12,86,314 cannot be recommended.

Weir and canal at Rajghat.

£1,130,417.

II. That the project for opening an additional canal head, including the construction of a weir on the Ganges at Rajghat, or other point in that part of the river, at a cost of Rs. 1,13,04,170, for bringing under irrigation lands not now watered by the canal is feasible, but should be held in abeyance until the probable returns appear more proportionate to the outlay than at present.

Weir across the Jumna, and canal for irrigation.

£354,570.

III. That the construction of a weir across the Jumna at Toghlukabad with a canal for the irrigation of that part of the Doab below Allyghur, not under the influence of the Ganges canal, at a probable cost of Rs. 35,45,701, inclusive of branch channels, is practicable, and that the project should be further investigated; but they are of opinion that it cannot be substituted for any portion of Major Crofton's project.

Major Crofton's project.

IV. That Major Crofton's project for remodelling the Ganges canal should be proceeded with, subject to the modifications suggested in this Report.

Weir at Hurdwar.

V. That the construction of a permanent weir across the Ganges at Hurdwar, though not indispensable while the present reduced quantity of water is passed down the canal, will become a matter of absolute necessity in order to maintain without risk of interruption the full supply of 7,000 cubic feet per second.

Digitized by Google

PROPOSED HEADS FOR THE GANGES CANAL.

PRELIMINARY OBSERVATIONS.

1. As the Committee think that the peculiarities of the Ganges are somewhat remarkable, and that a comprehension of them is indispensable before an opinion of any value can be formed as to the relative advantages of different sites for the opening out of new canals, they will endeavour to describe them.

Peculiarities of Ganges somewhat remarkable.

2. The Plains in the N. W. Provinces, unlike the Deltas on the East Coast, are far above the limit of the inundation of the rivers. In the course of ages the Ganges and the Jumna have scooped out their beds to a far lower level than they must have had at some former period, and this operation has completely changed the relation of the land with the rivers. The N. W. Provinces for a distance of several hundred miles from the base of the hills are thus formed of a vast plateau, which rises many feet above the highest flood level of the Ganges and Jumna. This elevated tract is termed the Bangur, in contradistinction to the Khadir, or the strip of low land in the actual valleys of the rivers, and which is more or less inundated by them during high floods. The fall of the Bangur is not exactly the same as that of the rivers; or, in other words, the plane of the surface is not parallel to the surface of the rivers. That of the Ganges is more elevated near the hills than it is at any point lower down. For instance at Sookertal, at the distance of 34 miles from the hills, it is 80 feet above the flood level of the Ganges opposite; and at Cawnpore, 350 miles below Hurdwar, the elevation is only 38 feet. But the difference is in a nearly regular gradation, so that knowing the height of the Bangur above the river at any two points, say 40 miles apart, it may be assumed with confidence that the height at the point midway between them would be almost exactly the mean of the other two.

Character of the Plains in the N. W. Provinces, in relation to the rivers flowing through them.

3. A range of low hills called the Sewaliks runs in a nearly straight line across the head of the Bangur land from the Ganges to the Jumna. From their base to the junction of the two rivers at Allahabad, the great plain is unbroken by a single elevation larger than a sand hillock.

Unbroken plain from Sewalik hills to Allahabad.

4. The drainage water from the southern slopes of the Sewalik

Drainage from the Sewaliks.

Digitized by Google

range has to find its way into the Ganges and Jumna. The portion due to the latter, that is the Western section, runs for the most part through the Bangur, and united with the minor drainages form the river Hindun which joins the Jumna below Delhi. But the drainage courses on the eastern section of the Sewaliks turn off abruptly towards the Ganges, constituting a series of torrents which have completely altered the character of the portion of the Bangur traversed by them, that is along a distance of about 20 miles, extending between the well known towns of Hurdwar and Roorkee. Hurdwar is on the east flank of the Sewaliks and close to the Ganges; Roorkee is on the Bangur land beyond the influence of the hill drainage.

The country slopes along the drainage courses towards the Ganges between Hurdwar and Roorkee: great expense of carrying canal across the drainage.

5. Thus the original formation of the Bangur from Hurdwar to Roorkee is broken. It has in fact been washed down by the torrents, which have thus formed a plane sloping towards the Ganges. But this plane also has a slope parallel to or along the Ganges, so that when selecting the line for a Canal to open from the Ganges at Hurdwar, the Engineer could obtain the required fall (indeed there was more than sufficient), and could at the same time work up the course of the drainages, so as after crossing the last of them, to be able to enter the Bangur land, in a moderate cutting. Thus the point selected for crossing the Solani, the last of the hill torrents, is 80 feet below the head of the canal at Hurdwar, but it is 70 feet above the level of the Ganges immediately opposite. The aqueduct across the Solani raises the sole of the canal 20 feet, and the level of the Bangur at Roorkee being 45 to 50 feet below the head of the canal; it can be entered in a cutting 10 to 15 feet in depth. Besides the advantages thus gained by opening the canal at Hurdwar the two other important objects have been attained. I. The water from the river enters the canal charged with much less silt than would have been the case had the head been lower down. II. The channel being of a comparatively permanent nature, the sluice and regulating works are secure against the action of the stream, which can be more easily controlled, and by temporary arrangements more easily diverted towards the mouth of the canal, than at any point below. On the other hand, the Hurdwar head involved an enormous expense in masonry works for the Solani and other hill torrents which the canal had to cross, and for overcoming this excessive slope of country.

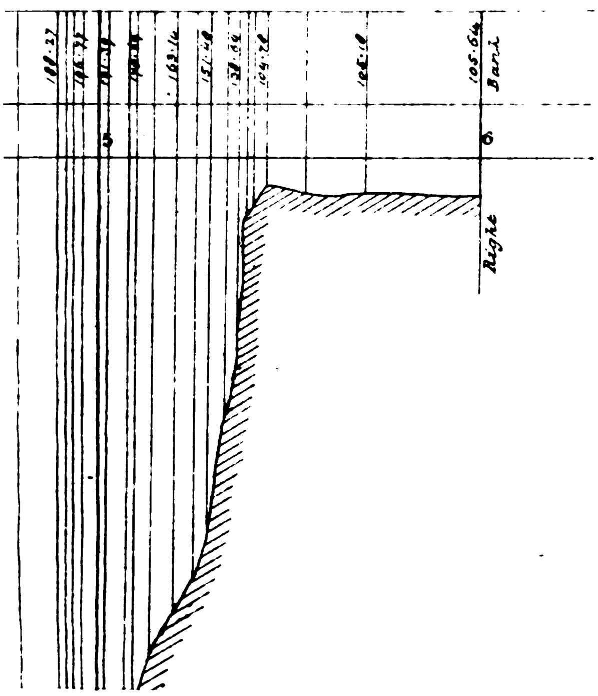
Sir A. Cotton in favor of a head near Sookertal.

6. Sir A. Cotton maintains that it would have been far better to have opened the canal head in the first instance near Sookertal, below the confluence of the Solani with the Ganges; and that even now, instead of spending a large sum to improve the existing line, it would be preferable to open a new head about Sookertal.

Width of Ganges at Sookertal.

7. The Committee refer to this point, and find that the valley of the Ganges is four miles wide. The river is only about half a mile in width during the dry season, but in high floods the whole of the valley is submerged.

Digitized by Google



c

Digitized by Google

8. The Khadir, or low land forming the valley, is formed of a crust of alluvial soil, which may vary from the thickness of a few inches to a yard or more, overlying pure and exceedingly fine micaceous sand, which extends to an unknown depth. The Khadir everywhere possesses the same character, but is wider at one point than another; and while in some places the dry weather channel runs nearly through the centre of it, in others it may run on one flank or under the foot of the Bangur, as for instance at Rajghat, Futtehghur, and Cawnpore.

Nature of Khadir or valley of the Ganges.

9. The Khadir is intersected by deserted arms of the river, some of which have become choked by deposits, till there is only a depression to mark their course. The Khadir cannot properly be termed the channel of the river though mostly inundated in high floods; and it is liable to be, and frequently is, encroached upon by the action of the stream, so that at no single point can it be said to be safe from its influence. The experience of some of the Members of the Committee on the Ganges in Bengal, the Punjab rivers, and the Indus in Scinde, could furnish proofs of the extraordinarily rapid and extensive action of the Himalayan rivers in eroding their banks and altering their courses. Instances could be adduced of villages and trees being carried away bodily, even in ordinary floods, not by direct action of the stream during inundation, but by its undermining action before it rose to the level of the bank. The sand is sucked away by the current when the river is rising or falling, and the crust of stiff alluvial soil falls in masses by its own weight. There is thus no stability in the Khadir. If embanked, the action of the river being on the sand at a low level, the embankment would have no strength to resist the stream, and no material is procurable on the spot for protecting the foot of the slope.

Khadir frequently encroached upon by the river.

10. It would be irrelevant to seek for examples of the destructive and changeable character of the Himalayan rivers at points at a distance from those which do not more or less nearly concern the Ganges canal, but below Sookertal, the very point which Sir A. Cotton has selected as the most suitable head for the canal, the river instead of flowing close to the foot of the Bangur land, as it is shown in the Trigonometrical Survey sheets, has now a course more than one and a half miles to the eastward, while the confluence of the Hindun with the Jumna, about 20 miles below Delhi, which Major Crofton has similarily pointed out as a likely place for a head to the canal, is now four miles lower than it was, when the Trigonometrical Survey was made.

Changes at Sookertal on the Ganges, and at the confluence of Hindun with the Jumna.

11. The banks of the Godavery and Kistna are formed of alluvial soil containing a large proportion of clay down to and below the summer level of the water: here and there strata of sand are to be seen, but as a rule the banks are firm.

Banks of Godavery and Kistna more permanent.

12. On the Ganges it is different. Sir A. Cotton seems for-

Sir A. Cotton and

Digitized by Google

Major Haig, on the Godavery.

merly to have thought so also, as will be seen from the following extract from one of his Reports on the Godavery.

Professional Papers, Madras Engineers, Vol. III., p. 190.

"It must be observed that these changes, from the action of the river on its banks are much slower on the Godavery than in the Colleroon and Cauvery, and as it seems also on the Indus and Ganges; so that there is plenty of time to take the necessary precautions; and the stone we have here at hand is a material for barriers far beyond the power of the stream to remove, even though in pieces of the size of the fist." "In comparing the present state of the river with the map constructed 30 years ago, it will be seen how very slowly the encroachments of this river proceed." Major Haig bears testimony to the same effect. The following is an extract from his Report, dated

Parliamentary Blue Book on the Upper Godavery, 1862, p. 75.

3rd February, 1862. "In the first place the Godavery differs from the Ganges in two very important particulars. Its banks are but little liable to erosion and subject to little change. The changes which take place on the Ganges in the course of a few weeks or months would be on this river the work of a century, or rather, it would be more correct to say that the country along its banks presents incontestible proofs that no material alteration has taken place in the position of the channel for ages. In the second place, the material of which the bed is composed is a large course grained sand, totally unlike the fine powdery sand of the Ganges, and therefore requiring a very much more powerful current to displace it."

Works for control of Ganges require to be on a more extensive scale than those on the Godavery.

13. The obvious conclusion to be drawn from the above facts is that, although the Ganges for a considerable distance from the Himalayas discharges during floods, a very much smaller body of water than the Godavery, yet owing to the weakness of its banks and the long continuance of its floods, it is so much more destructive than the latter, that works on a more extensive scale in proportion to its discharge would be required to control it.

HEAD WORKS NEAR SOOKERTAL.

FLOOD DISCHARGE AND LENGTH OF WEIR REQUIRED.

Flood discharge of Ganges at Sookertal.

14. The Committee have no means of ascertaining with any high degree of accuracy the flood discharge of the Ganges. Mr. Login estimated it at between 180,000 and 190,000 cubic feet per second at Hurdwar; not however including the quantity discharged by the Myapoor Dam and the canal, which would probably amount to 20,000 cubic feet per second more. Sir Proby Cautley again

Ganges Canal Report, Vol. II., p. 465.

estimates the flood discharge of the Solani at 84,000 cubic feet per second, and the discharge of the other large drainages between the Solani and Hurdwar, must amount to at least as much more. A considerable body of water must also enter at the opposite bank of

Digitized by Google

the river. Hence it may be concluded that the flood discharge of the Ganges below the confluence of the Solani would be much greater than at Hurdwar. From the cross section which has been taken at Sookertal below the Solani, combined with the surface fall, it is found that a rise of $13\frac{1}{2}$ feet above the ordinary low level, would give a discharge of 516,000 cubic feet per second; but this is probably an extraordinarily high flood which might not be experienced under an interval of 20 years. According to the Registers, which were kept at Cawnpore and Futtehghur from 1843 to 1853, the highest flood at the former was 13 feet 8 inches, and at the latter 10 feet 8 inches, above low level. The highest rise at Cawnpore is probably attributable to the influx of the Ram Gunga, and 10 feet 8 inches, or say 11 feet, is more likely to represent the rise between Futtehghur and Hurdwar. Applying this to the section at Sookertal, the Committee find the discharge would be 279,000 cubic feet per second. Taking Sir A. Cotton's estimate of the flood discharge of the Godavery, at 1,500,000 cubic feet per second, and that of the Ganges at 280,000 cubic feet; it might be assumed that if the rise of the flood were the same in both cases and the circumstances in other respects similar, a weir of less than one-fifth the length of the Godavery anicut would suffice for the Ganges at Sookertal. As the length of the former is about 12,000 feet; the length of one for the Ganges would thus be about 2,200 feet.

Low water compared with flood level of Ganges and Godavery.

15. But the circumstances of the two rivers differ to a notable extent. The Ganges discharges a considerable body of water in the dry season, with a depth in mid channel of between 9 and 10 feet, and the floods rise from 10 to 14 feet above the level. The Godavery carries a comparatively small body of water in the summer. The surface is only 3 or 4 feet above the bed, while the flood rise to the height of 30 feet. The crest of the Godavery anicut is 14 feet above the bed. The passage of the flood water is therefore 16 feet deep. The length of the work being 12,000 feet, the mean velocity will be $\frac{1,500,000}{16 \times 12,000} = 8$ feet per second nearly.

Length and height of weir suitable to Ganges.

16. Sir A. Cotton, in one of his pamphlets, suggests a solid weir for the Ganges, 7 feet high above summer or low level. If the length of the weir were to have the same proportion to the discharge as the Godavery; and if, as Sir A. Cotton intended, there should be no perceptable afflux or heaping up of the water above the work, it would, as above-mentioned, be 2,200 feet long, so that as the rise in flood is 11 feet, the velocity would be $\frac{280,000}{2,200 \times 4} = 32$ feet a second nearly, or four times as much as that of the Godavery. If the length of the weir were to be increased to 4,000, the velocity would then be $17\frac{1}{2}$ feet per second, or still very much greater than that of the Godavery; but if the height of the weir be cut down from 7 feet above low water to 5 feet, there would then be a velocity of $\frac{280,000}{4,000 \times 6} = 11\frac{2}{3}$ feet per second,

Digitized by Google

or nearly 8 miles per hour. The afflux of the water above the natural level at that height of flood would be less than 1½ foot; there would therefore be no cause for apprehending injurious flooding of the Khadir. The above velocity corresponds very closely with that of the Kistna anicut, with a depth on the crest of 17 feet. Owing to the curve formed by the water in falling over the dam during moderate floods, the depth of water on a portion of it is less than at the crest, and the velocity is then considerably higher. There would be this same thing with the overfall on a weir on the Ganges. Were the discharge during an exceptionally high flood to amount to 500,000 cubic feet per second, which would be the case if the river rose to 13½ feet above summer level, the velocity would then be $\frac{500,000}{4,000 \times 8 \cdot 5} = 14$ feet 7 inches per second, or 10 miles per hour.

Length of weir proposed at 4,000 feet: height above low water 5 feet.

17. The length of the Kistna anicut at Bezwada is 3,600 feet, and its height above the bed of the river is 20 feet. What is considered suitable for the Ganges is a weir 4,000 feet long, and a height of 5 feet added to the ordinary depth of the river during the dry season, or in all 15 feet above the deep bed.

Additional height of 2 or 3 feet to be gained by moveable planks.

18. For the supply of a canal the surface might be raised in the dry season as suggested by Sir Arthur Cotton, by means of iron posts and moveable planks, to a height of 3 feet at the utmost above the crest of the weir, or 8 feet above low water level; but the Committee consider that 2 feet for the planking is as much as could be calculated on in practice, and that the weir would either have to be raised or the channel deepened one foot additional.

Discharge of Ganges at Sookertal during the dry season.

19. The discharge of the river near Sookertal was measured in April of this year, and found to be 5,300 cubic feet per second, while a supply of upwards of 5,000 cubic feet per second was entering the canal at Hurdwar, a portion of the latter having been returned to the river by the mill escapes. The river was then slightly higher than it had been during the winter, and allowing that the present supply of the canal is maintained, 5,000 cubic feet would be the most that could be counted on as available at Sookertal.

Capacity and fall of channel to carry 5,000 cubic feet per second.

20. A channel 180 feet bottom width, side slopes 2 horizontal to 1 vertical, and with a fall of 5½ inches per mile, would discharge that quantity with a depth of 10 feet, and velocity of 2½ feet per second. The latter is the highest the lighter kinds of soil could stand, while any reduction would render necessary an additional width of channel and an additional expense, besides causing an increased deposit of silt. The bed of the channel would thus be 2 feet below low water level of the river.

Most suitable site for a weir at Raolee Ghât, 4½ miles below Sookertal.

21. The most suitable spot for the head to the canal in the neighbourhood of Sookertal is at the bridge of boats, 4½ miles below that village, known as the Raolee Ghât. The level of the surface of the river in April was 206 below the head of the Ganges canal, and

Digitized by Google

the head of the proposed new channel would therefore be 208 feet below the same datum.

22. The bed of the Ganges canal at the $116\frac{2}{3}$ mile from Hurdwar is 242 below the head of the canal, the distance of the site of the proposed weir to this point, measured along the line which is considered best calculated to meet Sir A. Cotton's views, is 70 miles, and the fall required to carry a supply of 5,000 cubic feet a second with a velocity of $2\frac{1}{2}$ feet per second, and depth of 10 feet, being $5\frac{1}{2}$ inches per mile, there will be $\frac{70 \times 5\frac{1}{2}}{12}$ = 32 feet 1 inch, as the total fall from the head. Adding this to the relative level above-mentioned 208 feet, gives 240 feet 1 inch, which corresponds closely enough with the level of the present canal bed at $116\frac{2}{3}$ mile. A channel from the weir to the main canal would be 70 miles long.

23. Before entering upon an estimate of the cost of constructing a weir across the Ganges, the Committee propose to specify the approximate cost of the channel. It would be carried along the Khadir or low land for a distance in all of 29 miles. The surface of the Khadir falls much more rapidly than the proposed bed of the canal, and as the total height of the Bangur land above the Khadir is between 50 and 60 feet, it is desirable, in order to avoid a cutting of that depth, to carry the bed of the canal for some distance above the level of the Khadir, or in other words within embankments. For the last 13 miles of this section of the canal it is proposed to follow the base of the Bangur land, as the ground is considerably higher there than the general level of the Khadir. It however presents great irregularities. The edge of the Bangur is cut up by ravines, some of which extend back to the distance of about half a mile, and their beds are only slightly above the Khadir level. The section therefore presents a series of sharp undulations, which will necessitate a cutting in one place, and a heavy embankment in another. According to the arrangements proposed, the maximum height of the water level will be 24 feet above the ground, and as the soil is generally very sandy, this is considered as much as could be allowed with any degree of safety. A simple earthern embankment would not be sufficient along a portion of the channel under consideration. Puddling would be the most effectual mode of preventing leakage, but as suitable earth would have to be brought from a distance, the Committee recommend, as an addition to the ordinary soil obtainable on the spot, a rough concrete wall in the centre of the bank for ten miles out of the whole distance of thirteen miles. This would also have the effect of protecting the bank against vermin, a precaution which the Committee consider to be very necessary. Only one embankment where the channel runs close to the Bangur is allowed The water is supposed to stand back in the ravines, which would thus form silt traps, but the raising of the bed would only be a question of time, and sooner or later the drainage water would have to be carried under the channel, or a large body of silt would be brought into it; for the drainage courses, though Line of channel through Khadir described.

Digitized by Google

embracing an insignificant area, drop from the Bangur 50 feet above the level of the channel, and the erosion must evidently be considerable.

Drainage works ultimately necessary.

24. A catch-water drain carried along the Bangur behind the head of the ravines, would cut off part of the drainage water, but still it is considered that the portion of the channel affected by it would always be liable to damage, and that the ultimate cost of the work is likely to be much greater than an approximate estimate based on a simple section of the ground would show. In taking the cost of this part of the channel into consideration the additional expense of constructing under-tunnels and catch-water drains should not be lost sight of.

Objection to high embankments.

25. Some of the Committee consider that it would be objectionable to carry an embanked channel through the Khadir, with the surface water more than 4 or 5 feet above the level of the ground: that in consequence of the sandy character of the soil, embankments could not be guarded effectually against excessive percolation or breaches, excepting at a much heavier outlay than the present estimate provides for. They would further remark that the large body of drainage water that will be admitted into the channel, will increase the danger of breaches, and that in the event of the bank giving way in the rains, it could not in all probability be repaired till the next dry weather.

Deep cutting through Bangur land, and masonry works.

26. At the end of the 29th mile the channel would enter the Bangur in a cutting of about 35 feet, which would work out to 15 feet at the 52nd mile. From thence to the junction with the present line of canal the cutting would be moderate. Masonry works are allowed for on the scale of Major Crofton's estimate for the 1st section of the "alternative line," proposed by Sir P. Cautley (after deducting the cost of the falls and regulator at head), which was to have the same capacity as the channel now under consideration. The rate allowed for contingences and establishment, is also the same as in Major Crofton's estimate. The masonry works would be very heavy as the channel from beginning to end is carried across the drainage of the country. No separate allowance is made for catch-water drains or for the masonry works which will eventually be required to dispose of the drainage of the Bangur where the line of channel runs at its foot.

Estimate of cost of channel.

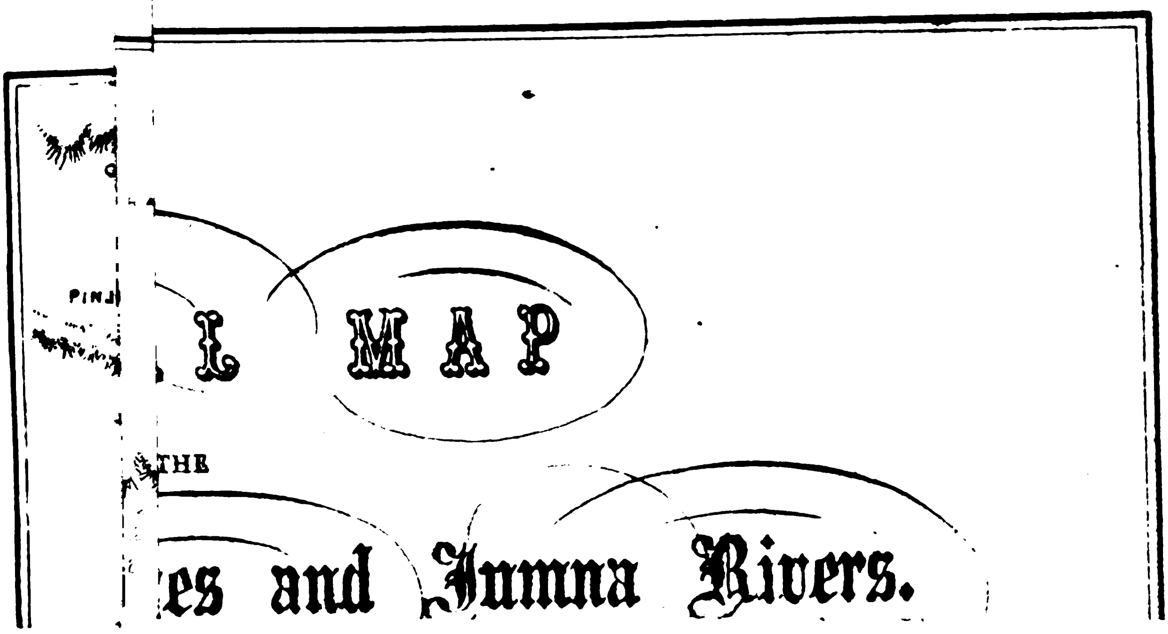
27. The Committee estimate the cost of the channel at nearly 68¾ lakhs of rupees. An abstract of the cost of the different portions of it is given in the Appendix.

Form of weir for Ganges.

28. As regards the proposed weir across the Ganges a section has been proposed which assimilates to a considerable extent to that of the Godavery anicut. The form of overfall has however been changed. Sir A. Cotton has expressed his opinion on the subject in the following terms; after he had completed the Godavery anicut, "I must however say that here as in the Coleroon, I would now prefer building a work with a vertical fall as safer in sandy rivers; and so it would in any place excepting one similar to the Kistna, where there

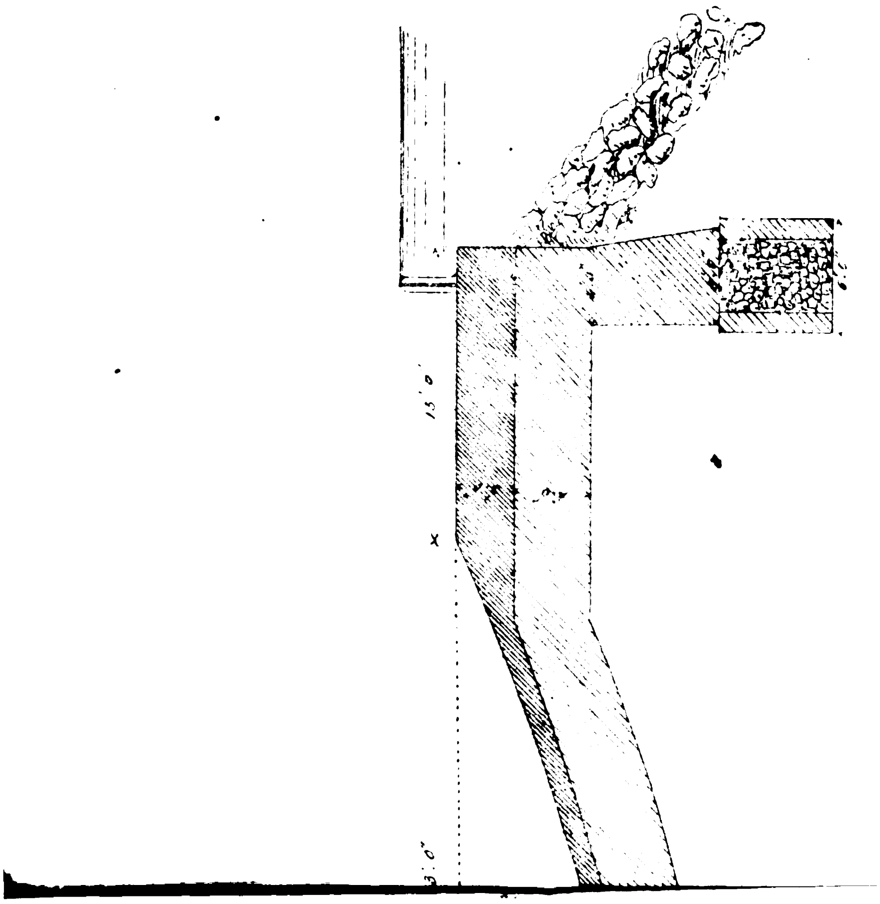
Professional Papers, Madras Engineers, Vol. III., p. 189.

Digitized by Google



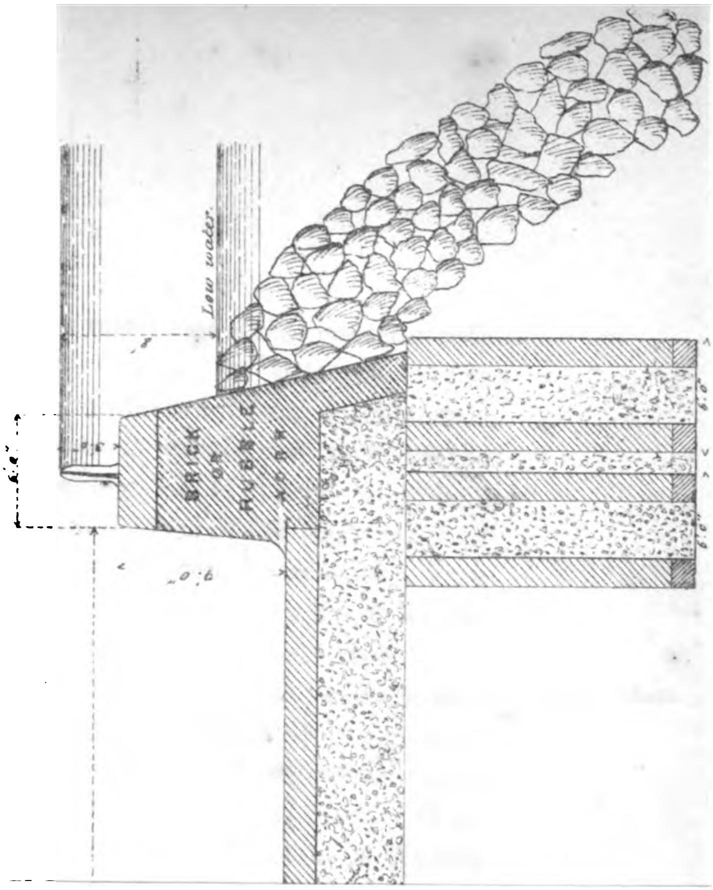
Digitized by Google

Digitized by Google



Digitized by Google

Digitized by Google



Digitized by Google

Digitized by Google

is unlimited supply of stone at very low rates, and where consequently 20 cubic yards of rough stone could be obtained at the same cost as one of cut stone. When I planned the Coleroon anicut, I considered that the great point in these rivers was to break the force of the water effectually, and prevent it scouring the lower channel; and what I have here seen makes me think still more of the importance of that principle. But I believe where stone can be obtained very cheaply, a large mass of rough stone with a very long slope on the lower side, will be the cheapest and safest work in a sandy river."

29. It will be observed that a depth of 15 feet has been allowed for the well foundations. This depth though considerably in excess of that allowed in the Madras works, is about half what is generally considered necessary in the N. W. Provinces in the foundation of falls, and other works subjected to a scouring action. The plans of Madras anicuts, as at first constructed, do not show the works in their present state; for example, the rough stone in rear of the Godavery anicut extended in the first instance to a width of only 75 feet, now according to a section which the Committee have received from the Superintending Engineer of the division, it extends to a width varying from 120 to 150 feet. The anicut across the Kistna has also received considerable additions since it was first built, and large masses of rough stone have been thrown in along the front of the works, which do not appear in any plan. The Committee learn from Colonel Dyas, that several dams in Rohilkund have lately given way, owing to the want of a stone apron; vitrified lumps of kiln refuse, the only material available, having proved an altogether inefficient substitute. Depth of foundations.

30. In designing a weir across a river like the Ganges, the foundations have to be secured against two distinct actions: firstly, the scouring action which is produced when the stream meets with an obstruction, and which would undermine and destroy the foundations, unless they are either carried down to the full depth to which the scouring extends, or unless they are protected by a mass of stone or other suitable material; and secondly the pressure arising from the water on the up-stream side of the weir being ponded up above the level of the water on the down-stream side. Unless the pressure is counteracted by the formation of the foundation wells or filling between them into a water-tight screen, it will force the water through between them, and by carrying with it the sand under the body of the work would cause it to subside and fall to pieces. Nature of action to which a weir is subjected.

31. An instructive example of the scouring action is furnished in one of the Reports of the Godavery works. One of the sections of the anicut had not been carried completely across the channel, but for a distance of 260 yards an embankment and wing wall had been substituted. The course of the stream being obstructed by these works, and the only outlet for the water being over the anicut, a current was formed towards it along the face of the wing wall, and that of the Example of scouring action on the Godavery anicut. Professional Papers, Madras Engineers, Vol. III., p. 141.

anicut itself. The result was the formation of a deep channel far below the bottom of the foundations, and a reference to the sections will show that the only thing that saved them was the deposition of a great mass of rough stone.*

Example of effect of hydraulic pressure on Coleroon anicut.

Professional Papers, Madras Engineers, Vol. I., p. 144.

32. As an example of the effect of hydraulic pressure, the Committee quote the following from a report by Colonel D. Sim, on the Coleroon anicuts. "This anicut was completed about the end of April, and was breached the following June during one of the freshes, about 80 yards of the northern division having been entirely destroyed; various causes have been assigned for the failure, and it is difficult at this time to ascertain which is the true one. It has been supposed by some to have been caused by a tall upright stone which had been fixed in the body of the work where the breach occurred, to indicate the height of the river in freshes, having got entangled in a quantity of straw and bushes floating down the stream, the large surface exposed by which acted upon by a powerful current tore it out of the anicut, and the water thereby getting access to the masonry which had not had sufficient time to set, easily destroyed the work. Others attributed the failure to the anicut having been undermined by the water being forced through its foundation by the heavy pressure during high freshes, and washing from under it the sand on which it rested. This appears to me the most probable cause of the failure of the lower anicut which was breached at the end of the second season, but I think the upper one could scarcely have been destroyed in that manner in the short period of a fortnight or three weeks. The water it is evident was forced under the foundation, and it was observed bubbling up in many places through the apron below, the anicuts whenever there were 5 or 6 feet standing above them, and if it passed in considerable quantities, which there is reason to believe it did, it would be very liable to wash away the sand by degrees and leave the work without support. During the last two years both anicuts have been materially strengthened by substantial aprons of cut stone in chunam being constructed behind them, to break the overfall of water, which have been executed in a very efficient manner. Since these additions the passage of the water underneath the foundation would seem to be considerably diminished, for it now spouts through the apron in only a few places and in small quantities, but I am not inclined to attribute this improvement so much to the aprons as to the large quantities of fine clay, and which has been collected in front of the anicut, and prevents the water being forced underneath them."

Protection against scouring action of the Ganges.

33. To apply the above facts to the case before the Committee, they have to remark that the length of the proposed weir, which for

* The Committee have been informed that the following large weirs at Madras have been breached at different times, viz:—Upper Coleroon anicut, in 1836 and 1859. Lower ditto, 1837, 1862, 1863, 1864, and 1865. Pennair anicut, 1858 and 1859. Vellaur anicut, 1853. Godavery anicut—(year unknown).

Digitized by Google

economical reasons has been limited to 4,000 feet, is only nine-sixteenths the width of the channel of the river during high floods. It is certain, therefore, that a scouring action similar to that above described as having occurred on the Godavery anicut, would be liable to be induced along the flanks of the work, and that they would require either a great depth of foundation or have to be protected in front by a large quantity of rough stone. To what depth the Ganges is liable to scour when it encounters such an obstruction as it would then meet with, there is no means of ascertaining; but it is known that the sand of which the bed and banks are formed is of a remarkably mobile quality, partaking in fact of the nature of quicksand, and that it is not unusual for the beds of the Himalayan rivers under conditions similar to those of the Ganges at Sookertal, to be scoured to a depth exceeding 20 feet below the ordinary level, when the stream sets against an exceptionally firm piece of bank. It may therefore be reasonably concluded that the foundation of a weir on the Ganges would require to be protected to a depth of at least 30 feet below the bed. It is proposed to allow 800 feet in length of wing walls for the up and down-stream sides together, on each flank of the weir, or 1,600 running feet in all; but in addition to this, the river would either have to be trained by means of rough stone groins for a considerable distance above the weir, or if defensive measures were confined to the embanked roadway which would have to be carried through the Khadir land, a large quantity of stone would have to be thrown in along the foot of its slope. It is impossible to judge precisely to what extent this protection would be necessary, but it is indispensable that precautions should be taken to resist the action of the river at any point against which the stream would be liable to set, and as this would be the case throughout the whole width of the Khadir, stone must be provided for the protection of the whole embankment. It would not necessarily be thrown in until the embankment should be threatened, but it would have to be collected at the spot ready for use at a moment's notice. The total length of bank to be thus protected would be 4½ miles. For this it is proposed to provide stone of the section 30 × 7 for a length of one mile which would have to be divided over the whole 4½ miles at such intervals as should in practice be found necessary.

Protection agains the action arising from hydraulic pressure.

34. As regards the undermining action generated by the simple pressure arising from the head of the waters on the weir, it is usual to puddle with clay in front and between the foundation walls to as great a depth as possible, but it would be difficult in the Ganges to work such material through the natural bed of semifluid silt, and it would be unsafe to wait until a scouring action should deepen the bed, before arrangements should be made for covering the front of the wells with a layer of clay. The actual process could hardly be arranged beforehand, but in one form or another it would be indispensable.

Digitized by Google

The closing of the dam must also be a difficult and expensive process. Captain Orr, in one of his Reports on the Kistna anicut, mentions "the almost insufferable difficulties we met with in closing the Rallee branch of that river (Godavery), and the alarming doubt that for some time existed of our being able to so at all."

Professional Papers, Madras Engineers, Vol. IV., p. 44.

Summer discharge of Godavery and Ganges compared.

35. The discharge of the Godavery, according to Captain Haig, ranges from 3,750 cubic feet per second in February to 1,500 cubic feet in the first half of June. The discharge of the Ganges at the site of the proposed weir is 5,000 cubic feet per second. It is possible that when the Godavery anicut was closed there was an exceptionally high supply in the river; but the same contingency might occur with the Ganges.

Heavy contingencies in constructing a weir across the Ganges.

36. In preparing an estimate for a weir, it may therefore be assumed that the expenditure on temporary embankments and in baling out water, and the losses occasioned by interruption of the works by unseasonable floods, and by the damage that would be produced by the floods passing over an unfinished work, would be very heavy; and that 50 per cent. would not be too large an addition to make to the rates at which the work (excepting cut stone) could be carried out for on dry land, free from all the drawbacks that have been mentioned.

Rates.

37. The ordinary rates are as follows:—Cut stone from Bhurtpore, Rs. 2-8 per cubic foot; it is possible however that stone of suitable quality may be obtained from the Himalayas at Rs. 2, if the road from thence to Hurdwar, 16 miles in length, is made practicable for heavily laden carts. For rough stone, boulders might be used, but as they would have to be brought from some distance above Hurdwar, and as the carriage would be very costly, it will probably be advisable to use blocks of concrete instead. Any quantity of shingle can be obtained from the bed of the river 25 to 30 miles above the site of the proposed weir. It cannot be delivered at a lower rate than an equal quantity of brick, and allowing that the extra quantity of lime which would be used would be nearly an equivalent to the saving of bricklayers, it may be assumed without great risk of error that the concrete would cost much the same as brickwork, that is Rs. 20 for the commonest work.

Estimate for weir 44 lakhs.

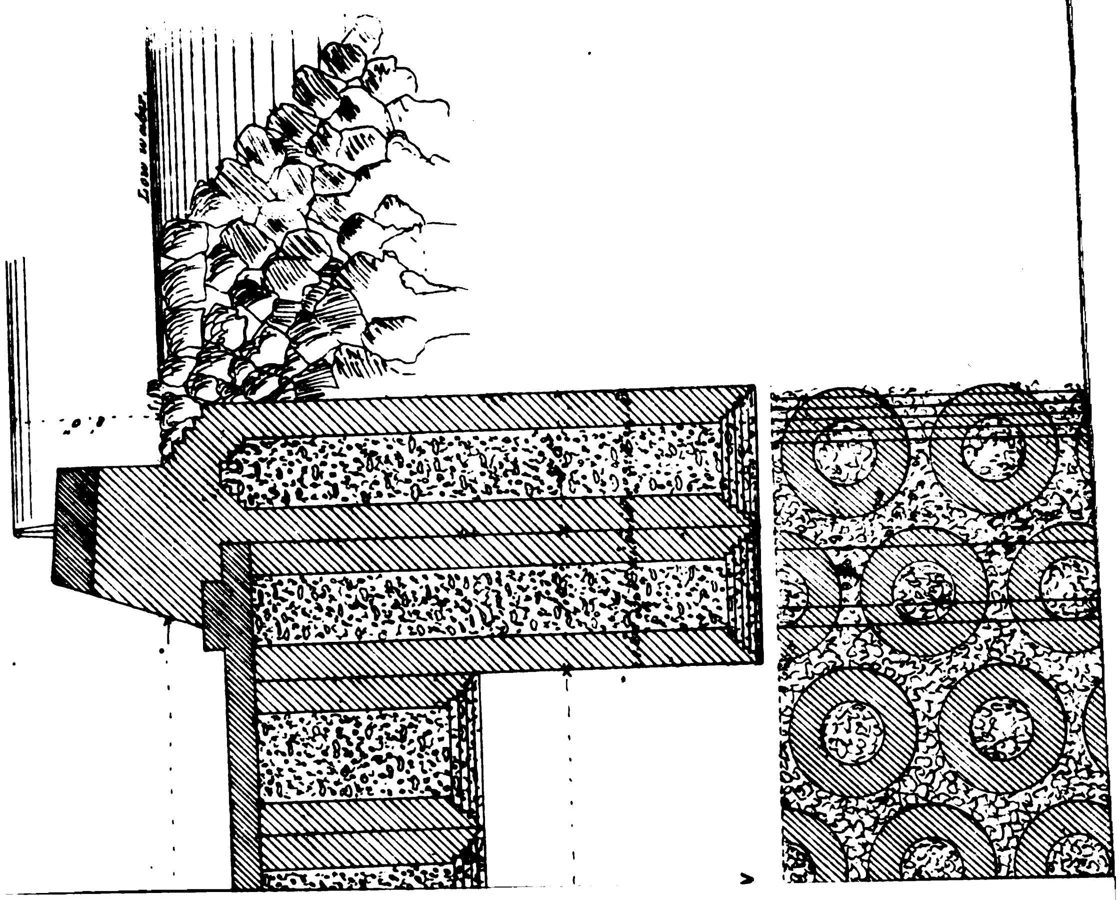
38. The estimate for the weir amounts to 44 lakhs of rupees. This may appear an inordinate amount compared with the cost of the large works of a similar kind which have been executed in the Madras Presidency, but the extra cost of the material of the Ganges weir serves in a great measure to explain the difference.

Compared with cost of Anicut across Kistna at Bezwada.

Professional Papers, Madras Engineers, Vol. IV., p. 70.

39. The anicut across the Kistna at Bezwada, cost only Rs. 6,42,000, though a considerably larger amount of material was expended than has been provided for the Ganges weir. But at Bezwada there are inexhaustible quarries of easily worked but serviceable stone within 300 yards of the flanks of the work, and the

Digitized by Google



Digitized by Google

Digitized by Google

rough stone of which it was mainly constructed cost only 11 annas per cubic yard, or a fraction over Rs. 2-8 per 100 cubic feet. The cut stone cost Rs. 5, and the largest blocks Rs. 9 only, per cubic yard or from 3 to $5\frac{1}{3}$ annas per foot. Rough stone or concrete for the Ganges weir could not be delivered under eight times the Bezwada rate; or suitable cut stone under Rs. 2-8 per foot.

Proposed floor of Ganges weir might have to be constructed on a higher level.

40. Some doubt is entertained as to the possibility of laying the concrete or brick foundation of the weir to the depth shown in the section, namely 10 feet below low water level. Should it be found unpracticable, partly by the aid of baling and partly by working in water, to attain to this depth, the only alternative, without altering the plan would be to construct the floor on a higher level. This would necessitate an extension of the rough stone apron at a corresponding additional outlay.

A rough stone weir could be more expeditiously constructed, but would not be less expensive.

41. A weir on the pattern of the Bezwada anicut could be constructed more expeditiously than the one proposed by the Committee, but it is questionable whether any saving would be effected in first construction, while the annual repairs would be very costly.

Great cost of well foundations to under sluices.

42. The construction of under sluices at one or both flanks of weir must necessarily be a very expensive operation, as the whole of the floors would have to be founded on wells, and as the capacity of the sluices would not only have to be sufficient to discharge the ordinary supply of the river during the dry season, but the exceptionally high one, which is liable to be brought down in January and February.

Experience gained in Madras kept in view by Committee.

43. In the above enquiry, the valuable experience which has been gained in the construction of weirs in the Madras Presidency has been kept in view, and the plan adopted for a weir on the Ganges, differs no further from those approved in Madras, than is considered necessary to meet the peculiarities of the Ganges, which have been previously described.

Suggestion by a member of the Committee.

44. One of the members of the Committee not satisfied as to the stability of the wells 15 feet in depth, or the feasibility of constructing the flooring from a level 10 feet below low water, has drawn out a section for a weir, on the principles which are generally followed in the N. W. Provinces, when a scouring action has to be provided against.

Weir would cost much the same if well foundations were extended and rough stone reduced.

45. The cost of a weir on this pattern would be much the same as that of the other, the extra cost of the wells being counterbalanced by the saving in rough stone.

Deep foundations less costly than rough stone in certain localities.

46. It is generally supposed, or by at least a large section of the Engineers in other parts of India, that the foundations of bridges and other works in the N. W. Provinces are extravagant, but in many places rough stone is so costly as to render deep well foundations the most economical procedure that could be pursued, for securing a work against the action of a powerful current.

Digitized by Google

Cost of weir and channel together, 112¾ lakhs.

47. The total cost of a weir across the Ganges, near Sookertal, and a channel from it to the present main line of canal to carry 5,000 cubic feet per second would thus be 112¾ lakhs of rupees.

Compared with Major Crofton's project.

48. As Major Crofton's estimate for the rectification of the whole length of canal from Hurdwar to the head of the Cawnpore Branch, including compensation and loss of water-rents, if the canal were closed for a year, amounts to about 45½ lakhs, (Major Crofton's Report, p. 61,) it is evident that the Sookertal project cannot be recommended as a substitute.

Water in Ganges insufficient for full supply of canal at Hurdwar, and a separate canal at Sookertal.

49. When the additional works provided for by Major Crofton shall have been completed, the canal will be competent to carry the supply originally contemplated of 7,000 cubic feet per second. Now, as the Committee have before observed 5,000 cubic feet per second is the maximum* supply likely to be available at Sookertal, when an equal quantity is entering the canal at Hurdwar, there is not likely to be much above 3,000 cubic feet available when 7,000 are admitted at Hurdwar. In that event the great cost of a weir across the Ganges, which must be the same, whatever quantity might be taken from the river at Sookertal, would seem to render the consideration of a separate project for a head from that site superfluous.

Reference to Rajghat project.

50. The remarks however which have been made in the section of the Committee's Report relating to the proposed head from Rajghat, when a supply somewhat in excess of 3,000 cubic feet per second would probably be available, are applicable with slight modifications, to a project for conveying 3,000 cubic feet from Sookertal.

HEAD WORKS ON THE GANGES BELOW SOOKERTAL.

GURMUKTESUR.

51. The examination which the Committee made of the river at and about Gurmuktesur, led them to conclude that the site is unsuited for headworks; the great extent over which the river travels, the width of its bed, the unfavorable nature of its banks, combined with the scarcity of good building material in the neighbourhood, render it a most objectionable position for any such project.

RAJGHAT.

Best site for weir and head works.

52. The point on the Ganges which seems best adapted for the contruction of the necessary works either for supplementing the lower part of the canal, or for supplying water for irrigating additional land on that part of the Doab, is in the neighbourhood of Raj-

* For the year 1864-65, the average supply admitted into the canal was 4,026 cubic feet per second. An observation taken at Gurmuktesur, 50 miles below Sookertal, on 5th February, 1865, makes the discharge of the Ganges only 4,278 cubic feet per second; total 8,304 cubic feet.

Digitized by Google

ter.

d.

ay available
n and ram-
linders are sunk.

Digitized by Google

Digitized by Google

ghat, nearly opposite Allyghur. The banks of the river and the adjoining land there, seemed to be sufficiently favorable for the purpose, to warrant such a survey of the locality as would supply details for estimating the cost of the work.

Steps taken to collect information for estimating.

53. The Ganges canal plans, and the Trignometical Survey maps were first examined in order to ascertain the best trace to follow in the more detailed enquiry; the line was then levelled, a cross section and rough survey of the river made, and the discharge at low water measured. From these data the accompanying estimate has been drawn up.

Difficulty of estimating cost of weir.

54. The construction of a weir across the Ganges at this site will be attended with similar difficulties and heavy expense as at Sookertal, nor can the examples of the Madras works be fairly applied to the case, for it cannot be too clearly explained that the difficulty and cost of such undertakings does not depend so much on the heights of the floods of a few weeks duration as on their long continuance, and on the volume and steadiness of the permanent stream, the nature of the bed and banks of the river, and the facilities of procuring materials, on all which points there are essential differences between the Godavery and the Ganges. The Committee—while careful to estimate the cost of the works as correctly as possible—are aware, that some degree of uncertainty must exist, and feel it their duty to guard against the necessity of further outlay except for *bonâ fide* repairs; the weir has therefore been designed with every regard to stability, and as much economy as circumstances will allow.

Flood discharged and dimensions of weir.

55. The quantity of flood water for which provision has been made is 300,000 cubic feet per second, that is 20,000 feet more than has been provided for at Sookertal—see note on that project. It is proposed to build the weir 4,500 feet long, to raise the low water level 8 feet, $5\frac{1}{2}$ by a masonry weir, and $2\frac{1}{2}$ feet by a moveable board, and the flood level about $1\frac{1}{2}$ feet; this height would be attained during very high floods only, and would not injure the low land to any important extent. There would be a velocity of about 12 feet per second over the weir in high floods.

Materials and their cost.

56. The design for the work has been prepared with a view to using as far as possible the materials which are available in the district. It differs from the Sookertal weir so far, that the wells are designed to be sunk 30 feet below the bed of the river, and consequently, less protection of loose stone has been provided for. The most important of the local materials is the block kunker, it is found at a distance of about fourteen miles from the river; the cost in a rough state, delivered on the bank is about Rs. 10 per 100 cubic feet. Cut stone must be brought from Bhurtpore; the cost at Muthra is Rs. 1 per cubic foot, carriage from Muthra to Rajghat (a distance of about 80 miles) Rs. 1, dressing and setting, Rs. 0-8, a total of Rs. 2-8 per cubic foot.

Training and protection walls.

57. The extent and cost of training and protection walls and

Digitized by Google

embankments is very uncertain; the right bank of the river is good and would therefore require very light works, but the left bank is subject to much erosion, and consequently would require heavy works and constant attention.

Water available in dry season.

58. The quantity of water passing Rajghat on the 10th April, 1866, when the Ganges was at a low level—some of the villagers said it was at its lowest for the year—was 5,630 cubic feet per second; while a measurement made at Cawnpore on the 5th of the same month, gave 5,438. The quantity for which provision is to be made in the new channel is 5,000 cubic feet per second, which is considered a fair quantity to fix for the purpose of this estimate; but it is tolerably certain that so much would not be available during very dry seasons with the canal taking its full supply from Hurdwar, while if a canal were to be opened from Sookertal to take off the whole supply of the river in the dry season at that point, the supply that would then be available at Rajghat would be very small.

Details of channel.

59. In fixing the dimensions of the channel the fall has been made as great as the nature of the soil permits, the object kept in view being to give as small a sectional area as possible through the deep cutting in the first twenty miles. By diminishing the slope and increasing the sectional area, the length of the line might be shortened; but the decrease in quantity by shortening, would be much more than counterbalanced by the additional width of excavation in the deep cutting. As the results of his enquiry, Major Crofton has adopted 2·5 feet per second as the highest velocity which the lightest of this kind of soil can stand, the same has been adopted here; consequently, the sectional area required to carry the quantity fixed upon is 2000 square feet. The depth of water to be carried has been fixed at 10 feet, and the side slopes of the channel at 2 to 1, with berms of 12 feet wide at 3 feet above high water.

Rate for excavation and cost of masonry works.

60. The rates for works have been fixed as nearly as possible in accordance with the prices now being paid in the district, making such additions for the great depth of cutting and consequent distance to which the spoil must be carried as were considered necessary. The number of bridges over the line has been estimated on the same principles as those by which the Ganges Canal Officers were guided; the rule being, that there should be a bridge at about every third mile. Very accurate estimates of the cost of crossing the small rivers, could not be made without waiting for detailed surveys and observations, which would cause much delay; they are, however, perhaps sufficiently accurate for a merely comparative estimate of this kind, the best information available having been collected from both Railway and Canal Officers.

Project cannot be substituted for Major Crofton's on account of cost.

61. The estimate for the work amounts to—

Channel, ...	67,54,550
Weir, ...	45,50,280
Total, ...	113,04,830

Digitized by Google

this sum is for conveying 5,000 cubic feet of water per second from the Ganges to a point in the Cawnpore branch of the canal about 18 miles below the Nanoon regulator. The whole cost of Major Crofton's scheme for remodelling the canal to carry the full supply down to this point does not amount to half this sum, it is therefore clear that the project cannot be recommended as a substitute in any way for his scheme.

Project as an independent scheme.

62. As an independent scheme for supplying additional water for the irrigation of new ground in the lower part of the Doab, the cost of forming distributing channels and rajbuhas must be added to the estimate quoted above. The cost of the Cawnpore and Etawah branches of the Ganges canal, which pass about 3,500 cubic feet per second, will be about Rs. 29,00,000; taking the cost of passing 5,000 in the same proportion, the amount would be 42,00,000. The cost of the rajbuhas for the Ganges canal will be about 53,00,000, this is for distributing 6,750 cubic feet per second; supposing the cost of distributing 5,000 to be in the same proportion, the rajbuhas for the Rajghat project would be 37,00,000, making the total cost, say 1,92,00,000.

Cost of Ganges canal water and of water from the Rajghat project compared.

63. The cost of the Ganges canal water is estimated by Major Crofton at 4,740 Rs. per cubic foot per second passed through the head works; this, however, includes the cost of navigation, for which a deduction of one-tenth may be made, making the cost for irrigation alone 4,260. The estimated cost per foot per second of the supply from Rajghat would be $\frac{192,00,000}{5000} = 3,840$ Rs. per cubic foot per second, so that the water would be a little less expensive than that of the Ganges canal.

Silt would be troublesome, but other annual expenses would be light.

64. The cost of clearing silt from a channel taken off from the Ganges at a point so low down as this, must be much greater than the cost of clearing a channel taken off at a point so near the hills as Hurdwar; but, on the other hand, this channel would be much shorter than the Hurdwar line, and consequently it would require less repairs and less establishment, and would not probably on the whole be more expensive to maintain.

Return on capital.

65. Again, supposing the quantity of land which may be irrigated by each cubic foot per second to be 200 acres, a result now attained on the Jumna canal—and one hoped to be attained on the Ganges canal—and suppose the value of water to be Rs. 2-8 per acre, which is about the average rate now charged on the Ganges canal, and that the profits be taken at Rs. 1-8 per acre, those of the Ganges canal in 1863-64 being Rs. 1-6 out of Rs. 2-4; the result would be a profit of 8 per cent on the capital.

5,000 feet per second not always certain.

66. It must however be remembered that 5,000 feet per second cannot always be relied on at Rajghat. If the Ganges canal were taking its full supply, that is about 3,000 feet per second more than

Digitized by Google

was entering at the time when the Ganges measurements above referred to were made, two-thirds of 5,000 would be fully much as could be calculated upon, while such a limited supply would continue the profits would be reduced to about 5 per cent.

Conclusion.

67. The Committee therefore conclude that the project can not be considered a reasonably profitable one to undertake at present; but it is not at all improbable that the value of water will rise, and that the quantity distributed per acre will be greatly reduced without any injury to the consumer, and if so, the project may be worthy of more careful examination at some future period.

HEAD WORKS ON THE JUMNA NEAR AGRA.

River near Agra.

68. The difference of level between low water at Agra and the high land is 61 feet, and the point at which water could be brought to the Etawah branch, allowing a fall on the channel of 6 inches per mile, is 116 miles from Agra, and within 27 miles of the termination of the branch. The Committee considered that on account of this great length of channel, and depth of cutting, and proximity to the termination of the present canal—beyond which are heavy drainages: further examination of that scheme was unnecessary.

NEAR DELHI.

River near Delhi—site well suited for head works.

69. The point on the Jumna which seems best adapted for head works, and for the formation of a channel to bring the water on to the land to be irrigated, is close to the village of Alee, about ten miles south of Delhi, and just opposite to the old fort of Toghlukabad. The selection of this site involves the necessity of building weirs across both the Jumna and the Hindun, but after having examined the river at and below the point where the Hindun joins, and also at Alee, the Committee have no hesitation in recommending the latter as the best position for such works. The right bank of the river is remarkably firm and good, and the left bank is not particularly bad; but the strongest recommendative in favor of the site is the abundance of stone—both of rubble and of blocks, almost completely dressed, which can be obtained from the old fort, opposite to and within a distance of three miles of the river bank at Alee. Neither is the country on the left bank near the site unfavorable for the formation of a channel; the water could be brought into the Ganges canal below Baroli bridge, about the 115th mile from Hurdwar, or to the surface of the ground where irrigation might be commenced, without any great depth of cutting, and by a length of fifty-seven or fifty-eight miles of channel.

Flood discharge Jumna and Hindun.

70. The information available regarding the flood discharge of the Jumna is even less than in the case of the Ganges; indeed there is

Digitized by Google

none to be found that can be safely relied upon. The railway engineers provided waterway of 2,400 feet in length at Delhi; but this has as much reference to the width of the river at that place as to the quantity of water to be passed through. An attempt has been made to calculate the discharge from a few isolated cross sections and the average fall, the results, however, have been so contradictory that they have been rejected as altogether untrustworthy, and it has been assumed that, as the heads of the rivers Ganges and Jumna are situated near each other, and almost similarly circumstanced as to sources of supply, the flood and dry weather discharges probably bear about the same proportion to each other in the two rivers. In the absence of better data, this mode of calculating has been adopted. The dry weather discharges of the Jumna is four-sevenths of that of the Ganges, the latter at Rajghat has been calculated at 300,000 cubic feet per second, four-sevenths of which or about 170,000, will be taken as the Jumna discharge. Regarding the Hindun, the railway engineers have porvided a length of 440 feet of waterway across it, and as there is no better means of calculating the discharge it will be taken in the same proportion to that of the Jumna, as the waterway of the bridges bear to each other; this gives about 31,000 cubic feet per second as the flood discharge of the Hindun.

Dry weather discharge of Jumna and Hindun.

71. Several measurements of the low water discharge of both the Jumna and the Hindun have been made. The register of the height of the former river kept by the Executive Engineer of Canals residing at Delhi shows, that as a general rule the water is lowest in January; hence it is in that month that discharges are generally taken. Information on this subject has been kindly furnished by the Resident Engineer of the railway, which is to the effect that the water was as low in April last as it was in December; but as his own registry shows that the river was higher in April, and as he accounts for the rise shown by his gauge by assuming merely, that the damming up of the river by the bridge works at Delhi, caused a rise of the water level equal to that shown by his gauge, the Committee think that his information cannot well be relied upon; they prefer trusting to the readings of a gauge near Delhi, regularly kept by canal officers, and removed from the influence of any changes of level caused by the bridge works.

Measurement of dry weather discharge.

72. The dry season discharges of the Jumna at Delhi, and of the Hindun near its junction with the Jumna, were measured, as shown below and were found to be—

JUMNA AT DELHI.

	Cubic feet per second.
19th December, 1864. Lieut. Moncrieff, ...	935
18th January, 1865. Sergt. Caernarton, ...	1,613
19th December, 1865. Mr. Garbett, ...	828
	3)33,376
Average discharge, ..	1,125

Digitized by Google

Hindun River.

19th January, 1865.	Sergt. Caernarton,	.. .. ..	357
18th „ 1866.	Mr. Garbett, ..	.. .. ..	501
			2)858
		Average discharge, ..	429

making a total average low water discharge of the two rivers of 1,554 cubic feet per second, or say 1,500, which will be taken as the dry weather supply available for irrigation. It will be observed that this is above the observed minimum supply, but the very low discharge cannot be of long duration. The measurement made in April last, when the river was considered to be low, gave Jumna 2,800, Hindun 500 = 3,300. There are other measurements, which although not taken at Delhi, go to show that 1,500 cubic feet per second is not too low for an average minimum supply. Sir Proby Cautley, in page 43, of his Ganges Canal Report, Vol. I., makes the discharge at Agra 2,061 cubic feet per second; and Capt. Stewart made it 1,153, at the same place on the 19th January, 1865. Mr. Garbett made 5,004 at Delhi on the 19th January, 1866, but in the registry is noted "rain on the hills," which of course renders the result useless as a minimum guide.

Weir across Jumna.

73. The design of weir which is considered best adapted for the site is one in which the least quantity of brick-work and the greatest quantity of rough stone can be used, an abundance of the latter material being available at a very low rate. It is not considered sufficient to build the foundation of dry rough stone alone, the leakage through such a base, unless it were of very great width, would be considerable, if not even large, and the sand forming the bed of the river being very fine, would pass through with even a small leakage, the rough stone base would then sink, and the masonry floor, and probably the weir would be in great danger of breaking down. The form of section designed for Sookertal, has therefore been adopted, that is wells of moderate depth, protected by a large quantity of rough stone. The part of this report relating to Sookertal weir explains why such a section has been proposed there. It is proposed to raise the low water level 8 feet, 6 feet by a solid weir, and 2 by a moveable board. The length of the weir has been fixed at 2,500 feet, that being in about the same proportion to the length of the Rajghat weir, as the floods of the Jumna at Delhi bear to those of the Ganges at Rajghat. Such a weir would pass the calculated floods with an afflux of about one and a half feet, and with a velocity over the crest of about 11 feet per second, and without causing much injury to the low land above it.

Locks.

74. As the river navigation past the weir should be provided for, and as the proposed canal would be important as a line of navigation, two locks would be necessary, one to pass the weir, which should be 24 feet wide, to allow the largest river boats to be locked, and one to pass

Digitized by Google

through the canal, which as it is probable that through the canal entrance would be the best way of passing the river, may require to be of the same size.

75. The right bank of the river is good, consisting of very sound clay and kunker, the amount of protection required to it would therefore be very small; but the left bank is of the usual sandy loamy nature, and would require nearly the same class of works, to protect it, as provided for the Rajghat project. Protection of banks.

76. For crossing the Hindun and taking in its dry weather water, works similar to those used for passing the Rutmoo river in the Ganges canal would seem to answer very well, it is quite possible however that a more careful examination may show that great modifications would be found desirable; the Rutmoo plan is only adopted now as the best available guide in forming the estimate. The width of waterway provided by the Railway Engineers for their bridge over the Hindun must be sufficient for the passage required on the irrigation channel; they allow 440 feet. No lock has been provided for passing boats up, although it is not certain that one might not ultimately be required. Both banks of the river are easily eroded, and will require considerable protection. Crossing the Hindun.

77. As the cost of weirs across the Jumna and Hindun remains the same, whatever quantity of water may be taken off by channels in connexion with them, it may be more desirable to take an addition to the low water supply, when the river affords it, for the irrigation of a Khureef crop, than to trust to the dry weather supply alone; both views of the question will be briefly examined. It may be well to take water for a Khurreef crop.

78. Probably the best rule to be guided by in fixing the quantity of water, above dry weather supply, which should be provided for in the new channel, is to make it as large as is consistent with keeping it navigable all the year round by the low water supply of 1,500 cubic feet per second. The lowest depth which is desirable for this purpose is about 6 feet, and the greatest depth in the channel may be limited to 10 feet, a maximum discharge of about 3,300 cubic feet per second will meet these conditions. Fixing the quantity of water to be taken for Khurreef crops.

79. The highest velocity which the weakest of the soil through which the channels would be cut, could bear, is 2·5 feet per second, and a lower velocity than this would rapidly deposit the silt, carried by the rivers of this part of the country, 2·5 may therefore be taken as the velocity for the maximum discharge when the water would be the most heavily laden with silt. When the discharge falls to the dry weather supply, the velocity would be only about 2 feet per second; but then the water would be comparatively clear, and hence the decrease of velocity would be of little consequence. Velocity of water in new channel.

80. The sectional area of channel required to discharge 3,300 cubic feet per second, with a velocity of 2·5 feet per second, is 1,320 square feet, and the fall required is about five and a half inches per mile. As in the Ganges projects, it is proposed to have the bed of Capacity and length of channel.

Digitized by Google

the channel 2 feet under the present low water level of the river or 10 feet under the crest of the regulating board of the weir, and following the most favorable line of country, the water in the proposed canal could thus be brought to the surface in a distance of about 58 miles from the river,—passing through the low land of the Jumna and Hindun valleys for 19 miles, then through higher land in a cutting not exceeding 26 feet deep, and coming to the surface near the village of Baroli.

Rates and cost of project.

81. The rates for the earthwork have been taken from Major Crofton's estimate for the alternative line of canal, and the estimate for the masonry works required has been based on the same information; of course great accuracy is not professed, nor could it be attained without a detailed survey. The cost of this project would then be—

Weir and works on the Jumna and Hindun,	.. ..	17,00,000
Channel, and all masonry works connected with it,	..	34,00,000
Total,	..	51,00,000

Cost of project if for dry weather supply only.

82. If instead of providing a supply for Khureef watering, provision be made for carrying the dry weather supply of 1,500 cubic feet per second only, a channel large enough to carry it, having the same fall of $5\frac{1}{2}$ inches per mile, and a depth of 10 feet, would give a velocity of 2·4 per second, which for the clear water of the dry weather would probably be enough; a sectional area of 50 feet bottom width, and side slopes of 2 to 1, would carry rather more than the required quantity. The cost of bridging and crossing small rivers would also be greatly diminished, but the weir works would remain the same. The cost of this project would be

Weir works, on the Jumna and Hindun, ..	..	17,00,000
Channel, including all masonry works, &c.,	..	18,65,791
Total,	..	35,65,791

This project was not meant as a substitute for the sanctioned work of remodelling.

83. It does not seem to have been contemplated either by Sir A. Cotton or by Government, that any work on the Jumna or on the lower part of the Ganges should have been in any way substituted for the present line of the Ganges canal; but it appears to the Committee that a few words may properly be introduced here on the subject before examining the Jumna work as an independent project.

Showing that it should not be substituted for the sanctioned work.

84. It is evident that aid from the Jumna, could only be substituted for the improvement of the Ganges canal, as sanctioned by Government, to the extent of the low water supply of that river. All the projection calculations, and all the calculations of the engineers who completed and worked the canal, are based on the supposition that it should have the full supply of 6,750 cubic feet per second during the whole dry season; an additional supply thrown in when the rivers would not be at their lowest, would not compensate in any way for the loss of water in January, when there is a large demand for the irrigation of the Rubbee crops, and when a continuous supply for them

Digitized by Google

is absolutely necessary. 1,500 feet per second is the full extent to which the Jumna at Dehli could afford aid, and consequently the supply to be received through the upper part of the canal could only be diminished by that quantity. Now, there can be very little room for doubt that the difference between the cost of improving the canal to carry 6,750 feet, and that of improving it to carry 5,250 feet would be small; if the Engineers should be obliged to turn off the water to carry out one project, they would certainly be obliged to turn it off to carry out the other, the difference of cost between the two works could not exceed twenty per cent., and it is not at all likely that it would amount to even so much. Major Crofton's estimate for remodelling down to Nanoon, is about 35,00,000, one-fifth of which, or 7,00,000, would be the probable gain by taking 1,500 feet from the Jumna, and 5,250 feet, instead of 6,750, from Hurdwar. But the cost of taking the 1,500 feet from the Jumna has been calculated at 35,50,000 rupees, so that the question of cost alone seems to the Committee to afford the most ample grounds for adhering to the project for remodelling.

Additional reasons why it should not be substituted for the sanctioned work.

85. But there are other reasons also. Adopting the Jumna scheme would be trusting to that which was not certain for that which may be considered tested and certain,—the feasibility of building and maintaining a weir across the Jumna is yet untried, and although there is no reasonable doubt but that it could be done, there is no certainty as to the time required to complete it, nor indeed as to the cost of the work. The quantity of silt which would be brought in by a head so low down the river is also an unsettled question, although known to be a very important one. Then there would be the evil of delay,—the Jumna project could not be undertaken without a careful examination, a detailed survey, and references for sanction; so that it would most likely be a year, or perhaps more, before any works could be commenced, and three or four years before they could be finished. And, lastly, although there is no appearance of immediate failure in the works of the canal, it is not at all certain that they would remain in a safe state for even one year; indeed, the Committee have recorded their opinion in another part of this Report, that it is of great importance that the repairs should be taken in hand as soon as possible. They have no hesitation whatever therefore in coming to the conclusion, that a new head from the Jumna cannot be substituted—either as a temporary or permanent arrangement—for the sanctioned project for remodelling.

Project considered as a work for supplying water to irrigate additional land.

86. If the work be adopted as a means of irrigating additional land, of which there is plenty available to the south-west, the cost of making distributing channels and rajbuhas must be added to the estimate given above; but on the other hand, the water would be brought to the surface of the land to be irrigated by channels at least 10 miles shorter than those required to bring it to the canal. Consider-

Digitized by Google

ing it first as a project for taking 3,300 feet per second when so much can be had, the shortening of the channels would lessen the expense of the main line by about 4,00,000 Rs. Then in order to make it complete as a navigation channel, the main line should be connected with the Ganges canal, this would require 10 miles of still water navigation at, say 15,000 a mile = 1,50,000. Making the total cost for weir and main channels 48,50,000.

The cost of distribution channels and rajbuhas for the Cawnpore and Etawah branches of the Ganges canal, which are to carry 3,250 feet per second, is—

Channels, ...	29,00,000
Rajbuhas, ...	9,50,000
Total, ...	38,50,000

This estimate would give a fair idea of the cost of distributing the 3,300 feet from the Jumna, if the whole were to be used for a Rubbee supply; but as about half of it is for a Khureef supply, and as one foot per second used for Khureef, waters less than half the area which it would do if applied to Rubbee crops, it is evident that the distribution channels for a certain quantity of water used for Khureef watering, would be only about half the length of those required for the same quantity if used for Rubbee crops, and they would be only about two-thirds of the capacity. Now, as more than half the supply of the project under consideration is for Khureef watering, a deduction of about one-sixth may be made from the cost of the Cawnpore and Etawah branches, making the amount 38,50,000 – 4,83,000 = 33,67,000; which, added to the cost of main channels, give a total of 82,17,000.

Probable returns from capital.

87. The probable return from this outlay would be,—for Rubbee and Khureef crops, 1,500 cubic feet per second, at 200 acres per foot per second = 3,00,000 acres, at a profit of 1-8 per acre (see note on Rajghat project) = 4,50,000. Again using the Cawnpore and Etawah branches of the Ganges canal as a guide, it is found that each cubic foot per second, waters under 60 acres of Khureef crop: but it is probable that in this instance all the water is not utilized. The returns of the Eastern Jumna canals for 1863-64, give 75 acres per foot per second as the quantity watered by the Khureef supply, using this as data, 1,800 cubic feet per second would water say 1,35,000 acres. The profit per acre would be about the same as that already calculated for Rubbee crops, giving a return of 2,00,000, and making a total on the whole outlay of 6,50,000, or a little under 8 per cent., exclusive of returns from navigation, plantations, &c.

Project considered as providing for a dry weather supply only.

88. If the project be confined to the use of the dry weather supply of 1,500 cubic feet per second only, the result would be,— cost of bringing the water from the Jumna to the Ganges canal, as

Digitized by Google

estimated above, 35,50,000; from which is to be deducted—cost of 10 miles of channel, by which the line would be shortened by delivering the water on the surface of the ground to be irrigated, 3,00,000, less the cost of 10 miles of navigation channel required to connect the irrigation channel with the Ganges canal, 1,50,000 = 35,50,000 − (3,00,000 − 1,50,000) = 34,00,000. The cost of distributing 1,610 cubic feet per second on the Cawnpore branch of the Ganges canal is 16,00,000, and the cost of rajbuhas for the same 5,50,000, making a total of 21,50,000. Taking the expenditure for distributing 1,500 to be in the same proportion, the cost would be 20,00,000 nearly, making the total cost 34,00,000 + 20,00,000 = 54,00,000. Using the calculation given above as to the value of the water, that is 1,500 cubic feet per second × 200 acres per cubic foot × $1\frac{1}{2}$ Rs. per acre profit = 4,50,000 on an expenditure of 54,00,000; giving a return of about $8\frac{1}{2}$ per cent., exclusive of returns from navigation, &c. From this it appears, that the project for taking in the dry weather supply only would be the more profitable. But further, the quantity of silt, which would be taken in by the Khureef supply when the river would be disturbed, and consequently muddy, would be very large, and without doubt must involve heavy additional expenditure for cleaning.

89. On the above grounds, the Committee are of opinion that the project for taking, either 1,500 cubic feet per second, or 3,300 cubic feet per second from the Jumna, is well worthy of a detailed examination, as an independent scheme for the irrigation of land in the lower part of the Doab. Opinion of Committee.

90. They would, however, draw attention to the separate paper recorded by Mr. Sibley (Appendix A.), dissenting from the views of the majority, and advocating the formation of a canal from the Jumna at Toghlukabad, in substitution for Major Crofton's project. Mr. Sibley dissents.

THE PRESENT CONDITION OF THE GANGES CANAL, WITH REMARKS ON ITS FAULTS AND UPON THE REMODELLING PROJECT.

91. So much has been said of the serious faults and inefficiency of this great work, that it has been a matter of some surprise to the Committee to find that it has been carrying nearly two-thirds of its full supply during the past twenty months; and that the navigation, though imperfect, has been going on without interruption during the same period, during which the canal has not been closed for even a single day. Present condition of canal. Full supply at Roorkee, 6,750. Supply maintained, 4,200 cubic feet per second.

92. The canal has now been in operation for eleven years, and though no outlay has been incurred for additional falls to lessen Increase of irrigation, but velocity of current too great.

Digitized by Google

the slope and velocity of current which have been found to be much too great for the soil to bear, the area of irrigation has steadily increased.

Cannot be used to its fullest capabilities till fall works are increased.

93. Looked at as an irrigation work, for which it was principally intended, it has one very serious defect. The excessive slope of the country is not sufficiently overcome by artificial masonry falls; and, consequently, as already mentioned, the velocity of current is too great. The canal cannot therefore be used to its fullest capabilities till the fall works are increased.

Navigation impeded by velocity of current.

94. Viewed with regard to navigation the velocity of current is a great obstacle to traffic. The want of sufficient headway under bridges on the Cawnpore Branch is also a serious disadvantage, as in carrying light and bulky cargo, boats are loaded to a great height above their decks. The insufficiency of headway is the more unfortunate, as it would not have added much to the original cost of the works to have given 10 feet, as in all the large bridges on the main line.

Imperfection of arrangements in regulating passage of water at falls.

95. The excessive velocity of current appears to have been further increased by an imperfection in the arrangement for regulating the flow of water over the falls. They were originally designed of of greater width than the earthen channel, and in several separate chambers or compartments, the entrances to which were fitted with sleepers to admit of their being closed for repairs. But when the canal was first brought into operation, and all the works were new and in good repair, the stream was permitted to pass through all the compartments, and its velocity as it approached the falls was thus accelerated. No evil would have resulted from this if the soil had been firm, but it was too soft to bear the rapid current.

Delay in applying remedy.

96. The canal authorities do not appear to have been fully aware till too late that the current was so much too rapid, and that it was steadily working upon the bed, and causing a retrogression of levels below each set of falls. What principally engrossed attention at first was the construction of minor distributing channels, and especially the arrangements for giving the water to the cultivators by measurement, the importance of which was certainly not over estimated. The canal, moreover, had only been in operation two years, when the district which it traversed became the scene of the mutinies, and Europeans of all ranks were compelled to leave their ordinary duties. The mutinies, and the unsettled state of affairs which immediately followed, were hardly over when this same part of the country was striken with famine, and the whole attention of the canal department was given to distributing the water to tide over the calamity; minor channels were pushed on in every direction with the utmost possible rapidity, and as much water as could be distributed was thrown into the canal.

97. Thus great delay occurred in reducing the waterway at the

Digitized by Google

falls; and when at length the urgent necessity of doing so became apparent, further delay occurred in carrying the necessary arrangement into effect, from the sleepers, which are 25 feet in length, giving way. It was not till 1862 that the waterway was effectually reduced, and by that time so much retrogression of level had taken place that it became impossible to apply means, which at an earlier stage would have been feasible. Whether at first it would have been quite safe to have completely closed several of the fall compartments, and have passed the water through the remainder with an increased depth, cannot now be decided; but there is no doubt that by delay the cushion of water on the floorings had become so much reduced that such a plan could not be attempted, and the expedient was adopted of partially closing all the compartments and distributing the water equally over them. This arrangement however in obviating one difficulty led to another. The water instead of gliding over the ogee descent in the manner intended, fell suddenly upon it from an increased height, and exposed the masonry to an action it was never designed to bear.

The delay increased the difficulty of applying a remedy.

98. The parts of the works which suffered most from the retrogression of levels were the floorings under the falls. The water now fell from an increased height upon the masonry itself instead of into a cushion of water, and the action thus intensified tore up the brickwork wherever it happened not to be of the very best quality, as was the case at the Mahmudpoor, and some other falls below Roorkee. Above Roorkee, as well as in other parts of the canal, the brickwork, though requiring occasional repair, has not suffered seriously.

Injury to the works from severe action of water.

99. Another evil which the retrogression of level caused was the greatly increased velocity with which the water escaped from the floorings into the earthen section of the canal below. Instead of flowing off with a moderate velocity, it made a rapid shoot and scooped deep holes in the soft soil where the protective boulder crib work terminated, an effect which was increased by the direction given to the wing walls at some of the falls. Thus the whole of the masonry work was endangered. An accident was only prevented by the crib work with which the foundations had been protected, and which accommodated itself to the change in the level of the canal bed without permitting the foundations to be completely exposed.

100. Various expedients were adopted by the canal officers to mitigate the evils caused by the retrogresion of levels. Small rough supplementary weirs were thrown across the floorings to hold up the water and thus obtain a "cushion" under the falls, and other rough weirs were carried across the canal at a distance of about 100 yards below the tails of the floorings, to head up the water and diminish the plunge over the crib work into the soil excavation. None of this work was of a permanent character, but it has enabled the canal officers to keep the canal steadily running with two-thirds of its full supply.

Expedients adopted to remedy evil of retrogression of levels.

Digitized by Google

Injury to road bridges prevented by protecting foundations with boulders.

101. At the road bridges also the retrogression had an injurious effect, but this was remedied partly by the crib work with which their floorings had been originally protected, and partly by adding loose boulders.

Expedients adopted prevented further serious damage, but retrogression not altogether arrested.

102. Since these expedients were adopted there has been no further serious damage, and the deep holes which had been formed near the masonry works have to some extent silted up; but that retrogression is still going on, was evidenced by the state of the water at different points along the canal at the time the Committee examined it. This view is concurred in by Colonel Dyas, who in reply to a question from the Committee, writes as follows:—

"As to the bed (of the canal) erosion is no doubt going on in many places, inasmuch as during the cold weather, when the water coming in from the Ganges river through the Myapoor regulator (the head of the canal) is almost quite clear, the water in the canal gradually becomes very muddy. But a comparison of cross sections of the canal bed, which I have lately had taken at every mile along the canal, with similar sections taken by Major Crofton in 1864, shows that no dangerous action is going on at present."

Falls still exposed to most violent action.

103. The falls, moreover, notwithstanding all the expedients that have been applied, are still exposed to a most violent action, which the brickwork was not designed to bear, and it is impossible to predicate how soon some accident may necessitate the sudden closing of the canal and the destruction of the crops dependent upon it. The Committee were anxious to have had the canal laid dry to enable them to closely examine the masonry works, but such strong objections were urged against it by the canal officers, on account of the time it would occupy and the injury to crops which required constant watering, but more especially on account of the injury which might be caused to the floorings of the falls when the depth was reduced, both when shutting off the water and re-admitting it again, that the point was not pressed. With respect to the condition of these works, Colonel Dyas replied to the Committee as follows:—

"As to the falls in the Northern division (from Myapoor to Jaoli) the extent of damage done (during the past twenty months), as far as can be ascertained by careful sounding and probing, consists of a slight displacement of crib work battens. In the Meerut division two falls have been slightly injured, but not sufficiently so to warrant a closure of the canal for the purpose of repairing them. The Chitoura fall (55 miles 4976 feet) has had part of the ogee in No. 3 bay ripped out, and that bay is kept closed in consequence, to prevent further damage; and the Sulawur fall (67 miles 2350 feet), has had two of the hammer-dressed Delhi stones in flooring of No. 3 bay, lifted out and turned over. This occurred in September 1864, and the stones have not moved since. The bridges are all secure." Colonel Dyas' report is on the whole a favorable one; but it is evident

Digitized by Google

to the Committee, as it is to all the canal officers, that the falls are still in danger, and that no time should be lost in taking steps to render them secure.

104. The navigation on the Ganges canal has always been necessarily imperfect from the great velocity of current which in the main canal was intended to be from $2\frac{1}{2}$ to $2\frac{3}{4}$ miles per hour; and in addition to this obstacle the retrogression of levels, and the consequent necessity for limiting the depth of water admitted into the canal has acted most injuriously. The lock channels, instead of having a depth of 9 or 10 feet of water in them, and a width at water line of 43 to 46 feet, have had barely enough water below the locks to float boats of light draught, and a width at water line of only about 28 feet, the width at bottom being 16 feet. This very limited capacity of channel has of course delayed the introduction of large boats, and has led to frequent interruption when silt accumulated. The shortness of water supply in the canal morever necessitated the alternate closing of the Cawnpore and Etawah branches to distribute the water for irrigation, and thus the navigation on the former which connects the main canal with the river Ganges has occasionally been completely closed. Under all these circumstances it is not surprising that the navigation has not increased satisfactorily. Navigation imperfect.

105. The Committee may remark here that the present lock channels would probably work efficiently if the eroding action of the stream in the main canal were less, and if the valves at the locks were larger to admit of more effectual scouring. But where new locks have to be constructed, they think that attaching them to the falls, as in Major Crofton's project, is a great improvement. Lock channels.

REMARKS ON THE REMODELLING PROJECT.

106. In correcting the great fault of the canal, or "remodelling" it as it has been termed, an expression which however is apt to lead to a somewhat erroneous impression of the measures required, the Committee remark that while on a work like this, of almost a national character, they would not expect to see such rigid restriction of expenditure to works of absolute necessity as is generally practised in the construction of ordinary irrigation canals, yet at the same time, considering how important it is both for the reputation of the Ganges canal itself, as well as for the interests of other large irrigation projects in other parts of India (whose execution is supposed to be delayed on account of uncertainty as to their financial success), that economy as well as efficiency should be studied, they cannot but regard some of the changes provided in the remodelling project as unnecessarily expensive, and they would therefore suggest that the following points be carefully reconsidered:— Importance of economy—some of the changes unnecessarily expensive.

Digitized by Google

The present shape of the cross section need not be altered, and requisite capacity to be obtained by raising crests of falls.

107. *The Excavation.*—It appears that the effect of the retrogression of levels has been to deepen the canal in the reaches between each set of falls, and in the remodelling it is proposed to alter the shape of the section by widening it and filling in the bed where material is furnished from the widening, and trusting to the deep spots ~~settling~~ silting up where material for filling is not available. Now, however desirable it would be in designing a new work to adopt a shallower section, it can hardly be necessary to alter an existing work to give it that precise form. The cost of the excavation from the head of the canal to Jaoli falls is estimated at upwards of four lakhs of rupees, and it is apparent to the Committee that by slightly raising each set of falls, so as to reduce the surface slope by about one inch per mile, the present excavation will generally answer, and a considerable outlay will be saved.

Grating at Kunkul bridge objectionable, and lock unnecessary.

108. *Grating and lock at Kunkul bridge.*—These are estimated over Rs. 30,000, and may well be omitted. The sunken grating in almost a perpendicular position seems to be actually objectionable, and the lock with its attendant working expenses, can hardly be required to meet the contingency of a boat passing up the stream at a time when there might be only a small supply of water in the canal. It will always be necessary to maintain a large volume in the canal, and supposing a boat to arrive at Kunkul, when there might accidentally happen to be a small supply, the acceleration of the current at the bridge could be checked by partially closing the compartments of the falls three miles below, especially if instead of giving the bed of the canal a sudden drop below the bridge, the change from the small to the large section be made gradual.

New fall and lock at Roorkee may be dispensed with. Objection to increasing depth of water on Solani aqueduct.

Protection of canal bed.

109. *New fall and lock at Roorkee.*—It appears to the Committee that by pitching the bed of the Solani aqueduct (earthen portion) and securing the floorings of the bridges at Rutmoo, Peeran Kullier and Mahewar, the new fall and lock may be dispensed with, and some reduction in the expense effected. But they also object to the proposed falls on other grounds. The Solani aqueduct was designed to carry a stream 10 feet in depth and if the falls are constructed this will be increased to nearly 13 feet. The Committee do not doubt that the aqueduct can be made to carry the increased depth, but sufficient provision is not made in the estimate for this, and as the expense will be heavy to render the work perfectly secure from accident, and there is already percolation through the brickwork of the masonry aqueduct which must in time do harm, they would prefer retaining the designed depth of water in place of increasing it to nearly 13 feet.

Reduction of slope below aqueduct to be effected by raising Asuffnugger falls.

110. With respect to the reduction of the velocity of current from the aqueduct down to the Asuffnugger falls, it will be necessary to raise those falls slightly; but this will not be attended with any difficulty, and it will have the effect of saving a large quantity of excavation in the manner indicated in a previous paragraph.

Digitized by Google

111. *Additional arch to increase the waterway under bridges.*—This does not appear to be absolutely necessary. All the bridges have already been subjected to a very severe test from the retrogression of levels, and the boulder protection to the floorings has been increased. When the floorings are lowered to suit the altered bed level of the canal, the waterway will be increased, and the velocity of current will not, the Committee consider, be too great. If the wide section proposed in the remodelling be adopted, the omission of the additional arch will only increase the velocity from 1¾ to 2¼ miles per hour, and this only for a few yards. If the deeper section recommended in para. 107 of this Report, be adopted, the increase of velocity will be even less. Additional arch to bridges not absolutely necessary.

112. Before leaving the subject of the works provided in the remodelling estimate, the Committee would make some observations on the question of closing the canal for a long period to admit of the works being executed. In Major Crofton's report the estimate of loss from closure amounts to Rs. 13,48,213; but owing to the extension of the irrigation since that estimate was made, and to the increase in the water-rate levied, it appears that the loss from a long closure now would probably amount to upwards of twenty lakhs of rupees. Large loss of revenue from closing the canal for a year, and modification of floorings under falls suggested.

The Committee are sanguine, however, that the works can be executed without a long closure, especially if the details of the floorings of the new falls are modified, With the view of obtaining a deeper cushion of water over the floorings, Major Crofton has placed them at about 4 feet below the bed of the canal, and at this depth a covering of brick-on-edge is considered by him sufficient to resist the action of the water. The advantage of the deep cushion is probably not over-rated, but placing the flooring at so low a level will cause great delay for unwatering or forming cofferdams, and as the loss from long closure will be very heavy, the Committee would recommend that the deep cistern be omitted, and that the flooring be placed at the level of the canal bed, and covered with Bhurtpore dressed stone, 15 inches in thickness; and they would remark that, though the stone is very expensive, there is this great advantage in the arrangement that, whenever repairs may be required to a flooring placed at the level of the bed of the canal, they can be readily executed, because directly the canal's supply is shut off the floorings would be exposed to view. With the aid of the gratings which the Committee understand Colonel Dyas has contrived with complete success on the Baree Doab canal, for breaking the water as it begins to fall, the Committee consider that the modification they recommend will be found to answer well.

113. Supposing that the works can be executed during two short closures of about 3½ months each, the loss of revenue would be comparatively trifling. From information furnished by Colonel Dyas, Comparatively small loss from short closures.

Digitized by Google

the Committee have approximately* estimated it at Rs. 350,000 for each closure, on the supposition that the crops which must be stopped are not replaced by others which can be watered at some other period of the year when there is an abundant supply in the canal. If other crops be substituted, the loss during each closure would only amount to about Rs. 150,000.†

114. The Committee believe that two such closures will be found sufficient to complete all the work up to water line, and they would point to the cases of the upper and lower Coleroon anicuts, and the Gunnarum aqueduct in Southern India,‡ each of which was commenced and completed in one dry season, as instances of what may be done in speedily executing hydraulic works.

Future improvements.

115. The Committee would now draw attention to some points affecting both the navigation and irrigation which seem to call for consideration as measures of future improvement.

Large proportion of artificial to natural flow irrigation on the Cawnpore and Etawah branches.

116. *The large proportion of "artificial"* § *to "natural flow"* || *irrigation on the Cawnpore and Etawah branches.*—There is a considerable loss of revenue on this account on the two branches, but whether this is caused by the smallness of the supply of water which keeps the surface at too low a level; by the levels of the country being unfavorable for the cross distributing channels; by a faulty alignment of those channels; or from the excavation of the canals themselves being unnecessarily deep; the Committee have not ascertained. A great part of the Cawnpore branch appears to be in light excavation. The Etawah branch¶ is generally deeper. The cross channels or rajbuhas are said to be badly laid out, and to work very imperfectly. However this may be the subject demands careful attention, and if it should be found necessary to introduce weirs at intervals to bring the water up to a higher level at certain spots, it would be desirable to make allowance for such alterations in level where the headway under the bridges is increased for navigation, otherwise it may be necessary to alter the bridges a second time. The introduction of weirs would be advantageous as affording the means of more efficiently controlling and distributing the water on

* The Committee applied to Colonel Dyas for an estimate of the loss, but have been disappointed in not receiving it. Since the Committees' Report was drawn out, Colonel Dyas has written demi-officially as follows :—" I have been disappointed about the information I wrote for to enable me to estimate the loss that would be incurred by closing the canal in March, April and May, and I fear when it does come it will be too late to be of use to the Committee, so I think you had better go upon the estimate you drew up, and which is founded on the latest information I have. I should be very much obliged by your sending me a copy of it. I will write again if the information I have written for comes soon; but don't wait for it."

† The Committee observe, *vide* Revenue Report, dated 4th March, 1864, that the loss sustained during a three months closure in 1862-63, amounted to Rs, 2,25,689. The closure was necessitated by an injury to one of the falls, and took place at an unfortunate period of the year, while the Rubbee irrigation was at its height.

‡ All of these works are on well foundations.

§ Artificial, *i. e.*, aided by machinery.

|| Natural flow, *i. e.*, by gravitation.

¶ Average depth of excavation in Cawnpore branch is 4·82 feet for the first 120 miles; average depth in Etawah branch for the same length is 6·65 feet. The water is 6 feet deep in both cases.

Digitized by Google

these long branch lines, and would also benefit the navigation by reducing the velocity of current. These are additional reasons for an investigation of the question by the canal officers. It may be found possible to improve the irrigation by extending the distributing channels till they command more low land.

Cawnpore branch to be enlarged at its terminus.

117. *Want of suffic.ent waterway at terminus of Cawnpore branch.*—This branch is too narrow near its terminus to allow of the largest class of boats passing each other, but this may easily be corrected by enlarging the canal from 20 to 27 feet bottom width from the 159th mile, and making it still water navigation from the 164th mile to Cawnpore, a distance of 5½ miles; arrangements will of course be necessary at the commencement of the still water canal to lead off for irrigation the volume of water which is brought down to that spot by the flowing canal. The silting and growth of weeds which are likely to occur in the still water must be accepted as unavoidable, but as the length is short there will be no serious difficulty in maintaining the canal in good order.

Etawah branch to have its navigation improved as recommended for Cawnpore branch.

118. *The Etawah branch.*—The headway under bridges on this branch is insufficient and should be increased, the tail should be locked down to the Jumna with still water navigation, arranged as recommended for the Cawnpore branch.

Short cross canals for navigation to connect main canals with each other, and with important towns.

119. *Cross canals for navigation.*—At present boats have to make a long circuit to get across from one canal to another, this should be provided for by constructing short cross lines; similar lines should also be formed to connect important places like Meerut, Bulundshuhr, Coel, &c., with the main lines, as the requirements of trade may indicate.

Width of lock 16 feet considered sufficient.

120. *The width of locks.*—This question seems to demand some remark from the Committee, as it has been proposed to go to some expense to obtain 20 feet in width. The existing locks are 16 wide, and after careful discussion the conclusion arrived at is, that this dimension is sufficient. The depth of water generally in the canal is so great that there could be no objection to the use of screw propellers if steam navigation should appear profitable: the stern wheel also could be used. Moreover, locks of 20 feet width would still be too small for side paddle steamers except of a very small class.

Branch canal for irrigation from Roorkee to Deobund recommended.

121. *New branch canal from Roorkee to Deobund.*—The construction of this work has been under consideration for some years, but the shortness of supply in the main canal has of course hitherto kept it in abeyance. In Colonel Turnbull's Canal Revenue Report of 1861-62, Mr. Login's opinion on the result of the survey is mentioned as most favorable. The Committee have also received the opinion of Mr. Williams, the Commissioner of Meerut, who strongly advocates the carrying out of the project for protecting the district through which it will pass, against famine, and for more equally distributing the benefit of canal irrigation throughout the country,

Digitized by Google

the Deobund district being most unfortunately circumstanced as regards water, which is only obtainable at present from very deep wells. The line which this branch will follow corresponds with that recommended by Sir Proby Cautley as the alternative line, and the Committee think that the time has arrived for turning attention to it.

Short periodical closure of canal recommended for examination and repair of works.

122. *Periodical closure of canal.*—In so large a work dependent on many masonry structures of a difficult nature, a short annual closure would be desirable to admit of everything being closely examined, and repaired if necessary. The canal officers will of course be able to decide upon the best period for such closures, as they know during which portion of the season the demand for water is least. If the plan of making a periodical closure is carried out, the cultivators will probably soon learn to store a small quantity of water near their fields to continue the irrigation till the canal is re-opened.

PROPOSED WEIR ACROSS THE GANGES AT HURDWAR.

Importance of a permanent weir at Hurdwar generally recognized.

123. The importance of gaining a control over the Ganges at Hurdwar by means of a masonry weir across the channel has been generally recognized. There is no difficulty however in throwing in the supply at present required by the canal, namely 5,000 cubic feet per second, and the expense has not increased to the extent that was anticipated by the late Colonel Turnbull. During the last four years the outlay incurred on the shingle bunds, or temporary dams, for diverting the supply from the river to the canal has amounted to 60,702, or 15,175 rupees per annum.

Not however necessary for the present supply of the canal.

124. If 5,000 cubic feet per second were to be the full supply of the canal, the Committee would not advocate the construction of a permanent weir across the Ganges. The expense of keeping such a work in repair would not certainly be less than 5,000 rupees per annum; 10,175 rupees would therefore be saved in maintenance, and allowing even that the expense of raising the bunds should increase so as to make the saving 15,000 rupees per annum, this would represent a capital of Rs. 300,000, and a permanent weir across the Ganges could not be built for that amount.

Temporary bunds rarely necessary during monsoon months.

125. It is true that although there is no difficulty in throwing 5,000 cubic feet per second into the canal during the dry season, there is the possibility of the river falling so low during some of the rainy months, as to render it necessary to have recourse to bunds even at that season; which was the case during the famine year of 1860-61, and the inefficiency of the temporary arrangements during the monsoon months, has afforded the strongest argument that has hitherto been brought forward for the construction of permanent works.

Digitized by Google

126. But the Executive Officers have now a much more extended experience of the management of the river, than they had up to the famine year; and the Committee consider that with the good management which may be expected, there ought to be no difficulty in feeding the canal during the monsoon. They believe that the failure during the famine year has been exaggerated. For a great part of that year, the whole supply of the river was turned into the canal, and the revenue returns were more than double those of the previous year; but the fact of 73 acres only having been irrigated per cubic foot of water admitted into the canal, while at present upwards of 140 are irrigated by the same quantity, indicates that the great want of the famine year, so far as the canal was concerned, was the means of distributing the water. The rajbuhas were then in their infancy, and without a proper proportion of them, it would have been useless to increase the supply from the river.

Experience of Executive Officers equal to such a contingency.

127. When the full supply of 7,000 cubic feet per second has to be thrown into the canal, the construction of a weir becomes more necessary than with a supply of 5,000 cubic feet. Sir Proby Cautley's estimate of the minimum discharge of the Ganges is over-rated; at times it falls considerably below 7,000 cubic feet per second. With shingle bunds there must always be considerable leakage, and at such times, the loss thereby occasioned might seriously affect the efficiency of the canal. The Committee look upon this as the most important argument in favor of a masonry weir, but they may add that it is very desirable that both Europeans and Natives should be saved from the exposure and sickness which they have to undergo in the construction of the temporary bunds during the most unhealthy time of the year.

With full supply in canal considerable loss of water by leakage through temporary bunds, and masonry weir necessary.

128. Several projects for a weir have already been before Government, but none of them have met with acceptance. Colonel Dyas was about to enter upon the subject, and was having detailed surveys prepared, when the Committee was ordered to assemble; but not knowing that the question of a weir at Hurdwar would occupy their attention, he removed the officer who was surveying there to employ him on a survey of the Khadir land between Sookertal and Gurmuktesur; some further measurements are therefore required before Colonel Dyas can submit a plan and estimate for a weir to Government. The Committee are not prepared to furnish a detailed plan, which would require a more comprehensive knowledge of the locality than they have had the means of acquiring.

Design for weir left to Colonel Dyas.

Digitized by Google

Observations on matters of secondary importance.

129. Having in the foregoing Reports stated their views and opinions on the principal points connected with the subject referred to them, the Committee proceed to offer some observations on matters, which, though of secondary importance, will not, they trust, be considered irrelevant to the complete elucidation of the state and prospects of the Ganges canal.

STONE FROM THE SEWALIK HILLS AND HIMALAYAS FOR THE CANAL WORKS.

Good stone only procurable in small quantities from different places in the Sewalik hills, and the search for stone in the Himalayas hitherto unsatisfactory.

130. With respect to the use of stone from the Sewalik hills at Hurdwar, and elsewhere on the canal, the Committee having made the most careful enquiries, and to some extent, inspection of the localities, are satisfied that although stone of good quality may be obtained in small quantities scattered over the hills, yet there is apparently no single spot where quarries can be opened with the prospect of an abundant supply being met with, and that as regards the main Himalayas, they find that the search for stone has hitherto proved equally unsatisfactory in its result.

Further and more extended search recommended.

131. The Committee are however convinced that the canal officers have used their best endeavors to obtain stone of suitable quality for the works, and beg to refer to the following replies from the Chief Engineer of Irrigation to queries put by them on the subject. They however think that the search on the main Himalayas should be extended when the weather will admit of its being done more carefully than it could be at this season; and also that a quarry on a more extended scale than any which the Committee have seen should be opened at Hurdwar.

Reply to Committee's enquiry.

132. Replies to questions in Colonel Lawford's letter of yesterday.

Question 1.—" What was the result of the search made for stone at Hurdwar and in the Sewaliks in the neighbourhood, stating cost of

" Quarrying,
" Dressing,
" Leading to canals,
" Making roads,
" Superintendence."

Reply.—The report made in para. 13 of my letter 4,293, dated 23rd November, 1864, which was printed with Captain Crofton's Report on the Ganges canal is correct, viz.: " The quantity of serviceable stone to be had at any one place is very small, and there are not very

Digitized by Google

many places within easy reach of the works or of water carriage where it can be had.

"The places where fair stone was found were soon worked out, and operations had to be closed on the 31st August, 1865, when 51,496 cubic feet of stone had been landed, at a cost of 51,455 rupees, say one cubic foot per rupee.

"The following is a tolerably accurate approximation to the details of cost:—

	RS.	A.	P.
"Quarry and leading to carts, ...	0	3	6
Dressing, ...	0	3	0
Leading to canal, with loading and unloading, ...	0	5	6
Making roads, ...	0	2	0
Establishment and tools, ...	0	2	0
Total per cubic foot, rupees, ...	1	0	0

"The stone is of very unequal quality and very uncertain; thus, part of the same block may be good hard stone and the rest so friable that it can be rubbed into sand with the fingers. The particles of sand are held together merely by infiltration of lime which partially dissolves in water, so that, after 60 hours' immersion the stone will bear only half the crushing weight which it will bear when dry.

"Dividing the stone landed into three classes—fair, middling and bad—I find that the crushing weight of each in lbs. per square inch, was as follows:—

Class.	Dry.	Wet.
Fair, ...	5,311	2,764
Middling, ...	5,356	1,879
Bad, ...	3,003	1,447

"The following is the result of similar experiments on our bricks.

Class.	Dry.	Wet.
	lbs.	lbs.
Best, ...	3,000	3,000
Seconds, ...	1,932	1,288

"The crushing weight for jamah, wet or dry, is 6,180, and for Dehli quartzite, 16,480."

I have already shown the details of these experiments, and the crushed specimens themselves to (I think) all the Members of the Committee.

Digitized by Google

Question 2.—" Has any search been made for stone in the main Himalayas in the neighbourbood of Luchmun Jhoola, or elsewhere, and if so the result ?"

Reply.—" There are now no European officers here who can give information concerning matters of ancient date, nor have I been able to find in the records of this office any report of explorations made beyond the Sewaliks. But I have ascertained from the old mistrees employed on the works that the country up to and beyond Luchmun Jhoola was often in vain explored for stone. In 1862, Professor H. B. Medlicott was employed in exploring, with Mr. Login, but I can find no other report of his than may be gathered from the printed memoirs of the Geological Survey of India, Vol. III., Part 2.

" Lately, at my request, Mr. Kelly has examined the valley of the Ganges and the streams which run into it on both sides as far as the stream above Tupobun, but he has not found anything worth quarrying. He reports that the sandstone about Rikheekes is much the same as the sandstone of the Sewaliks, that the black shale which underlies the limestone is in thin layers, that the limestone itself flies to pieces under the hammer, and that the slate is only to be had in small thin pieces.

" On Mr. Kelly's return with this report I requested him to offer a liberal reward to any one who would point out a place where good hard stone was to be had *in situ*, and he has men employed in exploring. He is now in all probability before the Committee, as I requested him to call on them and to communicate all his information personally.

" I have now the honor to inform you, that Mr. Kelly has made a further examination of the ground, this time on the left bank of the Ganges, up the Lal Nuddee, opposite Ghora Ghât; his men having brought in a good specimen of limestone from that locality.

" I regret to say that Mr. Kelly has ascertained that the sample stone was a boulder merely carried down possibly from some other locality. He describes the rock *in situ* as a 'very hard tough stone, well suited for coarse rubble masonry, but not for dressing, as the beds are very irregular and the joints run in every direction.' He adds, that 'possibly an odd stone might turn out in quarrying down a cliff,' and that 'there are lots of shapeless masses of stone in the ravine hard enough for anything, but all intersected with false joints, so that they cannot be split up straight, and being in scattered blocks, the carriage would be very expensive.' He does not think that a stone of 4 cubic feet when dressed could be found there; and his men, whom he has out on search, with the incentive of Rs. 100 reward before them, all say that at and above Rikheekes nothing capable of being dressed has been met with.

" I may add, that although I considered Mr. Kelly's report

Digitized by Google

to be conclusive as regards the localities examined by him; and although the prospect of finding good stone within a moderate distance of Hurdwar appears to be remote; yet, the search for it shall not be abandoned."

Question 3.—"The Committee are anxious to have a copy of Professor Medlicott's Report, if it can be found."

Reply.—"Memoirs of the Geological Survey of India, Vol. III., Part 2, sent by to-day's post."

Professor Medlicott states (page 176) "that stone fitted for ornamental or monumental purposes might be found among the thick bedded hard limestone of the "Krol group." Of this group the belt of limestone and slate which crosses the Ganges between Rikheekes and the stream beyond Tupobun, would appear to be the continuation; it seems strange though, and it is most disappointing that no vein of good hard stone should be found in such a locality. But as Mr. Kelly has remarked, if there were any veins of hard stone they would probably have contributed good hard boulders of fair size to the Ganges deposits, whereas it is notorious that the limestone boulders are small, mere shingle."

P.S.—The best stone to be had in the neighbourhood of Hurdwar is the conglomerate, of which the caps of the Myapoor dam spiers are made. It is hard and durable under running water. That one was not experimented on because from the nature of it, experiment on a small specimen would be useless. Unfortunately, the quantity of this stone, which is to be had within a moderate distance from Hurdwar, is very small. The visible supply has been almost worked out.

(Signed) J. H. DYAS, LIEUT.-COLONEL,
Chief Engineer, Irrigation Works,
N. W. Provinces.

ROORKEE,
31*st May*, 1866.

EXTENSION OF THE CANAL FROM CAWNPORE TO ALLAHABAD.

Sir Arthur Cotton's plan for extending the canal navigation to Allahabad.

133. In the concluding paragraph of his first letter to the Government of India, Sir Arthur Cotton has strongly urged the necessity of carrying the canal as a line of navigation to Allahabad, as the point "which is essential to its effective operation;" and the Committee have accordingly given the subject their best consideration, especially as it appears to have been Sir Proby Cautley's original intention to adopt the same terminal point.

Area of the lower part of the Doab and its means of communi-

134. The length of that part of the Doab is 120 miles, and its average breadth under 25 miles; it is bounded on each side by a

Digitized by Google

cation very favorable appears to render the extension not necessary at present.

navigable river, and intersected throughout by the East India railway, and the Grand Trunk road, and it appears to the Committee that no part of India is better provided in proportion to its area of 3,000 square miles with the means of transport, either for its own produce in favorable seasons, or for that of other districts for its relief in times of scarcity, and they therefore fail to perceive the necessity of an expenditure of at least 15 lakhs, in carrying a navigable canal through this narrow tract.

The irrigation of the extremity of the Doab not required so much as its extension in the upper districts.

135. With regard to the irrigation of this extremity of the Doab, the Committee have been informed that the failure of rain is less frequent there, than further northward, but without accepting this as an ascertained fact, they may remark that it will be equally advantageous and more economical, to extend irrigation in the upper districts, as the great length of the canal has unquestionably been one material cause of its heavy cost, and disproportionate financial returns.

The extension to Allahabad not recommended.

136. While, therefore, there are other objects of so much more urgent importance in connection with the canal, demanding attention, the Committee cannot do otherwise than advise that the Allahabad extension should for the present remain in abeyance.

FINANCIAL STATE OF CANAL.

Nett receipts from canal do not cover interest on capital.

137. The annual statement of remunerative works in the N. W. Provinces, exhibits the Ganges canal in an apparently hopeless state of indebtedness. The total expenditure on new work is charged with interest at the rate of 5 per cent., and the expenditure up to the end of 1863-64, having amounted to upwards of 2 millions, the charge for interest is over 10 lakhs of rupees. The total income for that year was Rs. 7,73,390, and the expenditure in maintainance and for establishments was Rs. 6,09,711, leaving only Rs. 1,63,679 to meet the charge of 10 lakhs. About Rs. 8,40,000 thus appear at the end of the year as a balance of charges against the canal. This operation which has been going on from the commencement has caused the accumulated charges up to the end of the year 1863-64, to amount to upwards of 83 lakhs of rupees.

Remunerative statement not a fair criterion of the merits of the canal.

138. If the above procedure be accepted as correct, it is evident that the canal must be pronounced a failure as a commercial speculation, until the nett receipts shall exceed the annual charge for interest. The Committee do not however consider that the annual statements of remunerative works, from which the foregoing particulars are taken, are at all a fair criterion of the merits of the canal.

Policy of Government in levying low water-rates.

139. The statement to the following effect of Colonel Colvin, which Major Crofton has quoted in his Report, well deserves attention; "that the object of Government was not so much to form a productive source of revenue from the actual price paid for the water, as to gain

Digitized by Google

a sufficient control over its expenditure and to prevent its being wasted, and that they looked to the general improvement of the country as the source from which they should derive a return adequate to the outlay." The Committee believe that until very recently the Home Government continued to hold the same views, and it is to this policy the extraordinarily low water-rate which has been charged on the Ganges canal up to the end of 1864-65 is to be attributed.

140. The Committee are not aware to what extent per acre the land revenue of the country watered by the Ganges canal has been enhanced by irrigation; but they are of opinion that whatever it may be, it should appear as an item of canal revenue, and if it cannot be separated from the ordinary land revenue, and incorporated with the proceeds from water-rates, it should at least be exhibited in the annual returns to the credit of the canal. On this point the Committee entirely agree with Colonel Dyas, who has expressed his views in the following terms in his report for 1863-64.

Increase of land revenue due to this canal should be exhibited in remunerative statement.

141. "Nothing appears clearer to me than that all proceeds resulting from the construction of a work of irrigation should be clearly shown, whether they happen to be on the debtor or on the creditor side, whether profit or loss, for if they are not shown, how is it possible for Government to know whether it is advisable to construct any new work. It matters little under what names or heads the proceeds are shown, whether as land revenue, enhancement of land revenue, diminution of land revenue (a negative proceed) or water-rate; the one thing needful is to show them all clearly and not to allow any of them to be muddled up with the land revenue proper, that is, with the land revenue assessable, had the canal no existence."

Colonel Dyas' opinion on the subject quoted.

142. As an example of the effect of a canal in the N. W. Provinces in improving the land revenue, we quote as follows from a report also by Colonel Dyas, with reference to the Meerut district, watered by the Eastern Jumna canal.

Increase of land revenue due to irrigation on Eastern Jumna canal.

"Of that district at the time of the settlement, 71,920 acres were irrigated, and the land revenue from that land in 1848 was Rs. 1,35,195; hence the rate of land revenue for land irrigated at the time of the settlement is Rs. 188 per 100 acres.

"Of the same district, 4,58,896 were (in 1848) unirrigated, and the land revenue secured amounted to Rs. 6,35,893, hence the rate of land revenue for unirrigated land is Rs. 138 per 100 acres.

"The increase therefore due to the Eastern Jumna canal is Rs. 50 per 100 acres, or eight annas per acre."

143. As regards the Ganges canal, it would appear that it has not heretofore received credit for any increase of land revenue, and it was impossible that the low water-rate that was charged up to the beginning of 1865-66, should alone suffice to return a profit on the capital expended.

No similar benefits on Ganges canal, and water-rates insufficient to yield a profit.

Digitized by Google

Probable increase due to Ganges canal assumed at 8 annas per acre of irrigated area.

144. Should however an increase of land revenue equal to that which as above has accrued to the irrigated land under the Eastern Jumna canal, be credited to the Ganges canal when the new settlement comes into operation, the annual receipts will be increased by 8 annas per acre, or about 583,000 acres, or nearly 3 lakhs of rupees. From the returns obtained by Colonel Dyas from the Collectors, it would appear that in two districts alone, the enhancement due to irrigation amounts to Rs. 97,863, and the above estimate is more likely to be below than above the mark.

Water-rate increased from 1st May, 1865.

145. Fortunately for the future prospects of the canal, the Government have lately sanctioned the introduction of increased water-rates. From 1st May, 1865, they will be equal to about double what they were before. The average yield for last year will be about Rs. 2-4 per acre. Should the area of land irrigated by flow of water or gravitation, as compared with that irrigated by machinery, be raised. as is certain to be the case when the full supply is admitted into the canal, the profit per acre will be considerably increased, and for future calculations, Rs. 2-8 is more likely than Rs. 2-4 to be the average rate.

Revenue from canal for 1865-66.

146. The irrigation returns for 1865-66, have been received by the Committee. The receipts will be as follows :—

Water-rents—Khureef, ...	Rs.	4,88,353
„ Rubbee, ...	„	7,43,806
Miscellaneous receipts from sale of produce, ...	„	63,226
Receipts from navigation, ...	„	43,662
Total, Rupees, ...		13,39,047

Charges and nett revenue.

147. The charges for the year for repairs and establishment which the Committee have obtained from the Controllor, P. W. Accounts, N. W. Provinces, amount to Rs. 5,98,531, the nett receipts will therefore be Rs. 7,40,516.

Return on capital outlay.

148. The total expenditure on new works on the canal, including rajbuhas, up to the end of 1864-65, was Rs. 2,08,14,654, the interest at 5 per cent., 10,40,732; the nett receipts only yield a return of fully 3½ per cent.; but if the enhancement of land revenue due to the canal, which is estimated approximately at upwards of Rs. 2,90,000, be credited in the receipts, the return for the year would be 5 per cent. on the outlay.

Failure of canal though in an unfinished state, of a modified kind.

149. However, if only the canal revenue proper is taken into account, the above figures show that the financial failure of the canal, even in its present half developed state, is of a very modified kind.

Progressive improvement certain.

150. An increase of irrigation may be confidently anticipated, and as the charges for establishment and maintainance do not increase in the same proportion, the nett receipts will go on steadily increasing year by year. While for the five years, from 1860-61 to 1864-65, the quantity of water discharged by the canal remained nearly uniform,

Digitized by Google

the irrigated area increased during that period from 3,42,909 acres to 5,66,514 acres, the revenue (at the old water-rates) from Rs. 6,45,111 to Rs. 9,90,866, and the area irrigated by each foot of discharge from 73 to 141 acres.

151. It is found on the old established canals from the Jumna, that each cubic foot of discharge irrigates from 190 to 290 acres; the average may be taken at about 220; and if the Ganges canal attains to this standard, its full supply of 6,750 cubic feet per second will irrigate 14,85,000 acres. But allowing only 200 acres per cubic foot, the area would be 13,50,000 acres, which at Rs. 2-8 per acre, will yield 33,75,000 rupees; to which may be added, at the lowest computation, 2,25,000 for miscellaneous revenue receipts and for navigation tolls or in all 36,00,000, exclusive of enhancement of land revenue. Ultimate duty of canal calculated.

152. Major Crofton estimates the total cost of the project, including all works in the original design, except the extension to Allahabad, at Rs. 3,10,00,000. If the additional works the Committee have recommended, raise the cost to Rs. 3,25,00,000, the annual charge at 5 per cent. will be 16¼ lakhs of rupees. Charge on capital to be met.

153. The maintenance eventually will, it is confidently expected, be on a far lower scale that it has been of late years, seeing that there have been unusually heavy repairs to masonry works, and extensive clearances due, not to the silt admitted from the river, but to the erosion of the bed and sides of the channel. Probably 7 lakhs per annum will suffice to cover all expenses. The nett returns would then be 29 lakhs, which would not only suffice to cover the charge of 5 per cent., but to pay off the accumulated interest of former years, and that once effected, to yield a clear profit of 8 per cent. per annum exclusive of the enhancement of land revenue. A good return anticipated.

154. Considering therefore all the circumstances noticed above, which have hitherto tended so materially to frustrate the success of the Ganges canal in a financial point of view, the Committee are of opinion that its comparative failure up to the present time affords no ground for doubt of a fair and reasonable return from other irrigation projects, constructed with the express object of yielding a direct profit. Delay in returns from Ganges canal should not disparage projects for irrigation works.

155. In concluding their enquiry into the financial prospects of the canal, the Committee would observe that complete economy in the use of water for irrigation cannot be looked for until the charge is made on the cubic quantity taken, and not on the area of land irrigated, as is the present practice. Water should be sold by measurement.

156. Under the present system no inducement is afforded to the cultivator to make the most economical use of the water; on the contrary, every inducement is towards wasteful profusion. Cultivator not encouraged at present to economize water.

157. He pays the same tax per acre, for a particular crop, whatever may be the amount of water thrown upon it; and thus, if by throwing double the quantity upon the land he could increase the Water-tax according to area irrigated, without reference to quantity of water expended.

Digitized by Google

yield by only 2 per cent., it would be to his pecuniary interest so wastefully to apply it.

Area irrigated per cubic foot per second on Ganges canal.

158. The number of acres irrigated on the Ganges canal by each 1 foot per second of discharge has been increased during the last five years from 73 to 141 in 1864-65.

Area irrigated on Eastern Jumna canal.

159. The quantity irrigated by each foot per second of discharge on the Eastern Jumna in 1864-65 was 220 acres.

Capable of further increase.

160. But this is far below the theoretical maximum; and, as in the latter canal the rajbuhas are now doubtless fully developed, indicates some defect in the system of disposal.

Quantity of water required for a wheat crop. Mr. Login's evidence.

161. Mr. T. Login, an officer of great experience in these subjects, reports that from careful experiment he found that four waterings of 2½ inches, or a total of 10 inches in depth of water, was amply sufficient for a wheat crop in these soils.

Opinion of cultivators.

162. A common concord of opinion amongst cultivators is that one foot of water suffices for a wheat crop.

Duty which should be performed per cubic foot of discharge.

163. Allowing 20 per cent. of the whole discharge for absorption and evaporation, this would make the total required 15 inches in depth; or one foot per second of discharge should theoretically irrigate 580 acres of crops, consuming equal amounts to wheat crops, assuming that the water were fully utilised throughout the year.

Four times the quantity required for a wheat crop expended at present.

164. The quantity of land actually irrigated by the Ganges canal in 1864-65 was 141 acres per 1 foot of discharge per second, and the depth of water consumed was 5·17 feet, or deducting 20 per cent. = 4·65, or nearly four times the quantity actually said to be required for wheat crops.

Theoretical duty per cubic foot Khureef and Rubbee combined.

165. But of the whole area irrigated, 30 per cent. consists of Khureef crops; which, on the average, as at present composed, consumes nearly the same total quantity of water as the Rubbee crops. Assuming the present proportion of Rubbee and Khureef, and the present composition of Khureef crops to remain the same, and assuming that the water on the Khureef is equally utilised, then the area irrigated of average crops, both Rubbee and Khureef, should be 414 acres per cubic foot of discharge.

Economy of water not of importance heretofore, but will be very necessary when canal is completed.

166. The Committee are aware that the subject of the disposal of water by cubic measurement has from time to time engaged the attention of the canal officers, but as owing to the imperfect development of the rajbuhas and to the demand for water for extension of irrigation being of gradual and slow growth, the necessity for economy of water has not been so urgent as it will be when the canal shall have been completed.

Committee recommend a course of experiments on water-meters.

167. The Committee would therefore recommend that the experiments now being made at Roorkee should include a comprehensive enquiry into the feasibility of bringing into use a cheap and effective water-meter, and they are of opinion that the great importance of the subject would warrant a liberal outlay.

Digitized by Google

COMPARISON OF FINANCIAL RESULTS OF MADRAS IRRIGATION WORKS WITH THOSE OF THE GANGES CANAL.

168. The financial results of the Great Irrigation Works in Southern India have been so prominently adduced as examples of what the Ganges canal, if constructed on sound principles, ought to have yielded, that the Committee think it necessary to remark briefly on the very different circumstances under which the works in the Northern and Southern Provinces appear to have been carried out, which are explained more fully in separate papers,* recorded by two of their number.

Works in Northern and Southern India carried out under different circumstances.

169. It appears that in Madras nearly all the large works undertaken by the British Government have been to an important extent for the purpose of restoring and developing irrigation systems which, in a more or less imperfect state, had existed for ages. In Tanjore especially extensive channels from the Cauvery covered the Delta, and needed only proper regulation to render them thoroughly effective. In the Godavery and Kistna Deltas also, it is stated, that numerous old channels, some of which were of considerable size, had served to distribute, though imperfectly, a supply of water from those rivers. They were incorporated with the Delta systems dependent on the anicuts, and formed serviceable feeders of the new canals, thus saving a considerable cost in excavation, and expediting the distribution of the improved supply of water.

Madras Delta works chiefly designed to improve and develope old systems of irrigation.

170. In other districts, extensive reservoirs of ancient construction, required only the powerful aid of weirs across the feeding rivers, and in some cases connecting lines of channel, to restore and develope their storage capacity to its fullest extent.

Ancient reservoirs improved by the construction of weirs.

171. Further, the rapid extension of irrigation in the South has been materially promoted by the fact of the people being accustomed to that mode of cultivation, and by their readiness to avail themselves of the large tracts of waste land fit for the cultivation of their great staple, rice, which can be raised only by artificial flooding in all the irrigated districts.

Rapid extension of irrigation in Madras.

172. The Ganges canal on the other hand is an entirely new project from which no return could be derived, till the main works had been completed, and the results of which must necessarily depend on the gradual development of an entirely new system of branches. Wheat, the great staple produce, can be raised in favorable seasons at moderate expense by well irrigation, and the proportion of available waste land is but small, added to which, although the water-rate has been fixed very low, the sale of water depends wholly on the demand

Difference of circumstances in the Ganges canal.

* Appendix B and C.

Digitized by Google

on the part of the landholders, which it is understood is not the case in Madras, while canal irrigation in these provinces is of but recent introduction; and not, as in the South, a system practised for centuries.

Difference of relative levels to the land between the Delta rivers and those of the Northern Doab.

173. The Committee consider the foregoing causes sufficient to account for a great and apparently disadvantageous contrast between the North and South; but when it is also borne in mind that owing to the essential difference between the relative levels of the Delta rivers to their field of irrigation, and those of the Northern Doab to the adjacent land, a vast additional expense must be incurred in the latter case, in bringing the water to the surface, whether by taking off a canal from above or below the rapid slope of the bed following the debouchment of the river from the hills; they cannot but feel that no just comparison can be made between the results of works so very different in character as those referred to.

ACKNOWLEDGEMENTS.

174. With reference to para. 10 of the order of Government, No. 20,410, the Committee desire to acknowledge the assistance and information they have received from Colonel Dyas and the Executive Engineers under his orders.

They were also favored with the valuable evidence of Mr. T. Login, late Superintendent of the Northern Division of the canal, as to its past history.

They regret that owing to the urgent pressure of his duties in Cuttack, Colonel Rundall was unable to join them in their inspection of the Ganges, and although that officer offered to reply to any written questions referred to him, they did not consider it expedient to delay their proceedings for that purpose, when personal examination of the localities seemed essential for arriving at a correct opinion; so far however as can be judged from Colonel Rundall's unofficial communications, it would appear that his views as to the best site for the weir and line of canal near the Solani, do not differ materially from those adopted by the Committee.

175. The Committee would further record their best acknowledgements of Major Crofton's unwearied efforts to promote the objects of their enquiry, both by efficient arrangements for their movements and by full explanations of his own plans.

Edward Lawford, Col.-Commandant, R E.
J. C. Anderson, Lieut.-Colonel, R.E.
J. G. Fife, Lieut.-Colonel, R.E.
Hugh Leonard, C.E.

Mussoorie,
18*th June*, 1866.

Digitized by Google

DISSENT.

1. I dissent from the above report mainly as to conclusions No. III. and No. IV., the first negativing the proposed canal from the Jumna near Delhi (bringing 3,300 feet per second to complement the present 4,400 now brought down by the main canal), as a substitute for the remodelling above the junction; the second recommending that the remodelling according to Major Crofton's plans (with certain modifications), be at once proceeded with.

2. In reference to the latter's conclusion, I dissent from paras. No. 140 and 142 of the report, which state that the main difficulty in the remodelling, as proposed by Major Crofton, lies in the depth of the cisterns below the new falls, and which further state that if these cisterns be modified, the work up to water line many be executed during two closures of the canal, each of 3½ months duration.

3. I dissent from this latter conclusion, because Major Crofton has, after careful investigation, expressed his opinion, in para. 102 of his report, that to execute the work as designed by him, the necessity for shutting off the canal supply for at least one irrigating season is inevitable, and that an entire year would not be too large an allowance; because Colonel Dyas, the Superintendent, Irrigation Works, N. W. Provinces, has concurred generally in that opinion; because in my judgment the period assigned is rather understated to carry out the works as designed; and because I do not regard the deep cisterns as the most troublesome part of new falls, nor nearly so likely to cause uncertainty and delay as the well foundations; and I decidedly do not think that the proposed modification of the cisterns would render it probable that the work up to water line could be executed (except at entire disregard of cost) during two periods of 3½ months stoppage of the canal.

4. Further, I am not satisfied with the estimate of probable loss from such a closure for 3½ months, Colonel Dyas having been asked for a statement of such loss and having not yet given it because he had not sufficient information.

5. In respect to conclusion No. IV., I dissent because I hold that it is only as a last resort that the serious evil of stopping the canal supply for a whole year, if not longer, should be incurred, and because the proposed canal from the Jumna offers a mode (if the 3,300 feet per second discharge of the Jumna and Hindun rivers can be depended upon, and for which conclusion there appears to me to be strong *primâ facia* ground) of making up with the 4,400 feet per second now brought down the main canal, an amount of water supply in excess of that provided under the remodelling scheme, at a less, or certainly not greater cost, and without incurring the serious evil of stopping the canal supply.

Digitized by Google

6. For the further elucidation of this subject, I refer to the Memo. in that project, printed in Appendix A., and I recommend that during the next season, a complete survey should be made of that project, and that, in addition to daily record of water level, the discharges of the rivers Jumna and Hindun should be taken on the 15th of each month, from October to May inclusive, and that if the result should show that a quantity approximating 3,300 feet per second can generally be relied upon during those months, then the canal from the Jumna should be made in supersession of the remodelling above the junction, if it be determined not to execute both, or in priority to the remodelling if it be determined that both should be carried out.

7. I further recommend that, meanwhile, stone and other material should be collected at existing falls, sufficient for their complete repair should failure occur, but that no further steps should be taken towards the remodelling above Nanoon junction, until the question of general minimum discharge of the Jumna and Hindun be settled.

8. I dissent generally from paras. No. 70 to 89 of the report, treating of the Jumna project.

9. In reference to para. 71 of the report, in which it is stated that the water gauge kept at the railway bridge at Delhi, was not a safe guide, because it was affected by the damming up of the bridge spans for girder erection purposes. I would point out that this damming gradually increased in extent from the beginning to the end of the dry season; and, consequently, so far as it affected the water level, would have the effect of making it appear relatively higher in April than in December.

10. I dissent from para. 73, which decides to adopt the same section for weir at Toghlukabad on the Jumna as at Sookertal on the Ganges. At Toghlukabad there is a practicably unlimited supply of stone from the old fort, much of it dressed, and any further quantity of rough stone can be quarried within 3 miles of the work.

11. At Sookertal there is no stone within 50 miles, and probably no sufficient supply of fit stone within 66 miles, and this last has not yet been explored.

12. These conditions are so essentially dissimilar as, in my judgment, to demand different treatment.

13. For the above reasons I dissent from the estimate of weir across Jumna given in para. 81.

14. In reference to para. No. 101, I do not concur in ascribing the deep holes below the falls, chiefly to the increased velocity with which the water escaped from the floorings.

15. I think that the most serious part of that scouring is due to the wings which curve inward, thus reducing the width of the channel, and throwing a current at right angles to the direction of the stream, by which a rotary motion is produced, and deep scouring naturally follows.

Digitized by Google

16. Had the scouring been chiefly due to the velocity of the water over the crib work, the greatest depth of scouring would naturally have been looked for immediately close to the crib work, where the light soil joins the protective work; but the deepest scour is not found there, but at a considerable distance lower down, and just where the conflicting currents are converted into a rotary motion.

17. At Nirgajnee falls (next below the Mahmudpoor falls) which is without these inward-curved wings, but little scour has taken place.

18. I would recommend that these inward-curving wings be altered at once, the work could be done without interrupting the canal.

19. On the subject of the supply of stone referred to in paras No. 130 and 132, it should be noted that Colonel Dyas' experiments were made on the Sewalik sandstone lately brought in, and are not necessarily to be regarded as representing the crushing weight of the sandstone seen in the old buildings at Hurdwar.

20. A more important point on the subject of stone is that the report does not, in my opinion, lay nearly sufficient emphasis on the importance of examining the apparently unexplored field in the main Himalayas in the neighbourhood of Luchmun Joola and Tupobun, where, at a distance of about 17 miles from Hurdwar, the hills for miles in extent appear to be formed of a hard ferruginous clay slate, and rather farther up the valley of the Ganges, of evenly stratified whin-stone.

21. Should a good building stone be discovered there, it would reduce the estimate for the weir at Sookertal by upwards of 4 lakhs, and would reduce the cost of ashlar stonework executed on the upper portion of the canal by from 30 to 50 per cent.

GEORGE SIBLEY.

Digitized by Google

APPENDIX A.

Memo. on a project for making a canal from the Jumna at Toghlukabad, about 10 *miles below Delhi, to the main canal near Birowlee bridge (or to the Simra falls), about* 20 *miles above Nanoon junction, the head of the Cawnpore and Etawah branches.*

1. In considering the relative merits of the various schemes for obtaining the desired result, of bringing down the full amount of water which the canal was originally designed to carry, there should be kept constantly in view the vital importance of not closing the canal and stopping irrigation, except as a last resort.

2. In para. 97 of Major Crofton's Report he writes, "the absolute "necessity of maintaining uninterruptedly the present volume of water "to supply existing irrigation, unless there be very cogent reasons to "the contrary, is assumed by all."

3. In para. 102, he states his conclusion that for executing the work proposed by him in remodelling, "the necessity of shutting off "the canal supply for at least one irrigating season, or half a year, "appears inevitable, and to do the work satisfactorily and give time "for the larger masses of masonry to harden sufficiently, an entire year "would, in my opinion, not be too large an allowance."

4. This opinion is concurred in generally by Colonel Dyas, Superintendent Irrigation Works, N. W. Provinces.

5. The Committee of Engineer Officers summarised the advantages of a duplicate channel to complement the supply, as presenting—

1st.—Facility of construction, and of forming reliable estimate of time and cost of construction.

2nd.—The very great convenience that may be anticipated from the possession of a duplicate line of main channel, which would admit of a considerable amount being sent down to the lower parts of the canal, while either of the main lines was closed for repairs.

6. Sir P. Cautley (in page 75 of the Discussion) writes, "the "remedy however appears to be rather in the division of the great body "of water and thereby in diminishing the effect of its action, than in "the continuance of the existing channel as a single line:" again (in page 76) he writes, "I am much in favor of *reducing the present volume*

Digitized by Google

" *of water in the main canal*, with so many falls and so large a body of " water passing over them, perpetual repairs and interruption will in- " evitably occur, let the slope be reduced to any extent. *By the divi-* " *sion of the waters this will be avoided*, and the evil of accident on one " line will (as far as supplies for irrigation to the South are concerned) " be neutralised by the existence of an alternative line."

7. Sir P. Cautley also, in his Memo., printed in Appendix A. to Major Crofton's Report, insists on the value of having an alternative line for the security of the irrigation of the Southern districts; in this view, and also to avoid the serious evil of stopping the irrigation for an indefinite period Sir P. Cautley proposed a duplicate channel, leaving the main channel below Roorkee.

8. The Government of India in reviewing Major Crofton's Report rejected this project for an alternative channel--1stly, because it appeared from Major Crofton's figures that it would be more costly than the remodelling by some 30 lakhs; and secondly, and chiefly, because it appeared that the really serious objection to the remodelling, the necessity for closing the canal for a while, was found to be equally applicable to that scheme.

9. The Government of India at the sametime remarked that, had there been a prospect of the scheme being practicable without the necessity for closing the canal, it might have been thought desirable to incur additional outlay to avoid such serious interference with the convenience of the agricultural community, though it might have been doubtful whether even on that ground so large a charge as 30 or 40 lakhs should be incurred.

10. Major Crofton's comparison of the cost of the remodelling with Sir P. Cautley's alternative line, was based on the supposition that the present channel could carry with safety only 1,870 feet per second below Roorkee, leaving the alternative channel to carry 5,000 feet per second, or nearly three-fourths of the whole quantity.

11. Now, it appears that, since the last closure in August, 1864, (a period of 21 months) the canal has carried regularly 4,400 feet, being $2\frac{1}{3}$ times the estimated safe quantity; that the action in the bed, falls and bridges, has been carefully watched,. and that no injurious action worth noting has been ascertained to have occurred.

12. This fact, as to the comparatively favorable condition of the works, if well established, would lead to the conclusion that only 2,500 feet instead of 5,000 feet need have been provided for in the new channel, and would so far modify the comparison of cost between the alternative channel and the remodelling scheme; as, however, the alternative channel was rejected, not so much on the ground of extra cost alone, as on the ground that the serious evil of closing the canal appertained to that scheme also, it does not appear to be necessary to go into the question of how far the comparison between the two projects would be modified.

Digitized by Google

13. Without having the canal laid dry, it is of course impossible to state with absolute certainty whether any seriously injurious action has taken place, but the concord of evidence from surface observation leads to a contrary presumption.

14. The Committee made a formal request to Colonel Dyas, the Superintendent of Irrigation Works, N. W. Provinces, to have the waters shut off for a few days, so as to enable them to satisfy themselves, by actual inspection, as to the condition of some of the more important and previously threatened works, but this request was met by objections so numerous and so strongly urged as almost to amount to a protest, and under these circumstances the Committee decided not to press their request.

15. Colonel Dyas reports as to the condition of the works since the date of Major Crofton's Report, as follows:—

"As to the bed, erosion is no doubt going on in many places, in- "asmuch as during the cold weather, when the water coming in from "the Ganges river through the Myapoor regulators (the head of the "canal) is almost quite clear, the water in the canal gradually becomes "very muddy; but a comparison of the cross sections of the canal bed, "which I have lately had taken at every mile along the canal, with "similar sections taken by Major Crofton in 1864, shows that no dan- "gerous action is going on at present.

"As to falls in the Northern division (from Myapoor to Jaolee) "the extent of damage done, as far as can be ascertained by careful "sounding and probing, consists of a slight displacement of crib work "battens. In the Meerut division two falls have been slightly injured, "but not sufficiently as to warrant a closure of the canal for the pur- "pose of repairing them. The Chitoura fall, 55 miles 4,976 feet, has had "part of the ogee in No. 3 bay ripped out, and that bay is kept close "in consequence to prevent further damage; and the Sulawur fall (67 "miles 2,350 feet) has had two of the hammer-dressed Delhi stones in "flooring of No. 3 bay turned over: this occurred in September, 1864, "and the stones have not moved since. The bridges are all secure."

16. The result of the last 21 months' working appears therefore nearly conclusively to show that for a lengthened period this quantity of 4,400 may be safely sent down the present channel, so that if a quantity equal to that which is required for the irrigation below Birowlee bridge, on the Simra falls, can be brought in from any independent source, the whole irrigation below that point may be permanently secured; and if by repairs, such as may be effected during the ordinary periods of closure (the cost of which Major Crofton estimates at Rs. 1,06,424), the old channel may be made securely to carry permanently the present 4,400 feet per second, the result would be that a total quantity of 7,700 feet per second would be available for irrigation (as compared with the 6,742 feet of the remodelling scheme), and this result would be obtained without stopping the irrigation.

Digitized by Google

17. It appears from an examination of the country and of the levels, that such a complementary channel could be made at moderate cost by leading the water from the Jumna, opposite Toghlukabad, about 10 miles below Delhi, crossing the Hindun, and taking its waters also, and joining the main line at or near Birowlee bridge, near the 158th mile from Hurdwar.

18. The minimum discharge of the Jumna for this year, as appears from sections taken by the Resident Engineer, of the Jumna bridge, on the 9th April, 1866,

Being	2,820
And that of the Hindun, taken by an Assistant Engineer of the Railway at Gazeeabad, ..	480
Gives a total,	3,300

feet per second, which is very nearly the full amount required below the Birowlee bridge, on Simra falls, according to Major Crofton's scheme.

19. This discharge is corroborated by the discharge taken at Agra by Mr. Dodd, Executive Engineer, on the 5th April, 1866, which showed 3,544 feet per second, and which he reports to have been the lowest for the season.*

20. The Resident Engineer of the Delhi Railway bridge, who took the discharge on the 9th April, and who is on the river daily, reports however, that he is perfectly confident that the river was at its minimum for the season on the 9th April, that there was only 9 inches difference between water level on that date and on the 19th December, a difference that was fully accounted for by the channels having been bunded for the purpose of girder erection.

21. There appears to be at least sufficient *primâ facie* evidence of the general correctness of the minimum discharge taken, or 2,820 feet per second, to demand further investigation.

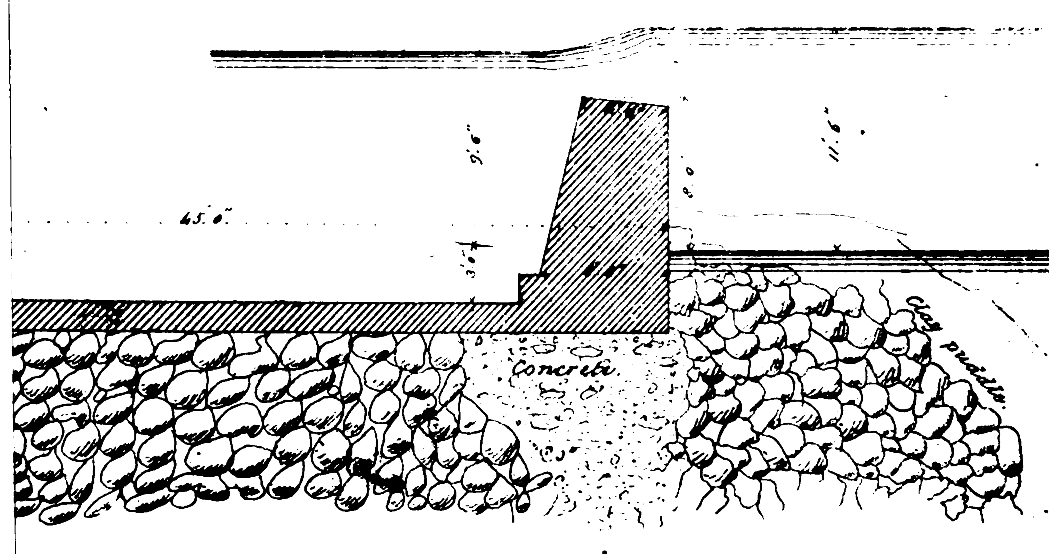
22. Toghlukabad is a very favorable position for the building of a weir across the Jumna—firstly, because the river bank, opposite the village of Alee, is of a very firm character (kunker and clay); and secondly, because there is a practically unlimited supply of stone admirably suited for such purposes, a very large amount of rough stone and a very considerable quantity of dressed stone (Delhi quartzite), being available from the ruins of the old fort of Toghlukabad, which is also built on rock.

23. A channel 130 feet wide at base, 10 feet deep, with slopes 2 to 1, and fall of 4½ inches per mile, giving a velocity of 2·20 feet per second, would discharge 3,300 feet per second, and would fall into the main canal at about the 158th mile from Hurdwar, or about 22 miles

---

* A doubt has since been thrown as to whether this was lowest minimum discharge, by its having been stated that the discharge of the Jumna on the 19th December, 1865, was only 829 feet per second.

Digitized by Google



N. B. Body wall to be built gradually
to full height.

Digitized by Google

Digitized by Google

above Nanoon junction, the head of the Cawnpore and Etawah branches.*

24. An approximate estimate of such a channel and weir shows that they could be executed for about 39 lakhs (£390,000) including superintendence.

The amount is composed as follows:—

	Rs.
Earthwork, ...	20,59,788
Bridges, &c. (19), ...	3,80,000
Weir and regulator at Jumna, ...	6,64,000
Weir and regulator at Hindun, ...	2,10,000
	33,13,788
Add contingencies, at 8 per cent., ..	2,65,103
	35,78,891
Add establishment, at 7 per cent., ..	2,50,522
	38,29,413
Land, 57 miles at 64 acres per mile, at Rs. 24 per acre, ...	87,552
Total, Rupees, ..	39,16,965

25. In the above estimate earthwork cutting, depth average 10 feet, has been taken at Rs. 3 per 1,000; and average depth 20 feet, Rs. 4 per 1,000. In the estimate for weir at Jumna, the rough rubble stone is taken at Rs. 10 in place, and the dressed masonry at Rs. 30 per 100 feet; probably the whole of the material required being obtainable from the old fort of Toghlukabad; or if further rubble stone be required, it can be quarried within 2 miles of the weir.

26. It is considered that with the mass of rubble stone available, and with a good puddle clay on the spot, wells would not be needed under the weir wall; if a double row of wells be added, they would increase the estimate by about Rs. 2,00,000.

27. In the estimate for Hindun river weir, the actual rates of work in the Hindun railway bridge have been adopted.

28. The percentage for contingencies and for establishment have been taken the same as in Major Crofton's alternative line.

	Rs.
29. To the total, ...	39,16,965
As above, there is to be added—	
Remodelling between Birowlee bridge and Nanoon, ...	3,58,458
Repairs above Birowlee, ...	1,06,424
Re-adjusting rajbuha heads above junction,	1,00,000
Total, ...	44,81,847
Remodelling Cawnpore branch, as per Major Crofton's estimate, ...	4,26,842
Giving as expenditure, Grand Total, Rupees, ..	49,08,689

* It might prove advisable to bring in the new channel below the Sirma falls, 5 miles lower down, or about the 163rd mile.

Digitized by Google

30. Major Crofton's estimate for remodelling the old canal—including the Cawnpore branch is, ... 39,19,850
Of which is debited for navigation above Birowlee, .. 9,05,000

Leaving debitable to irrigation, Rupees, .. 30,14,850

Now, though the above amount (9,05,000) may as a part of a whole be fairly debitable to navigation, it is doubtful whether the work due to irrigation alone could be executed for the balance.

31. Assuming however the above figures, to that balance, would have to be added the difference of cost between that of a permanent dam at Hurdwar, without which the full supply could not be relied on, and the capitalisation of cost of maintaining present bunds which suffice for present supply, this difference will probably not be less than Rs. 5,00,000.

32. Again is to be added the amount of loss and compensation due to the stoppage of the canal. In Major Crofton's estimate, this is put down at Rs. 13,48,213, but in this the canal revenue is taken at only Rs. 7,73,390, since the date of that estimate the rates have been raised, and it is expected that the canal revenue will, before the work can be undertaken have reached 15 lakhs.

	RS.	RS.
To the above, ...		13,48,213
Will therefore have to be added, ..	15,00,000	
	7,73,390	7,26,610
Giving a revised total,		20,74,823

33. The cost of the remodelling scheme then, exclusive of navigation above Birowlee, becomes—

	RS.
Works, as per Major Crofton's estimates, ...	30,14,850
Permanent head works (difference in cost), ..	5,00,000
	35,14,850
Losses and compensation, ...	20,74,823
Grand Total, ..	55,89,673
The cost of the duplicate channel scheme from the Jumna and remodelling below junction being, ...	49,08,689
Shows a difference of, ..	6,80,984

34. The rates for the duplicate channel, executed in the dry, have been taken at the same as in the remodelling; but it may be safely predicted that in work executed under pressure for time, with a "working bee," as proposed, the rates would rule far higher in the remodelling than in the duplicate channel.

35. As previously noted, the Government of India remarked, that it would be desirable to incur additional outlay to avoid such a serious interference with the convenience of the agricultural community, as would be caused by the closure of the canal; it appears however from the above figures that the duplicate line would cost absolutely less than the scheme, which involves the stoppage of the canal.

36. The disadvantages of the duplicate channel may be stated to be as follows:—

1st. That it does not improve the navigation above the junction near Birowlee to the extent contemplated in the remodelling scheme; leaving, as it does, a velocity of 4 feet per second where only 3 feet would be given by that scheme. The minimum headway is left nearly the same in both schemes by the water level being kept 3 feet 6 inches lower in the one than in the other. It is to be remembered, moreover, that the cost of such improvement is also omitted from the calculations; the improvement of the navigation below Nanoon (the really defective portion) is equally provided for in both events.

2ndly.—The asserted extra cost of maintaining and working the extra lengths. This is doubtful, the certain amount of extra establishment will probably be more than counterbalanced by the smaller bodies of water to be dealt with, and by the fact that 3,300 feet is carried only 57 miles in lieu of 158 miles.

3rdly.—The loss of head in the rajbuhas owing to the full depth originally intended not being maintained in the canal. Should it be deemed advisable in any particular case, the additional head could be obtained by taking the rajbuha from the fall above the present outlet—a sum of Rs. 1,00,000 has been provided for that purpose in the estimate. It is to be remembered that in any event many of the rajbuhas will have to be remodelled, owing to them being below the surface.

4thly.—The extra loss by absorption and evaporation. As regards the first, the 3,300 will have to travel only 57 miles before being utilised in lieu of 158 miles, and the latter is scarcely worth taking into consideration, as assuming an evaporation equal to 60 inches per annum, the total loss on the channel, 57 miles long, would be equal to a discharge of only 8 feet per second.

5thly.—The injury to navigation in the Jumna by abstraction of the water for the new canal. The whole of the water is at present abstracted from the Jumna at the canal heads, and yet there is nearly 3,000 feet flowing at Delhi, 140 miles lower down. Agra is 140 miles below the new proposed

Digitized by Google

weir; and practically there is in the cold weather no navigation above Muttra, but little above Agra, and but imperfect above the junction of the Chumbul river.

37. Among the advantages of the duplicate channel (from the Jumna scheme) are—

1st.—The maintaining irrigation permanently over, at least, the lower half of the main canal, and most probably over the whole, without any break from closing.

2nd.—Facility of construction, and of forming reliable estimate of time and cost of construction in the dry.

3rd.—The great convenience of a duplicate line of main canal.

4th.—The provision without extra cost of an additional 57 miles of first class navigation, without a lock in the whole length.

38. The balance of advantages appears to be so clearly in favor of the duplicate channel that, if the quantity of 3,300 feet per second can be generally relied on from the Jumna and Hindun—I have no hesitation in recommending the duplicate channel from the Jumna near Toghlukabad in preference to, and in supersession of the remodelling of the main canal above the point of junction.

39. As a matter of course no works should be commenced until that point, as to the discharge, is established; and I would recommend that, during the ensuing season, a complete survey should be made of this project; and that, in addition to the daily record of water level, the discharges of the rivers should be taken on the 15th of each month, from October to May inclusive.

40. I would also recommend that stone and other materials be collected at the existing falls, sufficient for their complete repair should failure occur; but that no further steps be taken towards the remodelling above Nanoon junction, until the question of general minimum discharge of Jumna and Hindun be settled.

41. Having regard further to the facts that the above total of 6,742 feet per second is calculated, at a standard 40 per cent. in excess of present duty, to irrigate only $1\frac{1}{4}$ million acres (or if 7,700 feet per second, about $1\frac{1}{2}$ million acres), and though this higher standard of duty will doubtless be much further raised when the system of measurement by volume shall be generally introduced; yet, seeing that the culturable area of the Doab above Cawnpore is upwards of nine million acres, of which only about 2,25,000, are irrigated by the Eastern Jumna canal, it would appear worthy of consideration whether, when the duplicate channel shall have been completed, and the irrigation of the lowest half of the canal secured, the remodelling of the main channel above the junction might not then be profitably carried out, generally as proposed by Major Crofton, but with modifications (except as to suggested shallower foundations for cisterns of new falls), as recommended by the Committee, when remarking on that project, and with such further modifications if possible (whether by use of

Digitized by Google

iron-piling or otherwise) as may avoid the necessity for any lengthened closure of the canal.

Estimate of the cost a canal from the Jumna near Toghlukabad, 10 miles below Delhi, and the main line near Birowlee bridge, on Simra falls, a length of 57 miles, to carry 3,300 feet per second.

Quantity.	Description of work.	Rate.	RS.	A.	P.
	EARTHWORK IN EXCAVATION.	RS.			
c. ft.					
135,533,333	1st section, 19 miles, average depth, 9·13, ..	3	4,06,600	0	0
261,233,000	2nd „ 14 „ „ 19·80, ..	4	10,44,932	0	0
202,752,000	3rd „ 24 „ „ 10·59, ..	3	6,08,256	0	0
599,518,333	57 „ Total of earthwork, ..		20,59,788	0	0
	JUMNA WEIR AND REGULATOR.				
c. ft.					
148,896	Dressed masonry, ...	30	1,48,896	0	0
3,474,240	Rubble stone at place, ...	10	3,47,424	0	0
per ft.	Regulator and lock, ...		67,680	0	0
2,000	Training walls, ...	50	1,00,000	0	0
			6,64,000	0	0
	Hindun weir and regulator, ...		2,10,000	0	0
	Bridge &c. (19), ...	20,000	3,80,000	0	0
	Earthwork, as above, ...		20,59,788	0	0
			33,13,788	0	0
	Contingences, at 8 per cent., ...		2,65,103	0	0
			35,78,891	0	0
	Establishment, at 7 per cent., ...		2,50,522	0	0
miles.			38,29,413	0	0
57	Land, 64 acres per mile, ...	29	87,552	0	0
	Grand Total, ...		39,16,965	0	0

GEORGE SIBLEY.

Digitized by Google

APPENDIX B.

Notes on the Comparative Financial Results of Irrigation Works in the Madras Presidency and the N. W. Provinces.

The financial results of irrigation works in Madras over estimated.

1. I have long been of opinion that the financial results of great irrigation works in the South of India have been over estimated, and that fallacious ideas of what may be effected elsewhere have been formed upon erroneous data, but it has not hitherto been any part of my duty to investigate the subject.

Other causes of increased revenue.

2. That the general prosperity and revenue of the districts in which such works have been carried out have been enhanced to a degree unknown in less favored provinces is an unquestionable fact, but as all of them are on the seaboard, it is certain that the great increase of foreign trade, and of the salt revenue, which has taken place in the last 20 years, must affect this result, and credit cannot I think be taken for the entire increase as due to the works of irrigation.

The works not entirely new.

3. Moreover (as the Government of India have recently suggested) the returns in many cases are the effect, not merely of British science and expenditure, but of an extensive system of hydraulic works which had been in operation for ages before the country came under our rule, but which had suffered deterioration, partly from from natural causes, and partly from neglect, and have only recently been restored to efficiency.

Description of the works in Tanjore, by Major H. C. Cotton.

4. It is well known that the works in Tanjore are the prototype of all other improvements in the coast districts; there irrigation had been carried on from time immemorial under the river Cauvery, the channels from which covered the province, and made it the "Garden of Southern India." In 1842, Major H. C. Cotton wrote as follows: "The main branches of the Cauvery with the branch which retains the parent name, the minor channels separating from these, and the innumerable ramifications threading the surface of the Delta, are so disposed that one can scarcely believe it was a gradual work, each portion the accidental result of what had been done before, but would rather suppose it the work of consummate skill and science, planning the whole system at once and establishing it. Changes have taken place during the last 40 or 50 years, disordering in some measure

Digitized by Google

the irrigation of certain tracts, and remedies have of late years been applied, but these have been almost entirely confined to restoring these tracts to the condition they had been in at some former period. The deterioration which had occurred was due to the tendency of one of the arms of the river to absorb a continually increasing proportion of the whole of the supply, and thus to injure the irrigation dependent on the other arm. The remedy applied was the construction of weirs or anicuts across the river, and various other works, for the regulation of the supply to different channels." These works were in the highest degree successful, and the revenue which had been falling off for a number of years, not only regained its former maximum but rose far above it, and produced returns exceeding 100 per cent. on the amounts actually laid out in the works above described. It is, however, clear that such profits were due not to these works alone, but to the improvement they caused in the pre-existing canals by which their benefits were conveyed to every part of the Delta, and which had cost the British Government nothing.

Their profits not due to the anicuts alone.

5. So also the construction of weirs across the Vellaur, Palaur, Pennair, Ponnyaur, Poiney, and other secondary rivers on the Eastern coast, was expressly designed for the better supply of large reservoirs of ancient formation; which at the best had received but a precarious supply and had yielded an uncertain revenue, and which had gradually become inefficient from deposits of silt and general decay; but it cannot be fairly said that the returns in the shape of increased revenue are owing to the weirs alone, independently of the vast embankments by which the increased supply of water was stored, and which likewise were heir-looms from former rulers, by whom their advantages were fully appreciated.

Ancient tanks and channels in other districts only improved by the British Government.

6. To institute a comparison between the remunerative returns from such works as those of Southern India, and the financial results of an extensive and costly project like the Ganges canal, involving an entirely new system of hydraulic works over a tract of country hitherto destitute of all such artificial aids to cultivation, and in which the Engineers themselves were almost as much concerned in teaching the people the value of canal irrigation, as in constructing the works, is obviously fallacious, and calculated to lead to unfounded expectations and disappointment.

Comparison of the results of such works with those of the Ganges canal fallacious.

7. The greater part of the Southern Presidency depends mainly for prosperity on its ancient system of irrigation by channels and reservoirs, without which it would be almost a desert, while the N. W. Provinces are favored with a fine climate and general fertility of soil, capable in ordinary seasons, of raising a great variety of produce without artificial irrigation, the introduction of which by the British Government was avowedly intended, not as a commercial investment, but as a means of mitigating the effects of those disastrous seasons with which Northern India is sometimes visited; and it is on

The Madras Presidency dependent on its ancient irrigation works, but the N. W. Provinces not so, and the canal constructed as a preventive of occasional famine.

Digitized by Google

such occasions that the profits derived from the canal are highest, because the demand for water is greatest.

Difference of revenue systems.

8. The great difference between the Madras revenue system, under which irrigated land bears a permanent increase of assessment, and the voluntary and annual purchase of water by the Zemindars of the N. W. Provinces, is another material cause of the discrepancy upon which so much stress has been laid. The Madras Ryot pays the same amount to Government, so long as his fields are irrigated whatever the season may be, but the Zemindar of Cawnpore or Meerut looks to the clouds, and purchases canal water or not, as he may judge the prospect of rain to be favorable or otherwise.

E. LAWFORD.

Digitized by Google

APPENDIX C.

1. I am quite willing to accept Sir A. Cotton's estimate of the benefits derived from the Godavery and Kistna works. But I am of opinion that these works were carried out under exceptionally favorable circumstances; and that there are few, if any, non-Delta formations in India where the same results could be attained at the same proportional expense. Not only would Government be disappointed were they to take the returns from the Madras Deltas, as the standard which properly managed irrigation works ought generally to yield, but private companies might be led, through the same mistake, to embark in schemes which a real knowledge of the Delta works would have shown them, could not be of an equally profitable character. In the belief that a description of the peculiar advantages under which the Godavery and Kistna works were executed will not only be useful in clearing away much mis-apprehension that prevails regarding them, but will help the Government to understand better than they seem to do at present, the cause of their yielding a much higher rate of profit than the irrigation works in the North of India, I proceed to impart such information as I possess on the subject.

The high profits derived from Godavery and Kistna works attributable to the exceptionally favorable circumstances under which they were executed.

2. In the Godavery and Kistna Deltas irrigation from old channels was carried on to a considerable extent before the new works were commenced. In the reports on the Godavery, frequent allusion is made to the old channels. They are described as being very imperfect, as they opened from the river bank on a high level, which rendered them liable either to get an insufficient supply when the river was low, or an excessive one when it was high. The actual value of the channels however was not only considerable, but they afforded the the means of at once distributing the water from the new main channels, and they possessed an agricultural class ready to use it as soon as it was offered them. The new works were thus enabled to return a profit much earlier than they could have done, had an entirely new system of distribution channels formed a part of the project.

Old channels for irrigation in Godavery and Kistna.

Vide Professional Papers, Madras Engineers, Vol. III., p. 115. Captain C. A. Orr's Report, No. 184; and page 159: Lieut.-Colonel A. T. Cotton's Report, No. 13.

3. That the old channels in question must have been valuable adjuncts to the new works, is shown very clearly in following extract from Captain Orr's Report. "By what has been shown as the benefit derivable from the anicut by means of the channels immediately affected by it, it will be seen, that with an expenditure of 9 lakhs, an annual increase (calculated on the lowest data) of Rs. 1,09,451 would be obtained, a result of itself sufficient to justify the construction of the anicut.

Valuable accessaries to new works.

Professional Papers, Madras Engineers, Vol. III., p. 118.

Digitized by Google

Old tanks and channels in Kistna Delta. Former supply defective.

4. In the Kistna Delta there were not only irrigation channels of considerable size, but a large number of tanks, both of which have been of invaluable service to the new works. Of the channels I may particularize the Pullairoo in the northern section of the Delta. Though now of moderate size, about 50 feet near the head, it is evidently an ancient arm of the river, running on a ridge like the Kistna itself, and admirably adapted for distributing the water for irrigation. It sufficed by means of numerous small branches to irrigate a large proportion of the Delta; that is when it had water. Before the construction of the anicut at Bezwada, it was liable like the channels in the Godavery, to receive either an insufficient or excessive supply, according as the freshes might be below or above the average, and like them and the channels in Tanjore, it only wanted a regular supply to secure the revenue due to the whole of the land under it. This want the anicut combined with a new head 15 miles in length, supplied, and the desired result was at once attained. The importance of this channel and its value to the new system may be understood from the fact, that when 65,000 rupees had been expended in the course of about eight years subsequently to the admission of water from the anicut, solely for clearance and repairs of the channel and its branches, 6,500 rupees only had been expended during the same period in new works and improvements. The cost of repairs to the Delta channels is under 8 annas per acre of irrigated area, and the water-rent was until lately 3 rupees per acre, or six times as much. The large expenditure on repairs therefore represents a large irrigated area.

Profit derived by throwing in an improved supply by means of new heads.

5. Another channel existed in the southern section of the Delta and conveyed water to a number of important tanks to supplement the supply from the local rain-fed streams. A cut of 12 miles in length connected it with the anicut, and changed its supply from a variable and uncertain quantity to a certain and uniform quantity. There were 17 tanks under this channel, and the average revenue derived from them, from 1851 to 1855, that is for four years prior to the introduction of a supply from the anicut, amounted to Rs. 52,929, the minimum being Rs. 31,458, and the maximum Rs. 70,092. The revenue derived from the same tanks in 1863, the last year of which I possess the accounts, was Rs. 1,39,323 showing an increase over the former average of Rs. 86,394. The fluctuation of the revenue before the admission of water from the anicut was very remarkable; thus in the course of four years only, four of the tanks yielded respectively a minimum revenue of Rs. 0, Rs. 10, Rs. 323, and Rs. 123, and a maximum of Rs. 3,321, Rs. 2,908, Rs. 3,663, and Rs. 6,327.

Precarious cultivation done way with; revenue secured and increased.

6. The supply of the tanks was formerly very precarious, and the above examples testify to what extent both Government and the Ryots were liable to suffer. The immediate effect of the more certain supply from the anicut was to give confidence to the Ryots, to secure

Digitized by Google

the revenue at the highest figure to which it could have risen had the tanks received a good supply from rain, and by doing away with all risk of loss to the cultivators, to induce an extension of the cultivation, and a further increase of revenue. But without the aid of the tanks and the channels leading to them, which were, as I may say, superadded gratis to the anicut works, the same increase of revenue could not have been attained, excepting by a large additional expenditure on new channels or tanks, and a delay of several years.

Another series of tanks in Kistna Delta.

7. Besides the above, there are another series of tanks in the Kistna Delta which were fed by a number of small channels from the river. A short branch from the new main channel into a cutting which had been formed to make an embankment along the river, fed these tanks with a regular, instead of their former precarious supply, and a large increase of revenue was the result.

No old works of irrigation in the country traversed by Ganges canal.

8. It will thus be seen that the Godavery, and still more the Kistna Delta works, started in possession of some advantages over an entirely new system of works like the Ganges canal, where not a single village channel existed along the length and breadth of the country to be irrigated, and where the cultivators were unused to any other mode of irrigation but that by means of wells. The Godavery and Kistna works have other advantages in regard to the alignment of new channels, which alone would render a comparison between them and the canals in the N. W. Provinces, altogether unfair.

Depth of cutting at head of main channels in Godavery and Kistna Deltas.

9. The anicuts which have been constructed across the Godavery and Kistna are about 14 and 19 feet, respectively, above the bed, and the ground along the banks may be from 13 to 17 feet above the crest of the anicuts. The heads of the main channels are between 5 and 6 feet lower than the crest, consequently the depth of cutting will be from 18 to 22 or 23 feet.

Limit of irrigation reached in a cutting several miles in length.

10. If this depth of cutting had to be maintained for any considerable distance, the expense of conveying the large body of water required for the irrigation of the Delta would be very great. But the fact of the country to be irrigated being liable to periodical inundation by the river from a remote period, implies that the deposits during a series of years have raised the land along the banks to a higher level than that at a distance from them, so that the deep cutting at the head of the main channels, works out into a moderate and inexpensive cutting in the course of a few miles.

Slope of the country from the bank of the Godavery described by Sir A. Cotton. Professional Papers, Madras Engineers, Vol. III., p. 20.

11. Sir A. Cotton in one of his early reports on the Godavery, thus describes the peculiarities I have mentioned :—"Besides the slope of the land towards the sea in a Delta, it has another slope, viz., a fall from the river in a direction perpendicular to its course, and the fall is much more rapid than that towards the sea. In the present case it has been ascertained to be, near the head of the Delta, 16 feet in two miles from the west, and 7 feet in two and a half miles on the east side. Thirteen miles lower down, that is twenty-

Digitized by Google

five miles from the sea, the fall is 9 feet in two and a half miles on the west side of the Godavery. Thus the river banks form a ridge from 18 to 7 feet above the level of the land, at the distance of from three quarters to two and a half miles distant on either side, providing most remarkably for the leading out of the water upon the lands.

"The apparently formidable operation of bringing the water from the bed of the river is upon an examination of the level reduced to this, that the highest part of the Delta is only 8 or 10 feet above the bed of the river in its immediate neighbourhood, that is within two miles of it, and that if an anicut be built 11 feet high above the deep channel of the river, the deepest excavation for the irrigating channels will be 18 feet, and within two miles, the country on the west side would be below the level of the top of the anicut. On the east side the lands would be on the same level within about four miles. The apparent objection arising from the great depth of the river is thus completely disposed of."

Ganges canal had to be carried across a number of torrents, or in a very long cutting, before the irrigation limit could be reached.

12. On the Ganges canal the water before reaching the tract of country requiring irrigation, had to be carried across a series of formidable torrents, which required a vast expenditure of time and money. Had the canal been opened from the river below the point where the last of the torrents joins it, it would have had to traverse a distance of 50 or 60 miles before the irrigation limit could be attained. In either case heavy expenditure was necessarily entailed before the water could be turned to any use.

Heads of main channels in the Deltas, simple and inexpensive works, and the length of distribution channels 30 or 40 miles on the average.

13. The main channels in the Godavery and Kistna are simple cuttings, unimpeded by any natural difficulties. Combined with the anicuts, these short cuts carry the water to the points from which it may be distributed to every field in advance, to near the sea, and the distribution channels have not to extend beyond an average distance of 30 or 40 miles.

Ganges canal necessarily of great length.

14. On the Ganges canal the water is conveyed over much more unfavorable ground to a distance of 350 miles from the head. Sir A. Cotton considers this fact, as one of the errors of the original project. The practicability of forming separate heads between Roorkee and Cawnpore in order to reduce the distance to which water is conveyed, without being utilized, forms the subject of separate enquiry. I may remark in this place, that the principal object of the Ganges canal was to ameliorate a famine, and with this object the water was distributed in a certain proportion over a much larger tract of country than was economically necessary. Had it not been for the restriction thus laid on the projector, he could have utilized the whole of the available supply of water in a canal of one-half or one-third the length to which it has been actually carried, and would have had the opportunity of effecting a large saving in the cost of the work.

Vide Sir P. Cautley's Report on Central Doab Canal, 1840.

Waste land in Deltas.

15. There are several other facts which serve to explain in

Digitized by Google

some measure the high and quick returns yielded by the Godavery and Kistna works. There is an enormous extent of waste land in the Deltas: the great mass of it is either sandy or more or less swamp, but large tracts not far removed from the sea and recently inundated by it are unfit for cultivation until the soil is improved. Both this and the sandy soil, however, become as valuable as any other land in the Deltas, after several floodings by the river water, loaded as it is with mud of the most fertilizing character.

Large profits derived.

16. Large tracts are thus rendered productive, which in their natural state were absolutely useless. A further extent of country is brought within the influence of the Delta channels by embanking or draining swamps. It is a common occurrence for 1,000 or even 2,000 acres of such waste land to be taken up in one plot for rice cultivation in a single season; and there is one instance in the Kistna Delta, of the Ryots of a number of villages uniting to present an agreement to take up in one block 15,000 acres of waste land as soon as certain drainage and irrigation channels should be completed, and to pay Government rent for it at the rate of Rs. 6 per acre, or Rs. 90,000 in all per annum.

No such advantage on the Doab.

17. This is no exaggeration, as the land was actually taken up on those terms as fast as the drainage and irrigation works progressed. The canals in the N. W. Provinces have no such advantages. Not only is the area of waste cultivable land in the Doab between the Ganges and Jumna of comparatively small extent, but the revenue settlement extends over a period of 30 years, and the cultivator has to pay no more for irrigating waste land, than the small water-rate which he has to pay for land already under cultivation.

Returns from Deltas retarded by insufficient allotments of funds to complete the works.

18. But on the other hand, high as the returns have been from the Delta works, they would have been far higher had the works experienced a tithe of the liberality with which the Ganges canal has been treated from first to last. Notwithstanding the Government have received incontestible proofs of great and manifold advantages having accrued, both to themselves and to the country, from the extension of irrigation in the Madras presidency, the works which above all others may be taken as the type of what can be accomplished, when a supply of water can be cheaply distributed, are only half finished.

Estimates sanctioned, but money not available to complete various works.

19. The Government readily sanction the estimates for the various new works and extensions that are submitted to them, but the money to carry them out is not forthcoming. Not even the modest demands of the local officers for a fixed and regular annual allotment of 5 lakhs of rupees per annum for new works on the Godavery and Kistna united, until the Delta system shall have been fully developed, has been complied with. Channels which may have been in progress in one year, are summarily stopped the next, or if the main channels are completed, the funds required to carry out the minor works, and to turn the others to profitable account may not be granted,

Digitized by Google

though the works themselves have received the complete approval of Government. Numerous instances could be adduced in which the delay that has thus arisen in utilizing the supply of water, has occasioned a large loss of revenue.

A notice of the grants for expenditure necessary to complete the comparison between Delta works and Ganges canal.

20. I have described the advantages which the Delta works had at starting over the Ganges canal, and to render the comparison a fair one, I think myself bound to take conspicuous notice of this one great disadvantage which they have had to contend against for a long succession of years.

Drainage channels used for irrigation in Deltas, but not in Ganges canal.

21. Many of the drainage channels in the Godavery and Kistna have been used for carrying the water for irrigation. In the country affected by the Ganges canal the drainage courses are deep, and nothing would be gained by using them as irrigation channels. Had they been shallow, the local Engineers would probably still have avoided them, and would have preferred to go to the expense of excavating new channels rather than interfere with the proper function of the drainages. Allowing that there are serious disadvantages in using channels for both purposes, there can be no doubt, that the Engineers in the Godavery and Kistna have secured a large additional revenue by being content to use imperfect channels, when time and money would have been required for the excavation of new ones.

Swamping in Deltas not unhealthy, as it is in the Doab.

22. The slight fall of many portions of the Deltas, combined with the system of using the natural channels for purposes of irrigation, serves to produce extensive swamping; notwithstanding this, it is a remarkable fact, that the Deltas are more healthy than other parts of the district. Fever especially is far less prevalent in the Deltas than in the country immediately beyond it, where there is but little rice cultivation and no swamps. The cause is unknown to me. It can hardly be the influence of the sea air, because the formation of the east coast of India closely resembles that of other countries which are notoriously unhealthy. It is more likely I think to be in the geological formation of the soil. However that may be, it would be useless to attempt to prove that ill-drained rice cultivation in the N. W. Provinces should be healthy because it is healthy in the Madras coast districts.

Few bridges across the Delta channels.

23. There are but few bridges on the Godavery and Kistna canals. In most cases bridges are built over the locks, but on several of the channels there are no bridges for 30 miles and upwards. On the Ganges canal the bridges are built at every two or three miles apart. They have not been constructed in such profusion simply because the Engineers thought them necessary or wished to construct them, but because the Local Government, acting as they would act towards a private company, insisted on having them where communications were intersected.

Small grants of

24. Sir A. Cotton's argument in favor of the procedure which

Digitized by Google

has been followed in Madras seems a sound one. Doubtless, in some parts of the Deltas, considerable inconvenience is occasioned by the want of bridges, but if only a limited sum was available for expenditure, it was best that it should be used to extend the irrigation.

money considered to be best applied in extending irrigation.

25. The actual want of bridges is not so great in the Deltas as in the N. W. Provinces, for the nature of the soil and absence of suitable material are almost prohibitory to the formation of roads, which should be passable in the rains. Indeed, there are no metalled roads in the Deltas, but the numerous navigable canals supply their place along the principal lines of traffic, and any other traffic is unimportant. In the Ganges and Jumna Doab, there are greater facilities for moving carts; the extent of thickly populated country is much greater; and there is a far higher proportion of important towns and villages, than are to be found in the Godavery and Kistna. Hence, more cross communication is necessary, and we may reasonably expect that bridges at short intervals will be looked upon as a necessary addition to the canals. I may add that the canals in the N. W. Provinces, are rarely closed unless for emergent repairs, when some sacrifice of revenue is likely to be entailed; and that bridges can be built at a considerably less cost in the first instance before water is admitted, than would be possible afterwards.

Bridges required in greater number in the Doab.

26. Thus it appears that a considerable expenditure on account of bridges has to be borne by the Ganges canal, while the Delta channels in Madras are relieved up to this time of any heavy charge on the same account.

Considerable outlay saved to Delta works.

27. In the Godavery and Kistna channels navigation and irrigation can be carried on together more favorably than is possible on the canals in the N. W. Provinces. The principal crop in the Deltas is rice, which requires water from July to December. There is also sugar-cane and a second crop of rice in the Godavery, but the area and quantity of water consumed by them is small compared with the requirements of the others. The channels are aligned with a slight fall, generally from 3 to 6 inches a mile, and locks are placed at such intervals as will allow of still water navigation, when the water is not required for irrigation.

Navigation combined with irrigation in Delta channels, more favorably than is possible in N. W. Provinces.

28. The surface fall of the channels does not necessarily correspond with the fall of the bed. For three or four months in the year, July to October, it may be increased to 9 inches per mile. The velocity, especially in the upper reaches, is then very considerable, and boats cannot work up stream without some difficulty. But for the remaining eight months of the year, a smaller body of water is admitted from the river, and for half that period there is practically still water navigation. On the Ganges canal, on the other hand, the principal demand for water is not during the rains, when the river could supply any quantity that might be required, but during the dry season. Rice is the great staple produce in the South of India, wheat

Large supply of water in Delta channels for only a portion of the year; different circumstances of crop in Delta and the Doab.

Digitized by Google

that in the N. W. Provinces. The one is raised in the rains, the other in the dry season. The wheat crop on the Jumna canals is greater than all the rain crops united. These canals have been in operation for many years, and rice cultivation has in no way been discouraged, unless near cantonments and large towns; yet it has not extended to such a degree as to require a greater supply of water than the wheat. The following figures which are taken from the last report (for 1864-65) of the Chief Engineer, Irrigation Department, Punjab, serve to show the state of the Irrigation under the Western Jumna canal.

Total number of acres irrigated during 1864-65, 434,965.

Area in acres of the principal crops irrigated for the last five year:—

	1860-61. (Famine year.)	1861-62.	1862-63.	1863-64.	1864-65.
Rice, ...	44,965	58,578	57,925	47,353	57,157
Cotton, ...	43,706	33,558	25,549	45,882	77,738
Sugar, ...	26,102	33,782	44,730	30,089	29,786
Wheat, ...	1,81,208	1,48,317	1,11,129	1,45,234	1,63,159
	2,95,971	2,74,235	2,39,333	2,68,558	3,27,840

The rice and cotton are rain, or "Khureef" crops. Wheat, dry weather crop, or "Rubbee:" the sugar is irrigated in both seasons.

Discharge of Western Jumna canal during each month.

29. The average monthly discharge of the canal was 1,784 cubic feet per second; 243 acres were therefore irrigated in 1864-65 by each cubic foot per second. The following was the discharge during the different months:—

Khureef.		Rubbee.	
May, ...	250	November, ...	2,481·8
June, ...	1,985·2	December, ...	1,717·5
July, ...	2,431·80	January, ...	482·72
August, ...	1,559·15	February, ...	1,532·28
September, ...	2,265	March, ...	1,898·05
October, ...	2,554	April, ...	2,554
Average, ..	1,791		1,777

Demand for water as great in dry season as in rains.

30. From the above it appears that the demand for water in April was as great as in July, and in December and March as in August, though July and August are months in which rice requires a plentiful supply of water.

No period of the year available for still water navigation.

31. Instead therefore of the demand for water being fluctuating as is the case in the Delta channels, it is nearly constant throughout

Digitized by Google

the year, an exceptionally high supply is not wanted owing to the rains; on the contrary the maximum supply required is that yielded by the river during the dry season, and the current will have to be kept up at its maximum during the whole of the period, which on the Godavery and Kistna is available for still or nearly still water navigation.

J. C. ANDERSON, Lieut.-Colonel,
Royal Engineers.

Digitized by Google

APPENDIX D.

Note on the deep cutting of the Ganges canal, and the supposed effects of irrigation in the salubrity of the N. W. Provinces.

Deep cutting of the canal imputed as the second fundamental mistake.

1. The second of the fundamental mistakes imputed by Sir Arthur Cotton to the original construction of the Ganges canal is, that the whole of it "has been cut so as to carry the water below the level of the surface, entailing a vast unnecessary expenditure, and keeping the water below the level at which it is required for irrigation; also that in cutting the canal deep in order to prevent the water keeping the neighbouring lands in a wet state, its Engineers produced the very effect they intended to prevent, because they cut through the water-tight stratum, and let the water into the lands below, which carry it all through the country."

2. There can be no doubt that a considerable saving might have been effected by carrying the canal on a higher level and keeping the surface above soil, but as the heads of the rajbuhas or main distributing channels are governed by the levels of the weirs or falls, there does not appear to be any difficulty (except in the Etawah branch) in regard to the irrigation, which commences within 19 miles from the canal head.

The effect considered to be exaggerated.

3. With respect to the evils supposed to be caused by the percolation of the canal water through the sandy soil below the harder upper crust, it seems that this effect has been exaggerated, as no evidence of it appeared along that part of the canal inspected by the Committee; the only appearance of ooze being where the level is high nor was any information received on the subject; but supposing it to be partly true, it cannot possibly extend "all through the country," nor can it cause the formation of swamps likely to influence the salubrity of the district. The general effect of extensive irrigation will no doubt eventually be to raise the spring level of the tract irrigated, but this will not depend on the surface level of the main canal.

Probable results of irrigation in raising the spring level.

Risk of carrying the canal on a high level.

4. On the other hand, there does seem to be no small risk in carrying a large body of water at a considerable elevation for a great distance between embankments, composed of such poor materials as even the best soil of these districts, and as it is very doubtful if it was possible to ensure throughout an impermeable bed, it seems that the deeper cutting although more expensive was the safest plan.

Digitized by Google

5. In the Delta of the Cauvery the annual rise of the rivers above the level of the country over which they spread is invariably followed by a corresponding appearance of spring water on the adjacent lands, and constant vigilance is required to secure the embankments.

Rise of springs in the Cauvery Delta, consequent on the floods.

6. But it is remarkable that although that Province is more or less inundated for half the year, and extensive swamps are formed along its southern coast, malaria is unknown; a fact as little capable of explanation as the existence of the evil on the rocky uplands of Coimbatore and Mysore, and especially along the banks of the same river Cauvery; and no inference can be fairly drawn from the salubrity of the Southern Deltas and other irrigated districts, to invalidate the common belief in the malaria caused by irrigation in the N. W. Provinces.

Malaria unknown in Tanjore, but commonly believed to result from irrigation in the N. W. Provinces.

E. LAWFORD.

Digitized by Google

APPENDIX E.

Note on the section of the proposed weirs across the Ganges and Jumna.

This section being avowedly prepared more in conformity with that of the Godavery anicut, than those of weirs in Tanjore and other Southern districts of Madras, I am desirous of explaining my own views on the principal points in which the proposed work differs from the latter.

1st. The depth of the wells. The Madras wells are sunk only 10 feet below the bed of the river, not merely because they are as firm at that depth as if they were carried lower, provided that no scour removes the sand, but on account of the great difficulty and expense of increasing their depth. Experience has however shown that without an almost unlimited supply of rough stone for their protection, it is not safe to rely on this depth, even in the firm coarse sands of the Southern rivers; much less then would it be prudent to do so in the beds of the Ganges and Jumna, consisting of remarkably fine micaceous sand, totally unlike the former, and sinking when wetted under the slightest pressure.

2nd. The breadth of the cut stone apron. This has been fixed at 50 feet, for a dam 9 feet, or with its upper board 12 feet high, and may seem excessive compared to those of the South, which seldom do if ever exceed three or four times the height of the weir. I, however, concur in the proposed plan, because I believe it will often be found impossible to remove the board in time, and then the height of overfall will closely approximate to the same proportion to the apron as in the Southern rivers. This difficulty has been felt at the Godavery anicut. Further, as there is no doubt that the beds of the rivers will become raised even above the height of the weirs, the overfall will in time be extended beyond its first distance, and may act on the rough apron with too great force.

3rd. The rough concrete apron is carried out 120 feet, with 7 feet of depth at the inner, and 3 feet at the outer, edge. With a cut stone apron of 50 feet, I cannot think such a broad mass of rough material beyond will at first be necessary, but considering the nature of the sand already described, and the inferior kind of material of which this part of the work must necessarily be formed, I have no doubt that the aggregate quantity will be required in a year or two, and it ought certainly to be provided for in the estimates.

E. LAWFORD.

Digitized by Google

APPENDIX F.

ESTIMATE, No. 1, of the probable expense of a channel from the Ganges at Raoli Ghat to join the Ganges Canal, at $116\frac{2}{8}$ miles from Hurdwar.

Width, 180 feet, side slopes, 2 to 1; depth of water, 10 feet; embankments, 12 feet wide at crest; 5 feet high above water surface; side slopes, 2 to 1; fall, $5\frac{1}{2}$ inches per mile; total length, 70 miles.

	Rupees.
1. 1 to 9th mile. Depth of cutting varying from 3·5 to 11·5 feet; contents, 81,404,400 cubic feet, at 3 Rs. per 1000, ...	2,44,213·2
2. 10 to 16th mile. Embankment from 9·5 to 13·75 high; contents, 31,159,920, at Rs. 5 per 1000, ...	1,55,799·6
3. 17 to $29\frac{3}{8}$th mile, $10\frac{5}{8}$ miles. Embankment, average height 19·4 feet; contents, 55,287,672 cubic feet, at Rs. 5 per 1000, ..	2,76,438·4
Concrete wall in centre of bank, at Rs. 6 per running foot, ..	3,36,600·0
$2\frac{3}{4}$ miles cutting, average depth 8·3 feet; contents, 23,693,243, at Rs. 3 per 1000, ...	71,079·7
4. $29\frac{3}{8}$ mile to 52nd mile. Berms 12 feet wide, three above water; cutting, $10\frac{5}{8}$ mile, from 25·2 to 36·4 feet; contents, 418,532,664 cubic feet, at Rs. 5 per 1000, ...	20,92,663·3
Cutting for 11 miles, from 15 feet to 24·3 feet; contents, 260,973,504 cubic feet, at Rs. 4 per 1000, ...	10,43,894·0
Embankment across Kala Nuddee, width of crest 20 feet; height 14·6; contents 70,96,320, at Rs. 8 per 1000, ...	56,770·5
5. 53 to 70th mile. Cutting from 5 to 14 feet; contents, 172,666,560, at Rs. 3 per 1000, ...	5,17,999·7

Abstract.

	Rupees.
1 to 9th mile, ...	2,44,213·2
10 to 16th mile, ...	1,55,799·6
17 to $29\frac{3}{8}$th mile, ...	6,84,118·1
$29\frac{3}{8}$ to 52nd mile, ...	20,92,663·3 10,43,894·0
Embanking Kala Nuddee, ...	56,770·5
53 to 70th mile, ...	5,17,999·7
	47,95,458·4
Masonry works, 70 miles, at Rs. 15,000 per mile,	10,50,000
	58,45,458·4
Contingencies, at 8 per cent., ..	4,67,636·6
	63,13,095·0
Establishment, at 7 per cent., ..	4,41,916·0
Land, 70 acres per mile, for 70 miles, at Rs. 24,	1,17,600·0
	68,72,611·0

Digitized by Google

ESTIMATE, No. 2, of the probable cost of constructing a weir across the Ganges at Raoli Ghat, $4\frac{1}{2}$ miles below Sookertal.

I. Weir.

		Rupees.
1.	Cut stone floor, $50 \times 1\frac{1}{2} = 75$	
	,, $6 \times 2 = 12$	
	87, at Rs. 2-8 per foot.	217·5
	Concrete or brickwork—	
	Floor,.. .. $59 \times 4\frac{1}{2} = 265{\cdot}5$	
	Body wall,.. $8 \times 8\frac{1}{2} = 68$	
	Rear apron, $120 \times 5 = 600$	
	Front, .. $30 \times 7 = 210$	
	1143·5, at Rs. 30 per 100,.. ..	343·05
	Wells, .. $3 \times 6 \times 15 = 270$, at Rs. 60, ...	162·00
	Total, per foot run,..	722·55
	Total for weir, $722{\cdot}55 \times 4000 =$	28,90,200
	Cast-iron standards and planking, .. $5 \times 4000 =$	20,000

II. Wing Walls.

2.	Walls, $25 \times \frac{3+10}{2} = 162{\cdot}5$, at Rs. 30,	= 48·75	
	Wells, $2 \times 6 \times 15 = 180$, at Rs. 60,	= 108·00	
	Concrete apron, in front, $30 \times 7 = 210$, at Rs. 20 =	42·00	
	Total per foot run, ...	198·75	
	Total for wing walls, $198{\cdot}75 \times 1{,}600 =$		3,18,000
3.	Concrete blocks along foot of embankment through Khadir, $5280 \times 7 \times 30 = 11{,}08{,}800$, at Rs. 20 per 100,		2,21,760

Abstract.

		Rupees.
1.	Weir, ...	29,10,200
2.	Wing walls, ...	3,18,000
3.	Concrete blocks along embankment, ..	2,21,760
4.	Head sluice and under sluices, ...	2,50,000
	Embankment, ...	50,000
		37,49,960
	Add 10 per cent. for contingences, ..	3,74,996
		41,24,956
	Establishment, at 7 per cent, ...	2,88,747
		44,13,703

Note.—50 per cent. has been added to ordinary rates for work to be executed in water, to cover cost of temporary embankments, baling, losses from flood, &c., &c. An exceptionally high rate is allowed for well foundations, owing to the depth of their heads below low water.

Digitized by Google

ESTIMATE, No. 3. Weir and Works, near Rajghat.

CHANNEL.

	Rupees.
51,68,00,000 cubic feet in 36 feet cutting, at Rs. 5 per 1000, ..	25,84,000
38,58,00,000 „ 27 „ „ 4 „ ..	15,43,000
10,80,00,000 „ 15 „ „ 3-8 „ ..	3,78,000
19,30,00,000 „ 10 „ „ 3 „ ..	5,79,000
Bridges 10, at 25,000 each, ...	2,50,000
Crossing nullahs (4) and passing canal under Futtehghur branch, ...	4,50,000
	57,84,000
Contingencies, at 8 per cent., ..	4,62,720
	62,46,720
Superintendence, at 7 per cent., ..	4,37,270
	66,83,990
Land, 42 miles, at 70 acres per mile at Rs. 24 per acre, ..	70,560
Total for channel, ..	67,54,550

WEIR.

Wells 7 × 7 × ·7854 × 3 × 30 = 450, at Rs. 30 per 100 cubic feet = Rs.		135-0
Sinking and curbs for ditto, Rs.		90-0
Bhurtpore cut stone apron,	30 × 2 = 60	
Weir face, ..	6 × 3 = 18	
Coping, ...	5 × 3 = 15	
	93, at Rs. 2-8	= 232-8
Best block kunker, dressed,	20 × 1′·9″ = 35, at Rs. 1 =	35-0
Second „ „	10 × 1′·6″ = 15, at Rs. 0-12 =	11-4
Rubble masonry under apron,	60 × 6 = 360	
„ body of weir,	9 × 8 = 72	
	432 at $\frac{30}{100}$	= 130-0
Dry rubble, down-stream,	90 × 4 = 360	
„ up „	30 × 10 = 300	
	660 at $\frac{15}{100}$	= 99-0
Moveable board and posts, per foot run, ...		5-0
Puddle, per foot run, say, ...		10-0
Total, per foot run, ..		747-12, say 748

Digitized by Google

Length of weir, 4,500, at Rs. 748 per foot, ...	33,66,000
Sluice and regulator, ...	2,50,000
Wing walls and lock, 24 feet wide, ...	1,50,000
Training and protecting banks, ...	1,00,000
	38,66,000
Contingencies, at 10 per cent., ...	3,86,600
	42,52,600
Superintendence, at 7 per cent., ...	2,97,680
Total for weir, ...	45,50,280
Total for channel, ...	67,53,990
Total for the whole work, ...	1,13,04,270

Digitized by Google

ESTIMATE, No. 4. Weir and works on the Jumna, for a project to carry 3,300 cubic feet per second.

CHANNEL.

13,24,22,400 Excavation in 10 feet cutting, at Rs. 3,	3,97,267		
25,87,20,000 „ 14 „ „ 3,	7,76,160		
28,63,66,080 „ 23 „ „ 4,	11,45,464		
Bridges 19, at Rs. 2,000, ...	3,80,000		
Crossing drainages, ...	1,50,000		
Total, ...	28,49,891		
Contingencies, at 8 per cent., ..	2,27,991		
	30,77,882		
Superintendence, at 7 per cent., ..	2,15,451		
	32,93,333		
Land, 57 miles, at 64 acres per mile, at Rs. 24 per acre, ...	87,552	33,80,885	
Weir, per foot run—			
Cut stone apron, ... 50 × 1½ = 75			
Do. front of weir, ... 7 × 2 = 14			
Do. coping, ... 6·5 × 2 = 13			
102 at Rs. 0-12		=	76-8
Wells, including sinking and curbs, &c., 3 × 6 × 15 = 270, at Rs. 60 per 100, ...		=	162-0
Rubble rough stone, down-stream, 120 × 5 = 600			
„ „ up „ 30 × 7 = 210			
810, at Rs. 6 per 100		=	48-9
Rubble masonry, ... 59 × 4½ = 265			
8 × 8½ = 68			
333, at Rs. 18		=	60-0
			347-1
Length of weir 2,500, at Rs. 347 per foot, ..	8,67,500		
Moveable board and post, at Rs. 5 per foot run, ..	12,500		
Sluices and regulators, ...	1,50,000		
Wing walls and two locks, ...	1,50,000		
Training and protecting banks, ...	50,000		
Total,	12,30,000		
Contingencies, at 10 per cent., ..	1,23,000		
Total,	13,53,000		
Superintendence, at 7 per cent., ..	94,000		
Total, ...	14,47,000		
Weir and passage over Hindun, including training and protecting walls, .. 440,	2,50,000	16,97,000	
Total Rupees, ...		50,77,885	

Say, Rs. 51,00,000.

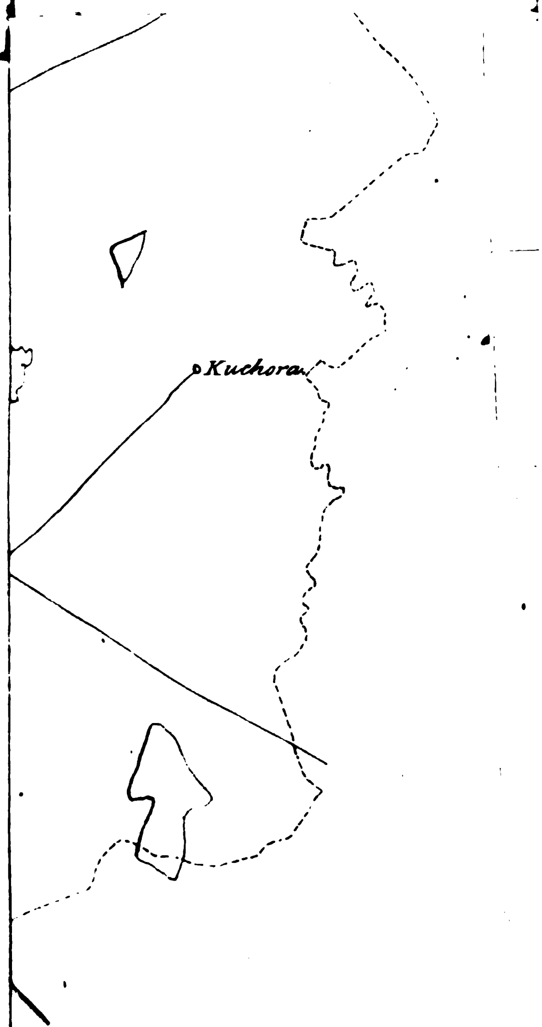
Digitized by Google

ESTIMATE, No. 5. Weir and works on the Jumna. Estimate for project to carry 1,500 feet per second.

CHANNEL.

	Rupees.
7,02,25,000 cubic feet in 10 feet cutting, at Rs. 2-8 per 100,	1,75,560
14,41,44,000 „ 14 „ „ 2-8 „	3,60,360
18,09,50,100 „ 23 „ „ 3-8 „	6,33,325
19 bridges, at Rs. 15,000, ...	2,85,000
Crossing drainages, ...	1,00,000
	15,54,245
Contingencies, at 8 per cent., ...	1,24,339
	16,78,584
Superintendence, at 7 per cent., ...	1,17,500
	17,96,084
Land, 58 miles, at 50 acres per mile, at Rs. 24 per acre, ..	69,600
Total for channel, ..	18,65,684
Total for weir over Jumna and Hindun, as in preceding estimate, ...	17,00,000
Total for project, ..	35,65,684

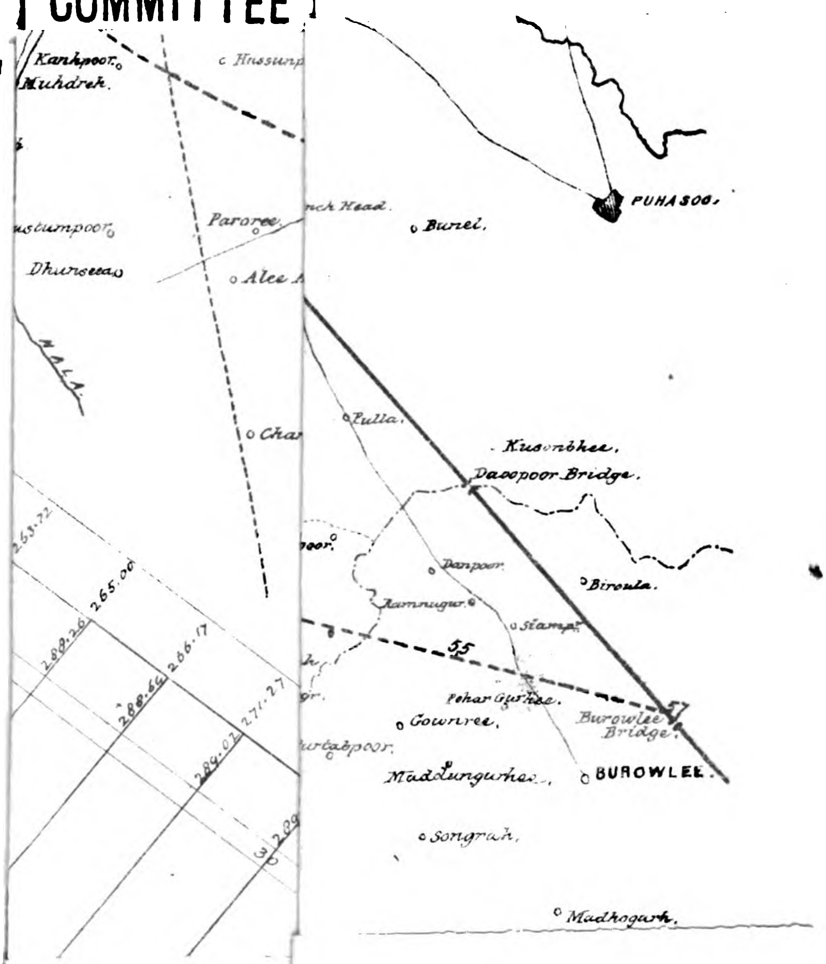
Digitized by Google



Digitized by Google

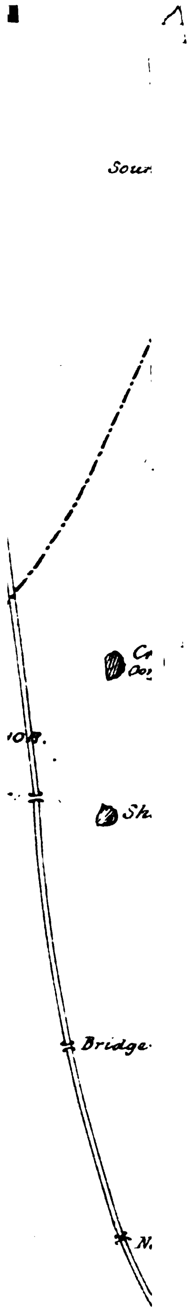
Digitized by Google

COMMITTEE



Digitized by Google

Digitized by Google



Digitized by Google