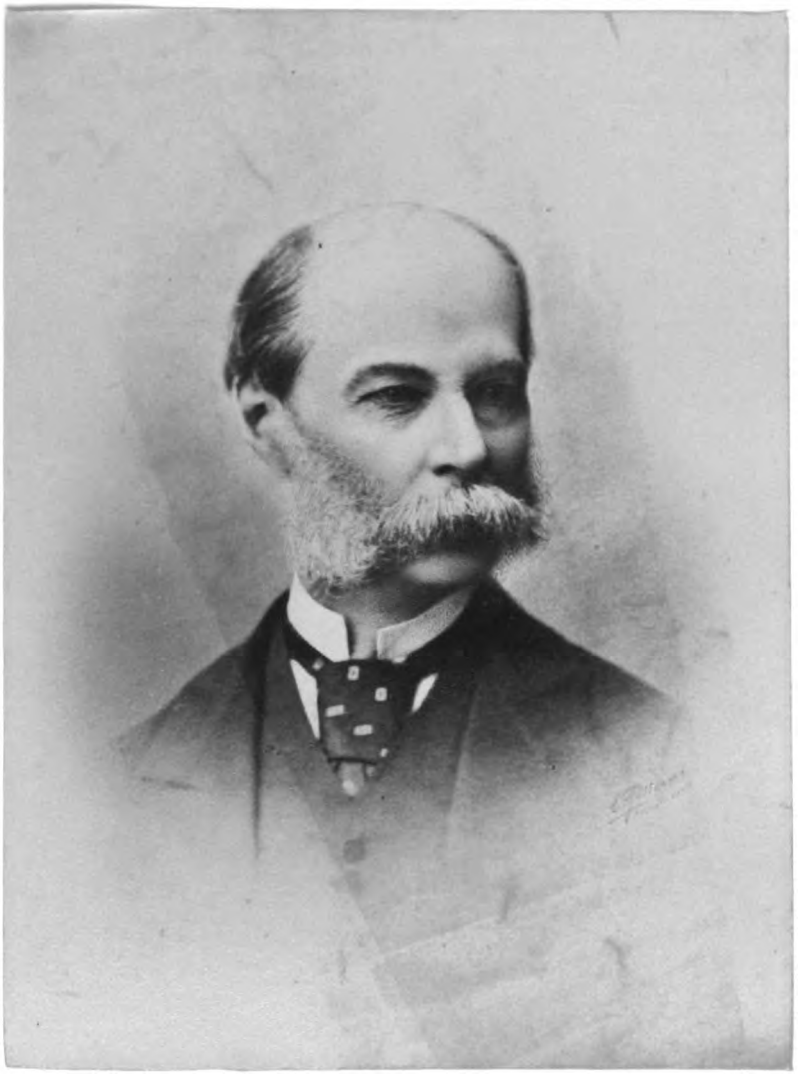
THE ENGINEERING WORKS

OF THE

KISTNA DELTA.

VOLUME I.



General CHARLES A. ORR, R.E.

From enlargement of a photograph taken by ELLIOT & FRY.

THE

ENGINEERING WORKS

OF THE

KISTNA DELTA:

A DESCRIPTIVE AND HISTORICAL ACCOUNT.

COMPILED FOR THE MADRAS GOVERNMENT

BY

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OF

THE KISTNA DELTA.

CHAPTER I.

THE KISTNA RIVER AND DISTRICT.

ALONG the western side of the Peninsula of India from the Valley of the Tapti to Cape Comorin, a distance of nearly 1,000 miles, rises the mountain range known as the 'Western Ghâts' roughly parallel to, and but a short distance from, the Arabian Sea.

Drainage basin of the Kistna River.

This great barrier is nowhere pierced by rivers, and all the country eastward of its summit levels, even though they are within sight of the West Coast, has to send its surplus waters to the Bay of Bengal. It thus comes that the drainage from 47,827 square miles of the Bombay Presidency, from the whole of the Nizám's Dominions and of the Mysore Territory, and from almost the whole of the Madras Presidency, besides that from upwards of 54,000 square miles of the Central Provinces and Berar,—a total area *in all* of about 338,100 square miles,—has to find its way into the sea along the eastern coast of the Madras Presidency.

This is effected chiefly by four great rivers—the Gódávari, Kistna, Pennér and Cauvery, the drainage areas of which are 115,000 square miles, 97,050 square miles, 20,000 square miles, and 26,266 square miles, respectively. This History has to treat of the Engineering Works, by which the delta of the second of these rivers has been converted from a poverty-stricken sparsely cultivated tract, subject to recurring droughts, into a prosperous country covered with cereal crops rendered virtually independent of the

precarious local rainfall by a network of canals and channels from the great river which formerly carried nearly all its wealth of waters uselessly to the sea.

Course of the Kistna.

The River KISTNA* ("*Krishna*") has its sources and those of its affluents spread along the eastern slope of the Western Ghâts over some six degrees of latitude, almost touching to the north the headwaters of the Gódávari, and to the south overlapping those of the Pennér and Cauvery. Of these sources the one which is the traditional fountain head of the Kistna issues from a spout fashioned into the image of a cow's mouth in an ancient temple of Mahádeo at the foot of a steep hill near the Bombay sanitarium of Mahábaleshwar, some 4,000 feet above sea-level. From this† "the Kistna runs southward in a rapid course, flowing through the British (Bombay) districts of Satára and Belgaum, the cluster of Native States which form the South Maráthá Agency, and the district of Kaládgi. There it turns east to pass into the dominions of the Nizám of Haiderábád. In this portion of its course it receives many tributaries, of which the chief are the Yerla, Warna, Idganga, Ghátprabha and Málprabha. All these, like the main stream, are characteristic rivers of the plateau of the Deccan. They run in deep channels, from which it is almost impossible to lead off channels for irrigation. In the rainy season they swell into brimming torrents, but during the remaining eight months of the year they shrink to mere threads of water, straggling through a sandy waste.

"On entering the Nizám's Dominions, the Kistna drops . . . to the 'alluvial *Doábs*' of Shorapúr and Raichúr. The fall is as much as 408 feet in about 3 miles . . . The first of the doábs mentioned above is formed by the confluence of the Bhima, which brings down the drainage of Ahmadnagar, Poona and Shorapúr; the second by the confluence of the Tungabhadra, which drains the north (and west) of Mysore, and the 'Ceded Districts' of Bellary and Karnúl (Kurnool). At the point of junction with the Tungabhadra the Kistna again strikes upon British Territory, and, still flowing east, forms for a considerable distance the boundary between the Madras Presidency and the Nizám's Dominions. There it is joined by its last important tributary, the Musi, on whose banks stands the Nizám's Capital of Haiderábád. On reaching the frontier chain of the Eastern Ghâts the Kistna turns south."

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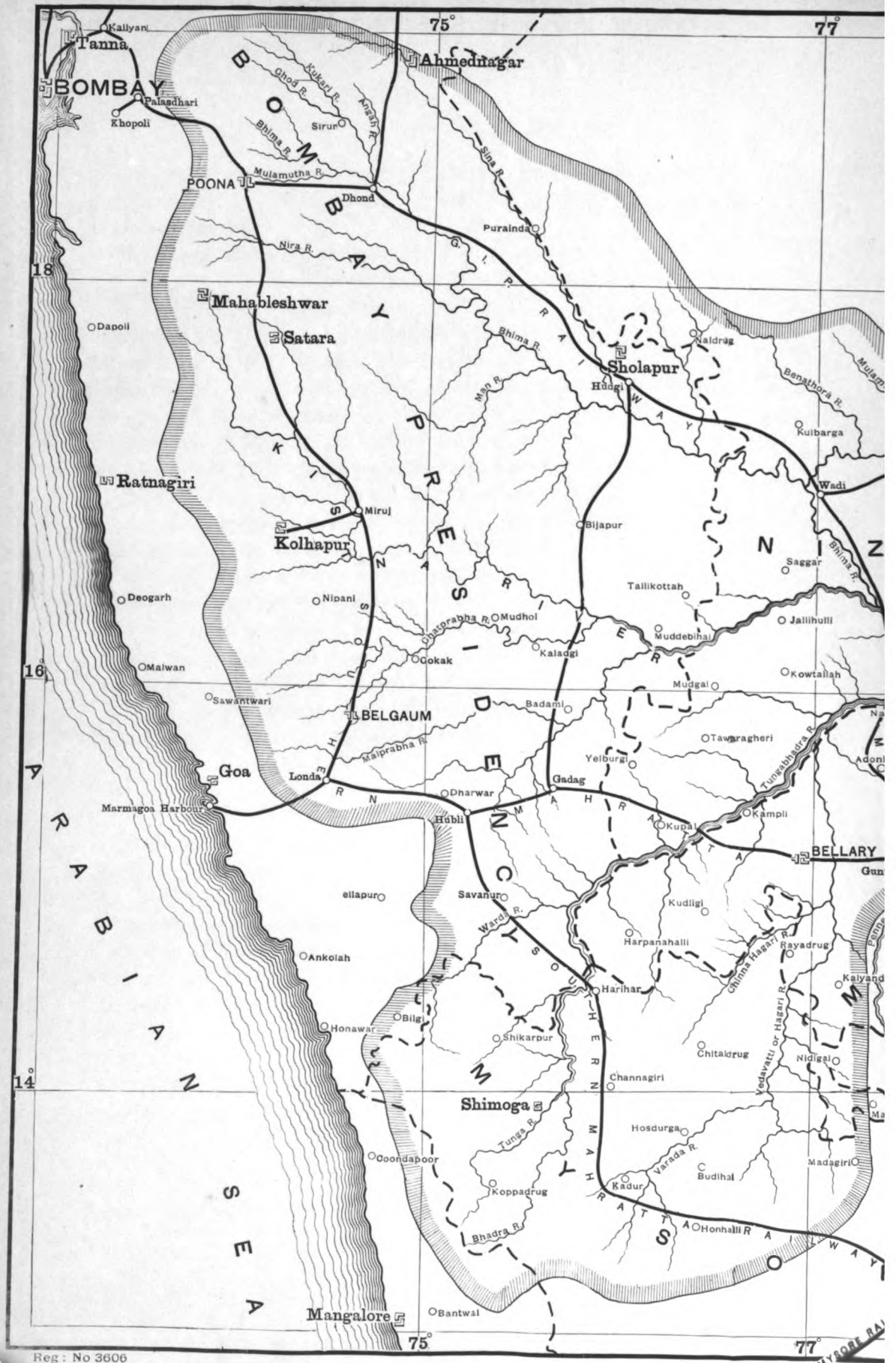
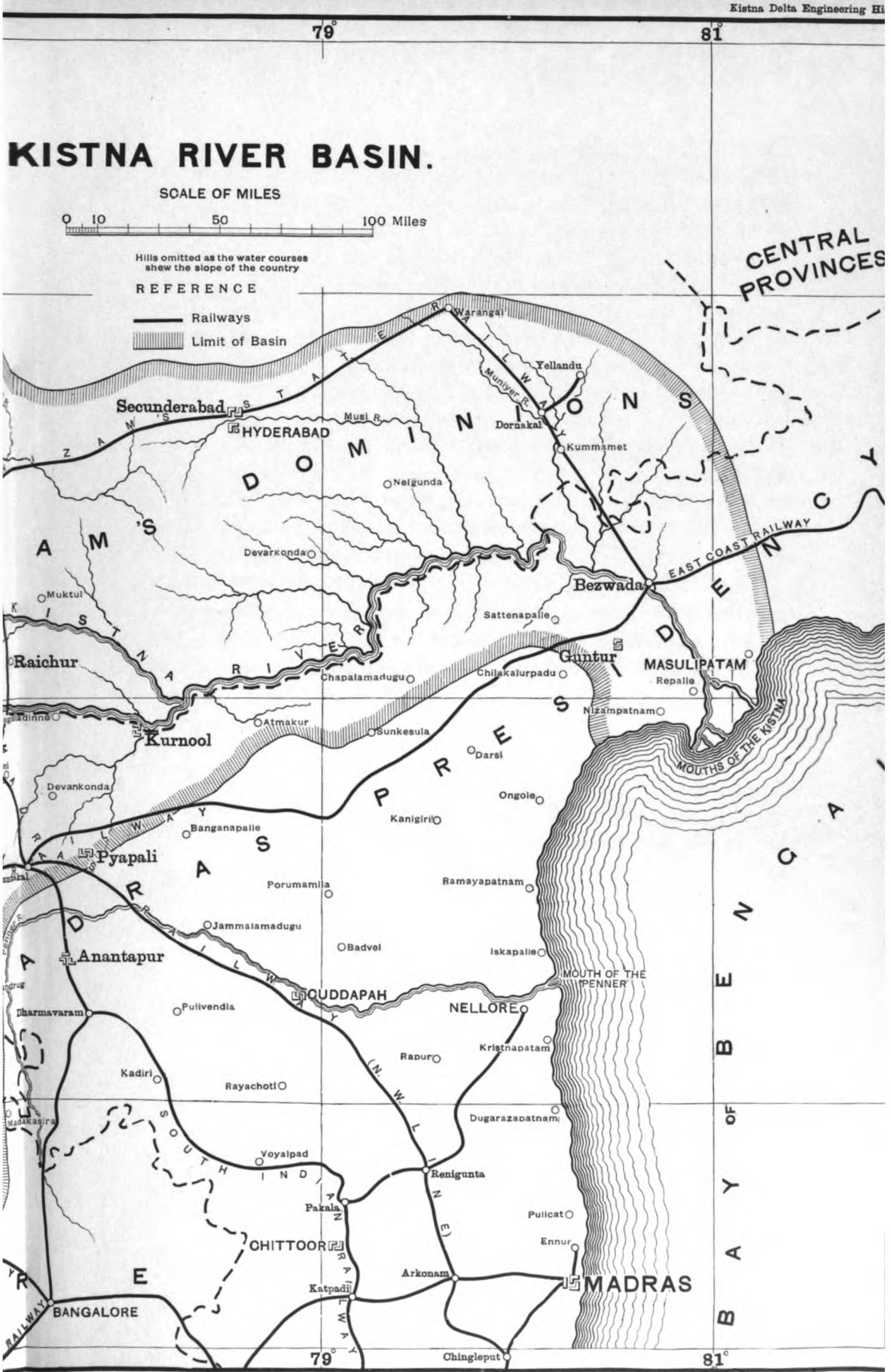
* "*Krishna*" is the correct transliteration of the vernacular, but "*Kistna*" having by long usage become the popular English spelling has been officially adopted.

† See Hunter's *Imperial Gazetteer of India*.





It then passes through a narrow gorge and enters the plains of the Coromandel Coast, but does not for another 35 miles or so get quite clear of outlying hills, till at Bezwada * it flows between two of them, which confront one another at a distance of only ¾ mile apart. Beyond this point stretching away on both sides of the river lies the alluvial plain it has formed, which bears the name of the "Kistna Delta." Through this the river continues in a single channel of great width for another 40 miles, when it sends off to the left a branch known as the "Puligadda" which forms the "Island of Divi," and after a course of 20 miles enters the sea at the "Point" of that name. The main stream continues for another 15 miles and then breaks up into three mouths, the 'Narsagunta Kistna,' 'Lankévanirichi Kistna' and 'Vénisagara Kistna,' separated from one another by two small islands covered for the greater part by dense mangrove jungles, and more or less submerged during spring tides and high floods, but having, nevertheless, some 2,000 inhabitants with a few hundred acres of precarious cultivation.

These mouths of the river lie in from 15° 45′ to 15° 49′ N. latitude, and between 80° 52′ and 81° E. longitude, about 200 miles north of Madras and only 60 miles south of the Vasista mouth of the Gódávari.

From its most distant source to the sea the Kistna is approximately 800 miles in length.

Flood discharge of the Kistna.

The drainage basin of the Kistna, like that of the Gódávari, lies chiefly under the influence of the South-west Monsoon rains, and it is therefore from June to October that it brings down by far the greater quantity of water, occasionally swelling into floods, in the highest of which as much as 770,000 cubic feet † a second sweep past Bezwada, a quantity 100 times as great as the maximum discharge of the Thames at Staines, and nearly twice as great as that of the Nile where it enters *its* delta. After October the water in the Kistna decreases rapidly till by the end of January or beginning of February it does not top the anicut if the head sluices are open, and during the following three months it dwindles to a petty stream meandering through a wide expanse of sand, its minimum discharge not exceeding 100 cubic feet per second.

Low water discharge of the Kistna.

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* This is the adopted spelling though Bezaváda would be more strictly correct. In old documents, and indeed in some comparatively recent ones, it appears under several fancy guises, *e.g.*, 'Bezoarah,' 'Baizwarah.'

† See Mullins' *Irrigation Manual*, article 15.

Diagrams of heights of water at Bezwada Anicut.

In the Atlas Volume will be found a diagram showing graphically the various stages of the river at Bezwada between 15th June and 1st December for a few average years, for some of exceptionally high floods, and for others of particularly low discharges, and another diagram showing the average depth of water on the anicut from 15th June to 15th December for 20 years, 1878 to 1897.

Kistna District and Delta.

The District which bears the name of the great river flowing through it is a portion of the "Northern Circars" acquired by the East India Company towards the end of last century. The 'district,' as it now exists, was formed in 1859 by the amalgamation of the two Collectorates of Guntúr and Masulipatam, a small portion of the latter being assigned to the Gódávari District. It is bounded on the north by the Kistna river, which there flows between it and the Nizám's Dominions; on the east by the Gódávari District and the sea; on the south by the sea and the Nellore District; and on the west by the Kurnool District. Its area is 8,470 square miles, of which about one quarter is known as the "Kistna Delta." This tract is divided by the river into two nearly equal parts, generally spoken of as the "Eastern" and "Western" deltas.

Eastern Section of the Delta.

The "EASTERN DELTA" has an area of 1,160 square miles; it stretches away eastward from the left bank of the Kistna for about 40 miles to the confines of the 'Western Section' of the Gódávari Delta, the navigable canals of the two systems being in communication at three places.

The Colair Lake.

Between the alluvial plains of the Kistna and the Gódávari there remains a depression unfilled by their deposits known as the Colair (or Koléru) Lake, covering when full an area of about 170 square miles including the several islands with which it is studded. Little silt-laden waters from the two great rivers now reach the lake, but upland streams draining some 1,600 square miles* fall into it. Its only outlet is the Upputéru (Salt-river), a deep tidal stream of some 20 miles in length which issues from the south-east corner of the lake. The Upputéru and an arbitrary line

* This is exclusive of the "Yerra Kalwa," a river draining some 850 square miles which used to flow into the lake from the Gódávari District, but is now partly canalized and has most of its flood waters diverted to the sea, only a small portion of them in very high floods reaching the Colair.

through the lake itself form the boundary between the lower portions of the Kistna and Gódávari Districts.

The natural main drainages of the "Eastern Delta" were—

Natural main drainages of the Eastern Delta.

First—The "Budaméru," which drains some 500 square miles of upland country. It rises about 35 miles north of Bezwada and runs as though it would fall into the Kistna at that place, but when within two miles of it the Bezwada hill interposes and the Budaméru after abrupt turns for a short distance, first to the north and then to the south, runs eastward for another 30 miles or so through the delta lands to the western corner of the Colair Lake.

In former days a cut was made from the Kistna to the Budaméru by which water was taken to it, when the freshes were sufficiently high, for irrigation along the lower portion of its course. That unsatisfactory arrangement has been entirely superseded and the Budaméru has been restored to its legitimate duty of simply carrying surplus waters to the Colair Lake. Even so it is the cause of frequent damage to the Ellore Canal, which had to be taken near it for some 5 miles at a level unsuited for efficient passing of flood waters under and across the canal.

Second—The "Pulléru"; this was doubtless once a spill channel of the Kistna, leaving the river near Bezwada and after a tortuous course of considerable length dividing into several channels, some flowing southwards to the tidal creeks near Masulipatam and others spreading eastwards through the extensive alluvial plains lying south of the Colair Lake and west of the Upputéru. These channels were made use of for irrigation, directly by means of dams across them, and indirectly by means of tanks which they fed when the Kistna was high enough to send considerable quantities of water into the Pulléru. The effect of so using these channels was, of course, to destroy, or at all events seriously interfere with, their effectiveness as drains.

The natural head of the Pulléru from the Kistna gradually closed, and in the interests of the irrigation which, as just explained, had grown up along it and its branches, recourse was had to artificial channels to lead water from the river at places which, from time to time, appeared the best. These channels having open heads were during high floods sources of great danger, not infrequently leading to disastrous inundation of the country they were intended to benefit. In 1837, therefore, the 'cut' or 'head' then in use, about 15 miles below Bezwada, was provided with a head sluice, of six vents 8 feet high by 4 feet wide, which did good service till the formation of a great sand bank in the river obstructed

the flow of water to it, and it was in its turn superseded by the vastly superior arrangements which came into force when the anicut was built. Many miles of the upper portion of the Pulléru were incorporated in the Masulipatam Canal, and considerable lengths of its branches have been converted into canals and irrigation distributaries, their places as drains being taken by new channels excavated specially for the purpose.

Masulipatam.

On the coast of this section of the delta, about halfway between the mouths of the Kistna and where the Upputéru joins the sea, is situated Masulipatam,* or "Bandar," one of the earliest and best known of the 'factories' of the East India Company, and a port formerly of considerable commercial and military importance. It is still the civil head-quarters of the district, with a population of upwards of 38,000, but the shoaling up of its bay by the Kistna silt has ruined it as a port, and its military value as the sea-gate of the Nizám's Dominions has disappeared since railways have brought them into easy communication with Madras and Bombay.

Storm-wave of 1st November 1864.

Masulipatam was on the night of the 1st November 1864 the scene of an appalling catastrophe, when a storm-wave swept over it and the adjacent country, drowning in a few moments upwards of 30,000 human beings and innumerable cattle.

Western Section of the Delta.

The "WESTERN DELTA," with an area of 950 square miles, lies to the right of the river, between it, the sea, and the higher lands of the Guntúr taluk. It is roughly triangular in shape, its base along the river being some 60 miles in length, whilst its apex, 70 miles from the head of the delta, but only 40 miles along the coast from the mouths of the river, is at Pedda Ganjám where the Commamúr Canal tails into the "Buckingham Canal" at its 196th mile from Madras.

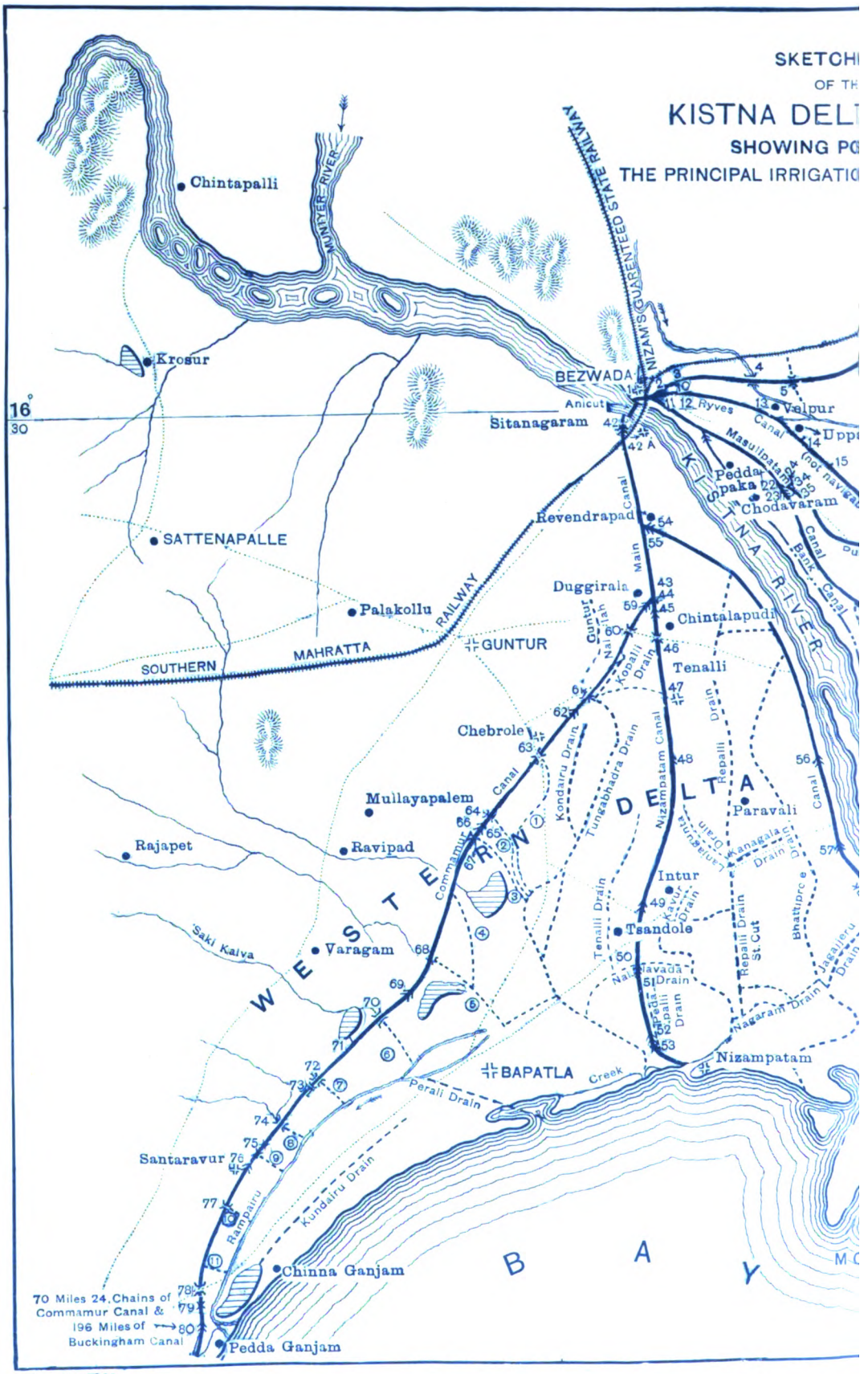
The natural main drainage lines of this section of the delta were—

Natural main drainages of the Western Delta.

First—The old river spill channel, known as the "Répalle drain," serving, with its affluents, the strip of the delta lying between the river and the Tungabhadra drain, and falling into the tidal creeks east of Nizampatam.

Second—"The Tungabhadra." This ran from near the Kistna at the back of the Sitanagaram hills through the heart of this section of the delta to the tidal creek west of Nizampatam. It received on its

* Correct transliteration of the Telugu name is "Machlipatnam."



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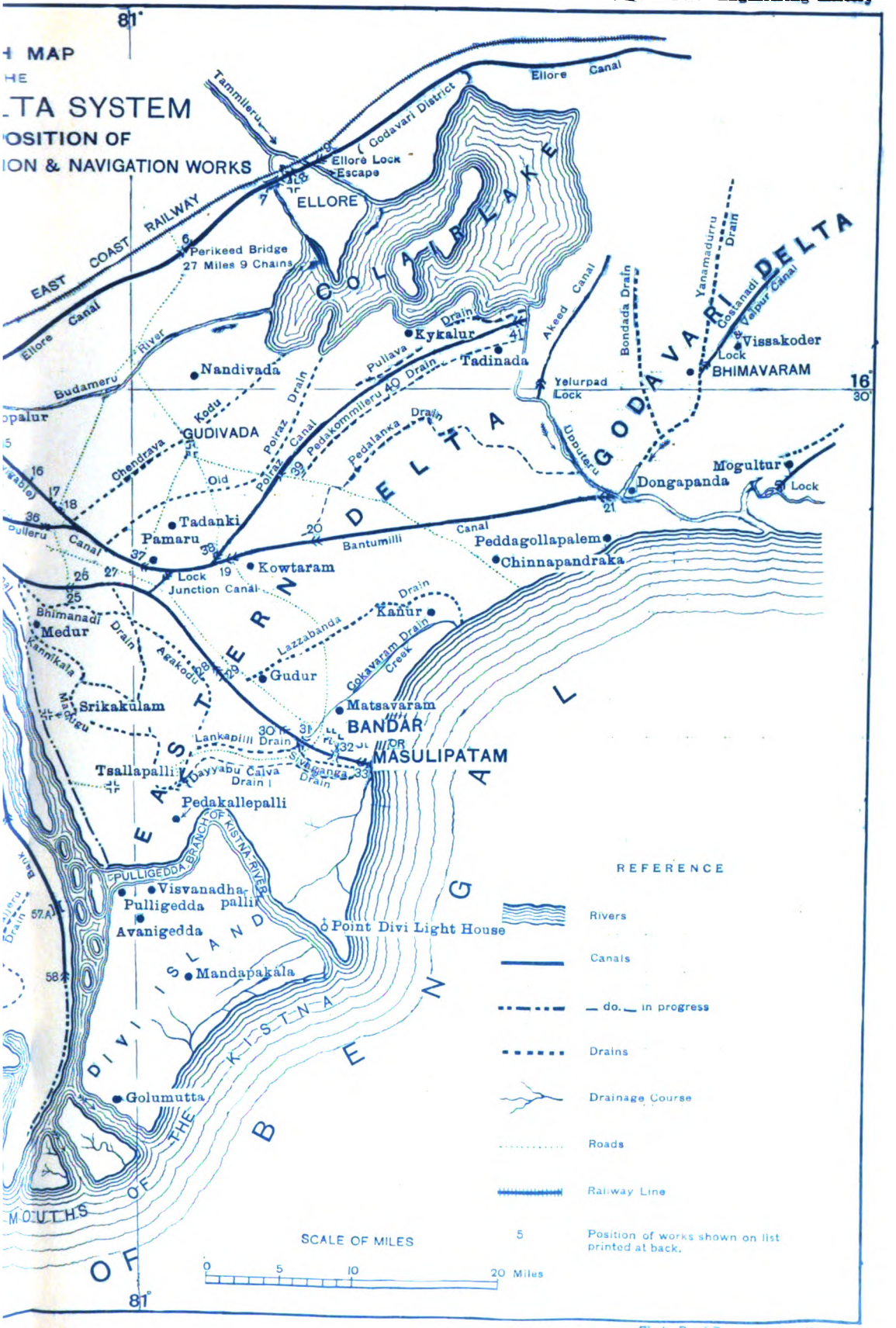

Photo-Print Survey Office, Madras
1897

PRINCIPAL MASONRY WORKS,

Positions of which are shown on the Sketch Map.

EASTERN SECTION.

No.	MAIN CANAL.	Delta Mileage. M.	CH.
1	Head Lock and Head Sluice ...	...	...
	ELLORE CANAL.		
2	Bridge at Head	...	45
3	Bridge (New)	1	5
4	Budamberu Aqueduct	7	50
5	Kesarapalli do.	10	70
6	Perikeed Bridge	27	9
7	West Tammileru Aqueduct ...	37	40
8	Girder Bridge	39	5
9	East Tammileru Outlet	40	20
	RYVES CANAL.		
10	Bridge at Head (formerly the Regulator)	...	51
11	Bridge of 3 Arches	1	28
12	New Regulator	1	51
13	Nidamanur Bridge	8	19
14	Uppalur Under Tunnel	11	65
15	Komatigunta Weir	14	21
16	Kunderu Bridge	17	51
17	Kadavakollu Bridge	19	49
18	Chendrayakodu Under Tunnel ...	20	68
	BANTUMILLI CANAL.		
19	Kowtaram Lock and Weir ...	39	29
20	Kamalapuram Lock and Weir ...	45	...
21	Tidal Lock and Weir (into Uppu-teru)	66	5

No.	MASULIPATAM CANAL.	Delta Mileage. M.	CH.
22	Kankipad Weir	12	48
23	Do. Lock	12	52
24	Do. Bridge	12	55
25	Veerankі Lock	24	42
26	Do. Weir ... ... } Do. Bridge ... ... }	24	45
27	Inampudi Under Tunnel	28	16
28	Nidumole Lock	37	...
29	Do. Weir ... ... } Do. Bridge ... ... }	37	24
30	Akamarru Lock and Weir ... } Do. Bridge ... ... }	43	8
31	Sultanagaram Under Tunnel ...	45	55
32	Chintaguntapalem Iron Girder Bridge	46	26
33	Tidal Lock	49	30
	PULLERU CANAL.		
34	Old Head Sluice	12	48
35	New do.	12	51
36	Witur Bridge	21	27
37	Pamuru Lock and Weir	33	...
	POLRAZ CANAL.		
38	Head Lock and Weir	39	27
39	Mudinepalle Bridge	46	27
40	Vinjiram Lock and Weir	54	73
41	Tadinada . do. (into Up-puteru)	64	71

WESTERN SECTION.

	MAIN CANAL.		
42	Sitanagaram Lock and Head Sluices	...	...
42-A	New (Auxiliary) Head Sluice ...	...	...
43	Old Escape at Duggirala	12	1
	NIZAMPATAM CANAL.		
44	Duggirala Weir	13	1
45	Do. Lock	13	2
46	Nandivellugu Bridge	14	51
47	Tenalli Bridge	18	47
48	Kuchipudi Lock	22	...
49	Intur do.	31	24
50	Nallavada Surplus Weir	35	33
51	Do. Lock	36	59
52	Surplus Weir at Tidal Lock ...	41	5
53	Tidal Lock	41	7
	BANK CANAL.		
54	Revendrapad Lock	7	58
55	Do. Weir	7	63
56	Kollur Lock and Weir	28	...
57	Vellatur Lock and Weir	33	54
57-A	Under Tunnel	41	30
58	Mortota Lock and Weir	45	44

	COMMAMUR CANAL.		
59	Commamur Lock	11	75
60	Kolakaluv Bridge	15	9
61	Guntur Nalla or Jagerlamudi Surplus Weir and 2 Under Tunnels	20	19
62	Jagerlamudi Lock and Weir ...	21	73
63	Chebrole Bridge	26	7
64	Kollimerla Aqueduct	31	42
65	Do. Lock and Weir ...	31	54
66	Pondrapad Surplus Calingulah.	33	61
67	Pondrapad Bridge	33	63
68	Nallamada Surplus Sluices ...	40	77
69	Do. Lock and Weir ...	43	36
70	Sakicalva Aqueduct	45	78
71	Parchuru-Vagu Surplus Sluices.	49	14
72	Karinchedu Aqueduct	51	45
73	Do. Bridge	52	6
74	Swarna Aqueduct	55	70
75	Allaru Surplus Sluices	58	63
76	Santaravur Lock	59	51
77	Inkollu Road Bridge	62	38
78	Coast Road Bridge	68	12
79	Uppukonduru Vagu Aqueduct ...	68	49
80	Pedda Ganjam Tidal Lock (Junc-tion with Buckingham Canal) ...	70	24

way the upland drainages known as the Guntúr-nalla, the Nakkavagu, and a branch of the Nallamada, carrying to the sea the flood waters from upwards of 1,100 square miles. It also used to receive near Sitanagaram spill water from the Kistna when in high flood. Between 1840 and 1847 a cut was made from the river just above the Sitanagaram hill to take water into the Tungabhadra, and from it irrigation channels were led off at various places, the principal being in the neighbourhood of Jagerlamudi to supplement the supply of the Bápatla, Commamúr, Nandur and other tanks. The dams across the stream for this purpose of course seriously interfered with its efficiency as a drain, and even to the present day there is one of these dams which holds up water for the irrigation of some 8,000 acres. This faulty arrangement will, however, soon be changed and the drain be free to perform its proper duties without obstruction. Nearly 13 miles of the Old Tungabhadra have been incorporated in the 'Main Canal' and a further 8 miles in the 'Commamúr Canal.'

Third—"The Rompéru." From Bápatla a continuous broad sand-ridge runs along the coast, and blocks the drainage of some 500 square miles, forcing it, when it has almost reached the sea, to flow for a considerable distance parallel to the coast till it finds an exit by the Chinna Ganjám creek which pierces the sand-ridge about 26 miles from Bápatla. The swamp thus formed along the back of the sand-ridge is known as the "*Rompéru*." During the rains this is a broad expanse of water which drains off but slowly.

Nizampatam.

On a tidal creek, about 15 miles west of the most southern mouth of the Kistna, is situated the town of Nizampatam where nearly 300 years ago the East India Company established a "factory," which for some time was looked on as a rival of Masulipatam, but soon faded into comparative insignificance. It is now visited only by small native craft and is of little importance except for its extensive Government salt "pans."

Sketch maps.

The accompanying sketch map, and the two larger ones at the end of Volume II, will, it is hoped, make this condensed description of the delta clear.

CHAPTER II.

THE KISTNA ANICUT AND HEAD-WORKS— PROPOSALS AND SANCTION.

MORE than a century ago the idea of utilizing the waters of the Kistna for extensive irrigation of its deltaic lands received considerable attention.

Major Beatson's letters.

In 1792 and 1793 a Major Beatson brought the matter to the notice of Government in letters from which the following is an extract :—

"This river Kistna is at no place so narrow within 130 miles of the sea as at Baizwarah, where the whole body of water is compressed between two mountains in a space not exceeding 1,100 yards, which at a small distance above and below expands over a surface of two miles and half, and which I should take to be nearly the mean breadth of the water of the Kistna all below Baizwarah.

"The mountains on either side of this strait appear to have been one continued chain until the river forced its way, and as they extend a few miles into the Guntúr Circar, and to the north join the hills about Nozeed, &c., it appears to me to be very practicable, if it were necessary, by means of a dam across this part of the river, entirely to turn its course into the Masulipatam or Guntúr Circars.

"Such a work, however, would require being raised to a very considerable height and to be of a proportional thickness ; and perhaps equal, if not greater, advantages might be obtained at a much less expense by raising the dam only to a certain height, in such a manner that a sufficiency of water for the purposes of agriculture might be diverted by means of aqueducts into these districts.

"The proper height necessary for such a dam to be raised can only be determined by a minute and accurate survey of the ground and a series of levels, in order to ascertain the difference of level between the bank of the river at Baizwarah and those parts of the Circars, to which it may be most eligible to have the water conveyed.

"And if it should be found (which I am inclined to hope may be the case), that the level of Baizwarah is even twelve feet higher than the level of the country at Ellore, the advantages from the proposed dam across the Kistna would be immense, as the whole country between Baizwarah and Ellore, and considerably to the eastward of this line might be watered at all seasons from the aqueduct.

"Similar advantages might be derived by conveying water into the Guntúr Circar by which a greater portion of the eastern part, which is very low, might be appropriated to the cultivation of rice.

"I have already remarked that by means of the aqueduct the adjacent fields might be watered at all seasons. This appears to me very practicable, as there is always a considerable stream of water in the Kistna; sufficient, I will venture to say, to replace the loss by evaporation from the water that would be retained by the dam, as well as to afford a sufficient supply for the aqueducts throughout the year, from which evidently very great advantages would arise in the culture of rice, because those parts contiguous to the aqueduct might be made to yield two or more crops a year as in the Tanjore and other well-watered countries; and I might add that all these advantages of water will be found of very material use in the cultivation of several important articles of commerce, such as sugar, indigo and others which it is unnecessary to specify.

"It is needless further to remark upon the advantages to be derived from the proposed dam. I will, therefore, finally add that it is my opinion it may be considered as the grand repository of water for the Masulipatam and Guntúr Circars placed in a most eligible situation, and receiving the benefits of both the Malabar and Coromandel monsoons.

"A dam to resist such a body of water and such a torrent as that of the Kistna must be constructed entirely of stone. Works of this nature I have seen at Seringapatam, where there are three dams across the Cauvery within the space of fifteen miles, which have been formed for the purpose of watering a very inconsiderable strip of paddy fields on each side of the river: perhaps two-thirds of the labour required in forming these dams from which, comparatively, so little benefit is derived, would produce all the advantages I have stated, and effectually prevent in future those melancholy consequences which have always attended a failure of rain in the Circars.

"But as to the probable expense of such a work it is impossible to form any judgment without a minute examination of this part of the river, and a thorough consideration of all the various circumstances connected with such an undertaking. I will, therefore, only observe that in my humble opinion the expense cannot be put in competition with the great advantages which would accrue from the accomplishment of such a work."

Mr. Topping's letters.

The Government referred the matter for investigation and report to its "Astronomer," Mr. Michael Topping, who * "was employed for nearly three years in a survey of the localities, and assisted by Captain Caldwell of the Engineers had minutely

* From letter, 25th August 1836, from the Inspector-General of Civil Estimates, to the Chief Secretary to Government.

surveyed and levelled the Kistna from Masulipatam to Incotallah, a distance of nearly 110 miles, as well as the country between the Kistna and the Godavery by Ellore and down the Godavery from Talapoody to Coringa, when the completion of the work was retarded by the want of proper instruments and the death of Mr. Topping" at Masulipatam in 1796. Between 1793 and 1795 Mr. Topping addressed three letters to Government on the subject, all of which are of such interest that extracts are given from them.

To

The Hon'ble Sir CHARLES OAKLEY, *Bart.*,
Governor and President in Council, Fort St. George.

HON'BLE SIR,

"I have duly received Mr. Secretary Clerk's letters of the 5th December and 19th January last, together with their enclosures; and, as I have formerly seen both the Guntúr and Masulipatam Circars, confess myself inclined to believe that the proposed object of "appropriating the waters of "the Godavery and Kistna to the purposes of cultivation" is by no means an impracticable one.

"Since receiving the Hon'ble Board's commands, and the letters to Government of Captain Beatson, I have visited the Tanjore anicut, and the banks of the Cauvery contiguous to it; which river, by a judicious management of its waters, and the adjacent slope of the Coleroon, is a well-known source of fertility in the Rajah's dominions. This happy object is, I find, effected by taking advantage of a situation where the two rivers have nearly a parallel direction to each other; and where their distance asunder is not great. At this critical place the Cauvery (the bed of which is considerably higher than that of the Coleroon, and above the level of the Tanjore country in general) is confined to its channel by an artificial mound of earth, called an anicut; in the centre of which a sluice of solid masonry is built for the purpose of discharging the superfluous water, and preventing its inundating the country south of it; while a sufficient quantity is, by the same means, retained for the purposes of cultivation.

"I have little doubt but that situations may be found in the Circars favourable to a similar management of one or both rivers; for the northern rivers are much larger than the Cauvery; and branched, or capable of being branched, into similar divisions, from the general flatness of the country through which they flow: should this, however, not be *exactly* the case, some other disposition of them might probably be contrived that would equally answer the great and humane purposes of Government—prevent future misery to the inhabitants, and loss to the revenues of the Honourable Company.

"But, in order to enable me to form a more correct judgment on this important question, it will be necessary to examine with attention the rivers Godavery and Kistna, and their adjacent territory; and this service I shall enter upon with an anxious zeal for its success, as soon as I am honoured with the commands of Government for commencing it.

I am, Hon'ble Sir,

With great respect,

Your most faithful and obedient servant,

MICHAEL TOPPING."

MADRAS,
3rd March 1793.

Extracts from a letter, dated 14th February 1794, *from Mr. Michael Topping, to the Hon'ble Sir C. Oakley, Bart., President in Council, Fort St. George.*

* * * *

"These rivers Kistna and Godavery, although they contain but little water in the cool season, are well known to swell annually with the periodical rains that fall between the months of June and November on the western side of India and to flow through the Company's district in a copious stream, even at seasons when the countries through which they pass are parched up with drought, and desolated with famine: could therefore their waters, by artificial means, be diverted through the adjacent country, the advantage would be great to the inhabitants and to the Company; indeed of far more important benefit to cultivation, than the method, necessity has taught the natives of these more southern districts to adopt, of the formation of separate tanks, or reservoirs; which, depending entirely on the immediate rain of the monsoon for their supply, when that is scanty are deficient of course; whereas the copious streams furnished by these never-failing torrents which at present run in waste to the sea, would be even more than an ample supply during the driest and most deficient season for rain.

"3. The question therefore proposed to my consideration being, whether the waters of the Kistna or Godavery could be brought to overflow and fertilize the adjacent country, my first object has been to examine the former of these rivers, and by an accurate survey to determine, with the most scrupulous exactness, the relative height of its waters at stated places, both when the river is full and rapid, and when at its lowest ebb, and I resolved, for various reasons, to commence these operations at Baizwarah, and to continue them upward, in the hope of finding a sufficient rise for the formation of an artificial canal that, in the course of a few miles digging, might bring the waters gradually upon the surface of the adjacent country.

* * * *

"7. Where the slope of a river is considerable, and the country adjacent to it in other respects favourable to the formation of an artificial canal, its waters may, by this method, be brought in the most natural manner to overflow the cultivated lands: when, however, the slope of a river is scanty and inconsiderable, and its waters lie deep beneath its banks (as appears to be the case with the Kistna), it will require a great length of artificial canal to be cut before this purpose can be effected, unless the waters of the river be kept up by strong dams, thrown across it in places judiciously chosen for such purposes."

"8. It is certainly a very desirable thing to avoid the expense and trouble of constructing dams, which though to be seen for like purposes on several parts of the Cauvery, would not be easily made across so large and deep a river as the Kistna. Whether or no they can be dispensed with, it is not in my power at present to decide. I shall, however, in the course of next season, by a continuation of my series of levels, spare no pains to determine this question, which is of the utmost importance to the object before us." * * * *

Extracts from a letter, dated Masulipatam 9th September 1795, *from Mr. Topping, to the Right Hon'ble Lord Hobart, Governor of Fort St. George.*

"I have the honour to transmit to Government a chart of the lower division of the Kistna; and a chart, exhibiting a series of levels from the sea-gate at Masulipatam to the permanent term at Bezoara. This work completes the Kistna, from its several entrances to beyond *Muctalah*—a distance of near one hundred and ten miles from the sea; and furnishes an accurate determination of the levels of the adjacent territory to that farthest inland point. * * * *

"I shall now state a few particulars in explanation of the work before us.

"The accompanying series of levels has been carried on independently of the survey of the Kistna; and for a very obvious reason—that of obtaining greater accuracy in it, by shortening the distance between its extreme terms. The first term of this process is a fixed stone forming the cill or threshold of the sea-gate of the Fort of Masulipatam. The last is that of the permanent term at Bezoara, established by myself last year, as a terminating point of my former series from *Muctalah* to that place. The whole of this distance has been measured with the chain; and the levels (as became peculiarly necessary in so long a series) have been taken with a painful attention to accuracy, and the preventing of errors. * * * *

"As to the result of this second series of levels, it will appear (by the chart) that the permanent term on Bezoara green is above that at the sea-gate of Masulipatam ft. 59-4·6 in a distance of about 44½ miles. But the top

of the stone at Bezoara was 14 feet above the surface of the water in the Kistna on the day the series was concluded (14th August 1794) and the lower, or sea-gate term is five feet above low-water mark at Masulipatam. The height of the water in the Kistna, on that day at Bezoara above the level of low-water at Masulipatam will therefore be easily determined thus:

$\frac{59{\cdot}5 \text{ ft.} - 14 \text{ ft.} + 5 \text{ ft.}}{44\frac{1}{2}} = 13\frac{1}{2}$ inches = the average slope or fall *per mile* of the surface of the water in the Kistna on that day, between Bezoara and Masulipatam. This is much the same as was found (by the former series) to have place between Muctalah and Bezoara.

"I am now under the necessity of acquainting Government with a circumstance that is likely to retard this, and every other similar operation in this country, whatever may be its magnitude or importance. This, my Lord, is a want of proper instruments for the indispensable process (where water is concerned) of taking levels. We have, hitherto, been in possession of *two* levelling instruments only; one of which was lent me (upon application to the late Governor-General, the Right Honourable Marquis Cornwallis) by Colonel Cameron of the Bengal establishment. The Colonel has, however, sent for his instrument, so that we have now no reliance but on receiving from Europe those I applied for by indent bearing date 26th February 1793, very soon after the surveys were ordered to be undertaken."

On this last letter was passed the following order of Government:—

"Ordered that the plan and survey mentioned by Mr. Topping, together with copy of his letter, be forwarded to the Honourable the Court of Directors by the present despatch."

And there the matter ended, as far as can be traced, for nearly half a century.

Great famine of 1832-33.

In 1832–33 a terrible famine devastated a great part of the Madras Presidency. Through the very heart of the area where the distress was greatest and human beings were dying by hundreds of thousands, because their crops had failed from drought, the Kistna was rolling down enormous quantities of water to the sea.

In the Guntûr District, lying on the right side of the river, part of which is now known as the "Western Delta," "not* less than 200,000" persons perished "by starvation and by the fever which followed the

* Paragraph 290 of "First Report of Madras Public Works Commission."

famine," whilst on the other side of the river in what is now known as the "Eastern Delta," an officer * wrote thus:—

"The Europeans throughout the country have subscribed liberally to feed as many of the poor starving wretches as possible, and by this means ten thousand are daily fed in Masulipatam alone. But ten times that number are still famishing and hundreds die daily, literally of starvation. The swamp around the fort is found each morning strewed with the bodies of those who have died during the night; and although a strong body of police are constantly employed in collecting the dead and throwing them into a huge pit prepared for the purpose, they cannot succeed in keeping the ground clear, and numbers of bodies are left to be devoured by dogs and vultures.

"The description in the 'Siege of Corinth' of the dogs gnawing human skulls is mild compared to the scenes of horror we are daily forced to witness in our morning and evening rides"; he adds some further and even more gruesome details.

Suggestions for channels from the Kistna.

This fearful year was followed by several unfavourable ones, and the effects on the "Northern Circars" compelled attention to all possible means of lessening the unmitigated dependance of all their crops on the capricious local rainfall. Accordingly, from time to time during the next few years various suggestions were made, and in some instances carried out, for channels from the main rivers to irrigate small areas of land, till at last, as regards the Kistna District, we find in 1839 the recommendations of Major Beatson and Mr. Topping, made 44 years previously, again brought to notice in a report from Captain Buckle, "Civil Engineer, Second Division," from which the following are extracts:—

Captain Buckle's reports.

"8. There are two principles on which channels may be led from the Kistnah, and which have remained disregarded on record for nearly half a century: the one pointed out by General Beatson, of throwing an annicut across the river, so as to connect the Seetanagarum with the Baizwarah hill, and thus dam up the water to a level which should command the whole of the country on both sides of the river, over which it might be distributed with ease by a well arranged series of channels. To this plan, the only objection is expense; the work would be a stupendous one; still it is one which would, beyond all doubt, repay its cost, provided only that Government

* Lieutenant W. Campbell, Her Majesty's 62nd Regiment; see "Mackenzie's *Manual of the Kistna District.*"

could ensure a proper administration of the revenue details which should accompany it.

"9. To accomplish a dam 1,300 yards long and seven yards high, including the foundation, ought not to defy the executive powers of the country, where the material also is all found at hand, and where it might speedily be prepared for the work by the most ordinary blasting processes, nor would it be difficult to submit a project and estimate for the object based on practical data; but unless it can be shown that Government would reap any benefit from the work, either directly or indirectly, it would be a mere waste of time to enter on a discussion of the plan of operations to be pursued.

* * * *

"40. The whole sweep of the Kistnah, as it traverses the boundary of the district, measures about 230 miles, but the breadth of the district taken from where the river enters Palnaud across to the sea, near Baupetlah, is only 90 miles: consequently as has been noticed by Mr. Topping, there is a most favorable fall of the country in that direction, but all advantages from this source appear to be cut off by the ranges of hills bordering the Kistnah. Judging from the delineations of which in the surveys, and from the course of all the nullahs in Palnaud, as well as from inspections made in that part of the country, there seems but little probability of its being possible to draw a supply from the Kistnah on the west side of the district. The whole Palnaud may be said to fall towards the Kistnah, so that of course the east boundary which divides it from Guntoor is very high. The Kistnah, in fact, flows along a valley receiving the drainage of the Hyderabad country on the one side, and of Palnaud on the other. The only place of the slightest promise for a cut from the river which I could discern, was towards Mucktalah, and even there all the land near it proved to be very high, as well as being hilly and stony. But the difficulties connected with the river do not cease even here, for in addition to its running along a hollow, its own bed is very deep, in some parts sixty feet, and even eighty feet below the lip of its banks: consequently to keep the river full in this part of its course would demand an annicut of prodigious dimensions, and if we suppose such a work to be constructed, still but little benefit would be derived from it, because as the country rises from the river, the water would not even then be high enough to irrigate it, and the only effect of such an annicut would be to force back the nullahs which fall into the river, and cause them to overflow in parts: in fact, nothing but danger would accrue from such a measure. This hypothetical annicut, indeed, either in or near Palnaud, would be impracticable, the risk that would accompany its execution having no probable advantages to justify the attempt. Having therefore seen that it would be impossible to convey a channel inland from the river, owing to the elevation of the country bordering it, it would also prove extremely difficult to conduct a channel parallel with the river, because

there would still be the same necessity for an annicut; while the channel, in its course, would be interrupted by all the water courses falling into the Kistnah, as well as by the high ridges between them: nor are there any places on the banks adapted for irrigation until the Kistnah approaches Baizwarah.

"41. There is nothing, therefore, to invite such an undertaking, though it is not unlikely that a channel, on a reduced scale, might be opened with good effect from a little below Amarawutty, keeping it, for some distance in the river, attached to the bank, as is not uncommonly done in this country.

"42. At Chintapully, I may observe, which is about 35 miles above Baizwarah, or 100 miles from the sea, there is a remarkable contraction in the passage of the Kistnah, its width decreasing suddenly to about 300 yards; but as might be expected, it is proportionately deep; even in the dry season the water stands there from fifty to sixty feet deep in some spots, while during the freshes the depth is from thirty to forty feet more; so that, however favorable the breadth might appear, such a site as this could hardly be contemplated for an annicut, even were the nature of the country such as could be traversed by a channel. In short, the conclusion at which I reluctantly arrive, as regards the Guntoor side of the Kistnah, is precisely the same as that formed by Major Beatson, in regard to the north bank, namely, that from the whole upper course of the river, until it arrives within 10 or 15 miles of Baizwarah, it would be impracticable to lead off a channel; the reason being the same in both cases, high banks to the river, increasing in elevation as they recede from it, and the succession of ridges and vallies through which the path of the river lies.

"52. The undertaking, however, which would benefit the country in the most extensive and permanent manner would be an annicut at Baizwarah, which would at once supply both sides of the river with water for irrigation, and thus for ever remove the prospect of famine, for want of the means of raising paddy; for so long as the courses of the seasons endure, the quantity of water which, even in the most unfavorable years, flows past between the Baizwarah and Seetanagaram hills, would suffice for the cultivation of very many square miles."

Captain Buckle's reports.

This report Captain Buckle seems to have supplemented by another with various suggestions for opening channels from the Kistna by which, when the river was high, water would flow to existing drainages and depressions in the delta, thus affording rough means of irrigation. No copy of this second report can however be found. Captain Buckle's two reports were in January 1840 sent to Government by the Board of Revenue with a letter

Letter of Revenue Board to Government.

which deals chiefly with the minor means of irrigation referred to, but has also the following paragraphs bearing on the suggestion for an Anicut at Bezwada :—

Extracts from letter No. 45, dated 30th January 1840, from the Board of Revenue to Government.

"22. The undertaking, however, of all others which would most extensively and permanently benefit the country and people would be an anicut across the Kistna at Baizwarah. This would at once secure an abundant and never failing supply of water for the whole country between the Kistna and Gódávari as well as on the south bank of the former river as far as the sea, and remove all apprehension of famine in future ; for even in the most unfavourable seasons, the quantity of water that flows past Baizwarah is ample for that purpose, if the means for raising it to the required height, and distributing it over the fields existed.

"23. The width of the Kistna at Baizwarah is, by a contraction of its bed at that spot, reduced to 1,300 yards, and the height to which it appears it would be necessary to raise the anicut is only 7 yards including its foundations, the expense, however, of such a work would be very great, and its construction attended with vast labour and many difficulties, but there seems nothing to render success in the least degree questionable, if the requisite means are available. There is no obstacle either in the character of the river or nature of the locality, which might not be readily overcome by skill and science, and the expense, it is probable, would not be so very large as at first may appear, for there is abundance of materials procurable from the adjoining hills, and labour is reasonable. The expediency would appear to be equally unquestionable if the country to be benefited by it were under the management of the Government, and the undertaking in all its branches, including the requisite revenue arrangements, could be carried out and matured by its officers.

"24. But as long as the permanent system on its present footing exists, and the zamindars or landholders continue to be, as they now are, an insurmountable impediment to any extended and general system of improvement, the benefits from such a work would be far from commensurate with its cost.

* * * *

"28. There are two ways in which the Masulipatam district may be irrigated from the Kistna, either by an anicut thrown across the river at Baizwarah, or by water-courses led off from it without the aid of an anicut. The first of these is the only effectual and complete mode of attaining this very important object, and by its adoption, Masulipatam might, like Tanjore, be converted into a garden to serve as a granary to the adjoining country

in seasons of scarcity, but from causes already explained, it is at present impracticable, and need not therefore be discussed."

And then in paragraph 39 of the letter, the disappointing conclusion is arrived at that "very large and costly works like an Anicut at Baizwarah are clearly inexpedient and impracticable under existing circumstances."

That seemed as if it would be the end of the matter for many a long year at all events, but fortunately in 1844 Major (now General Sir Arthur) Cotton, to whom Tanjore owed the construction of the Coleroon Anicuts which had done such wonders for that district, was sent to report on the feasibility of putting an Anicut across the Gódávari; he so enthusiastically recommended the execution of the work that attention was once again forcibly directed to the advisability of a similar work across the Kistna, and the matter was in 1845 referred for consideration to the "Civil Engineer, Second Division," Captain Lake, who ten years later, so distinguished himself in the defence of Kars, and became Sir H. Atwell Lake, K.C.B.

Sir Arthur Cotton advocates construction of Anicut across the Gódávari.

He sent in his report on 3rd July 1847. It commences with references to what had been written on the subject before, and then deals at length with the questions of "site, nature and expenses of the structure and the benefit to be derived from it." The more important paragraphs of the report bearing on these points are given below:—

Captain Lake's Report.

"11. In searching for a site for the work, the place that most naturally presents itself is opposite to Baizwarah, where the river narrows to between 1,000 and 1,100 yards, and where there are two large hills, one on either side and close to the river's bank. I have ascertained from the levels that I have taken, that a moderately high annicut here would command the whole of the Delta land of both the Guntoor and Masulipatam districts, and there can be no doubt that the many natural facilities for the construction of the work, which present themselves at this spot, render it, in every respect, the most desirable site.

"12. I shall proceed to show, how very inexpedient it would be to attempt placing the work higher up the river, with a view to bringing a more extensive tract of land under its influence. The river immediately above Baizwarah begins to widen very considerably, and at Ebramapatam, for instance, which is only about eight miles higher up, the width is nearly 3,000 yards. It will thus be seen, that a work placed here would be nearly three times the length of one at Baizwarah; but there are other and greater

SECTION

FROM SEETANAGRUM HIL

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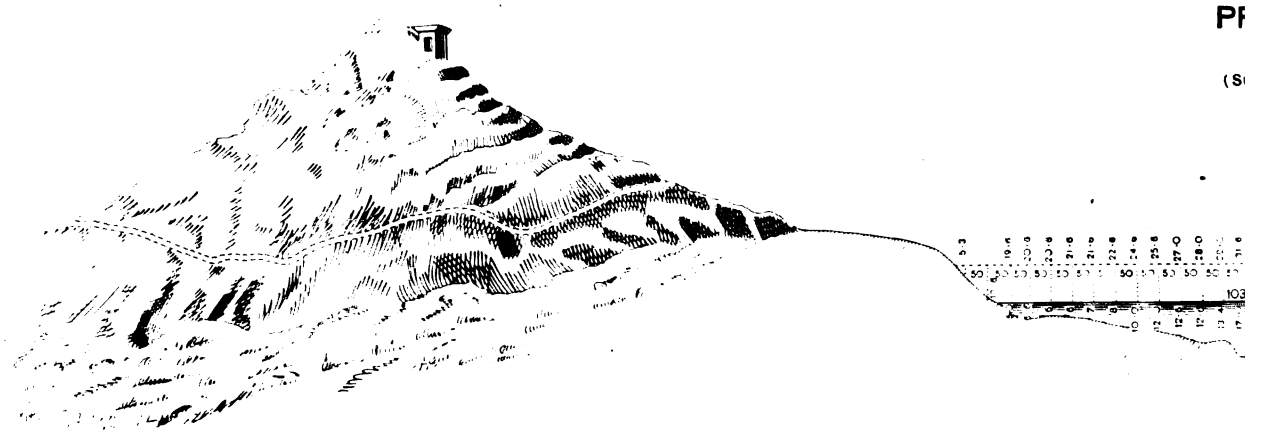
SEETANAGRUM HILL



SEETANAGRUM HILL

LO

a Lock
b Head Sluice of the Main channel

Reg. No. 3756
Copies 410

N THROUGH THE **RIVER KISTNA**

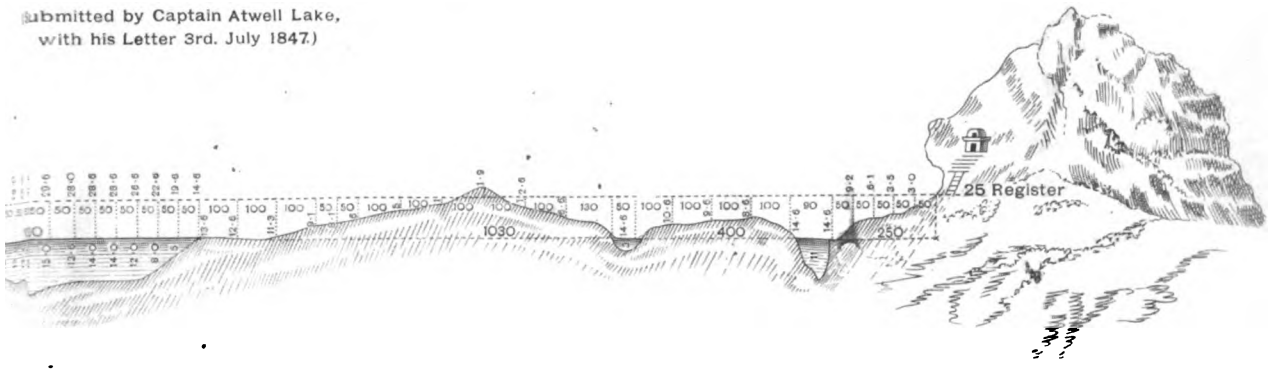
L IN A DIRECTION N. 7° E TOWARDS BAIZWARAH

SHOWING THE SITE OF THE

PROPOSED ANICUT.

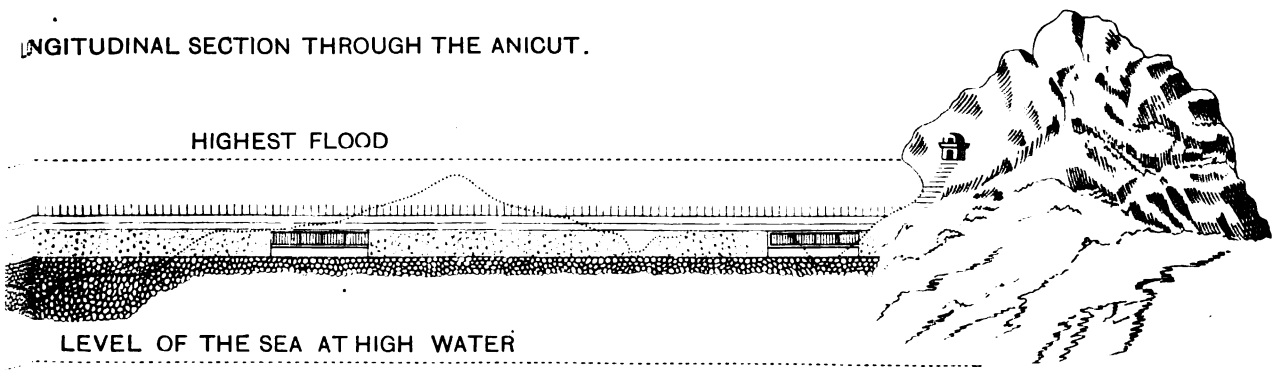
(Submitted by Captain Atwell Lake, with his Letter 3rd. July 1847.)

BAIZWARAH HILL



BAIZWARAH HILL

LONGITUDINAL SECTION THROUGH THE ANICUT.



Scale to distances

0 50 100 500 900

Scale to heights

0 50 100

(From Vol. IV Profl. papers Madras Engineers.)

(Signed) Atwell Lake, Captain, Civil Engineer, 2nd Division

Photo-Print Survey. Office Madras 1897

objections to the measure. In the map, marked No. 1, which accompanies this report, the parts coloured light green show the extent of land not more than 40 or 50 feet above the level of the sea, and which may be all brought under the influence of an annicut at Baizwarah. Above this boundary, as I before stated, the country raises 10 or more feet in a mile; and to include, therefore, an extra belt of land only one mile in width, or an area of about 100 square miles, to be irrigated by means of an annicut, the work would have to be placed about 13½ miles higher up the river, taking the fall of the surface of the river above Baizwarah at about 13 inches per mile, and allowing the channels a fall of three inches per mile.

"13. Owing to the country above the parallel of Baizwarah rising so rapidly, it is evident that, if the annicut be placed higher up, the channels must be formed by deep cuttings, parallel, or nearly so, to the course of the river, almost as far as the Baizwarah hill, and the expense of this, as will be seen by the following calculation, would be enormous. Supposing that the channel has a fall of three inches per mile, and that the quantity of water required for each acre be taken at 1½ cubic yards per hour (or deducting ¼ for waste land, 750 cubic yards for every square mile)—now, the mean velocity of water at four yards depth, with the fall above given, being about 1,400 yards per hour, the required section would be 1,600 square yards, which, with a depth of four yards, would give a breadth of 400 yards. With this breadth and, we will say, a depth of three yards of cutting, there would be an excavation of 2,100,000 cubic yards (in round numbers) which, at eight pice per cubic yard, would cost about 86,000 rupees per mile; and this is supposing you meet with nothing but plain cutting through alluvial soil.

"14. Taking also into consideration that an annicut higher up than Baizwarah would, from the great increase in the length of the work, as well as the extra expense that would be incurred by building it at a spot where there are not so many advantages with respect to the preparation of materials, natural wing walls, &c., cost nearly double the amount, I do not suppose that a doubt can exist as to this being the most favorable site: but, as it may possibly be urged that a dam might be placed very much higher up, so as to command the Palnaud in the Guntoor district, I shall briefly consider this point.

* * * *

"16. I may observe, that I have not only visited and carefully inspected the several sites above alluded to (with the exception of Muctalah, where I considered it quite unnecessary to go), but that I have had sections of the river taken in several places above Baizwarah, as well as lines of levels, where required, additional to those which I found in my office; and, after mature deliberation, I am decidedly of opinion that it would be by no means expedient to recommend the construction of an annicut any where but on

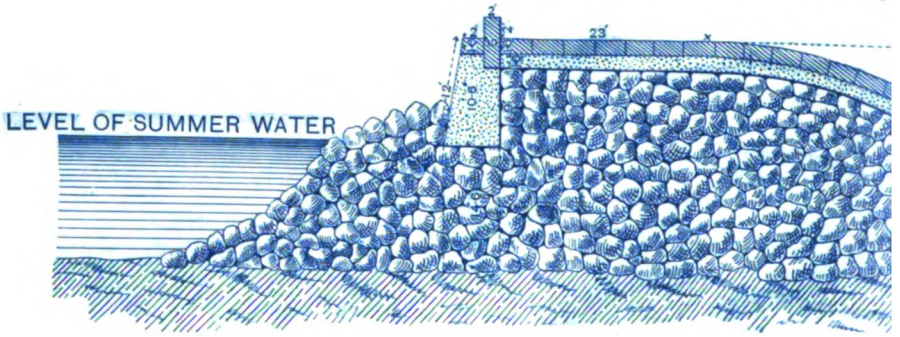
the site I have fixed upon. It appears to me, and will, I imagine, appear to all who consider the subject in connexion with the investigation I have made, quite evident that the irrigation of the upper portion of the districts, or the land lying on a higher level than that which an annicut at Baizwarah will command, must form altogether a separate project, entirely independent of the irrigation of the Delta; for it would be perfectly out of the question to attempt to lead the water, which would be required for the lower portion of the districts, from such a distance up the river as it would be necessary to proceed to, in order to place an annicut which would command the upper tract of country, rising as it does 10, 20 and even 30 feet a mile. Having I trust, satisfactorily explained my reasons for the selection of the site, I shall proceed to the next point to be discussed, viz., the nature and expense of the work, as well as the means proposed for its execution.

"17. I will preface this portion of my report by stating, that the hill at Baizwarah, and that nearly opposite to it, at Seetanagrum, afford an unlimited supply of most excellent material, being composed of a species of granite. I propose, therefore, as the first step in the undertaking, to throw in a mass of stone, in large blocks, until the upper surface, to which I would give a breadth of 9 yards, arrived at the level of the summer water; giving the base a slope of four times the height, which would be regulated by the section of the river. This rough dam might, I should imagine, with some exertion, be thrown up in one season, and would then be left to settle during the freshes. On the top of this dam, front and rear retaining walls will be built of rubble stone in chunam, and the space between filled in with rough stone. Over this there will be a covering $1\frac{1}{2}$ feet thick of rubble masonry, giving it a slope, as shown in the plan; and over all another covering of cyclopean work, making the height of the body of the work 12 feet, the breadth at bottom 72 feet, and at top 27 feet. The crown of the work would thus be 18 feet below the term A on the Seetanagrum Register, the highest, known level of the river, or 46 feet, above the level of the sea at high water. In order, however, to give a greater command to the annicut, I propose to let dam stones 3 feet apart, and 2 feet in height above the crown, into the body of the work, and the intermediate spaces can be either filled up with a masonry wall or wooden shutters, as may be found most convenient. The hill at Seetanagrum will form a natural wing wall for the southern extremity of the work; but, as I propose placing it perpendicular to the stream, it will be necessary to connect the other, or northern end, with the Baizwarah hill, by means of a masonry wing wall, and earthen embankment revetted with stone, of no considerable length. There will be three sets of sluices in the annicut, each containing 25 vents, 6 feet in breadth by 5 feet in height, with shutters made in the manner shown in the plan of the head sluice, which will render them more manageable than when formed, as is usual, of one piece. In

SECTIONS THRO' THE BODY OF THE

(Submitted by Captain Atwell Lake, with

AVERAGE TRANSVERSE SECTIONS THRO' $\frac{1}{5}$



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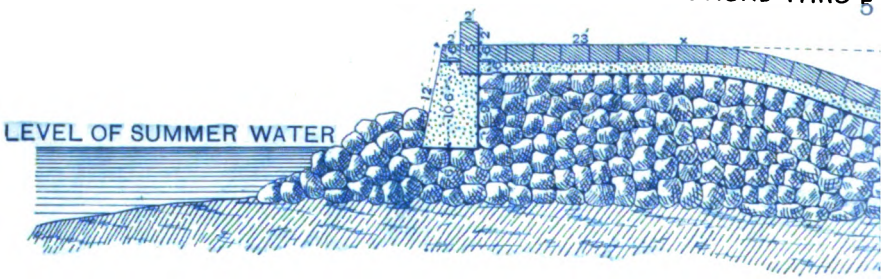

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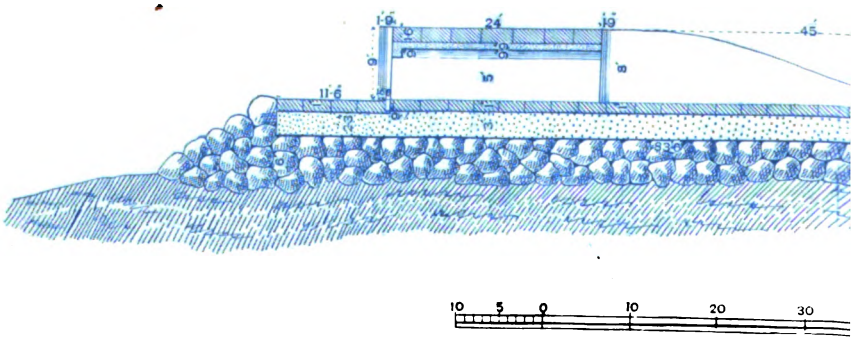


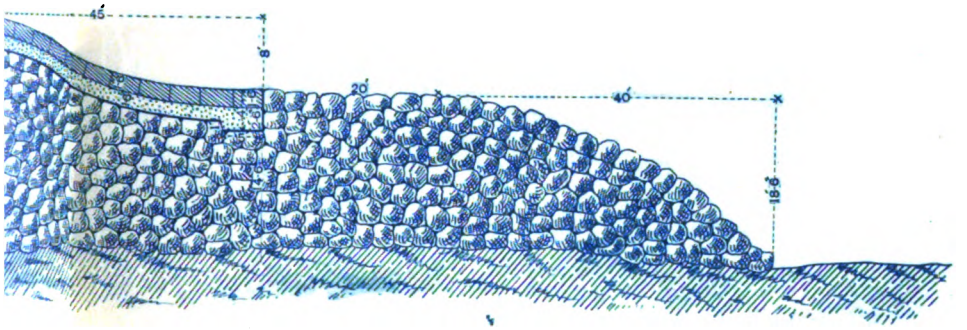
Reg. No. 3757.
Copies 410

OF THE PROPOSED **KISTNA ANICUT.**

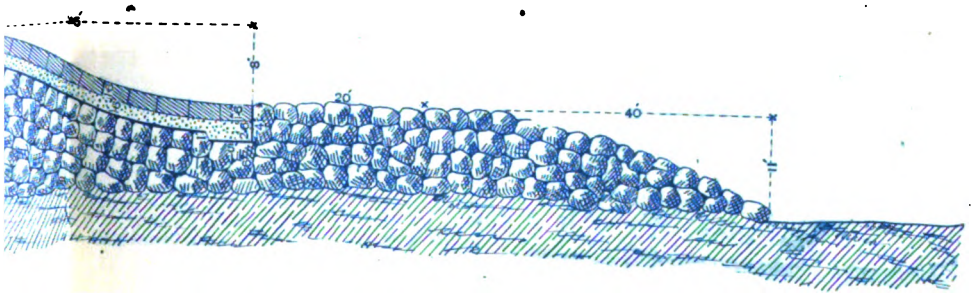
Lake, with his Letter 3rd. July 1847.)

(From Vol. IV Profl. papers Madras Engineers.)

S THRO' $\frac{1}{5}$TH OF THE BODY OF THE ANICUT.



THRO' $\frac{4}{5}$TH OF THE BODY OF THE ANICUT.



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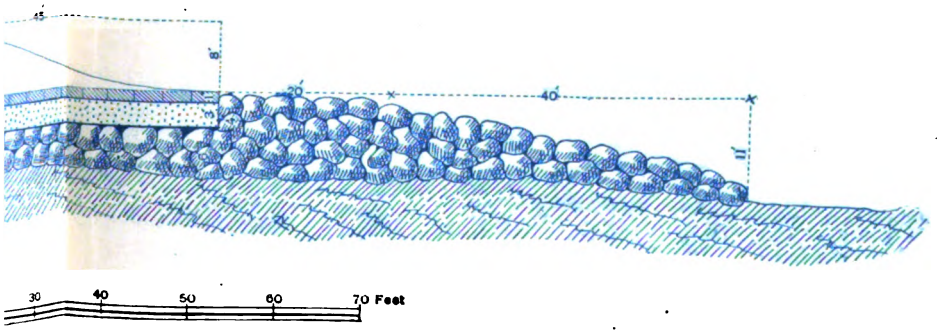

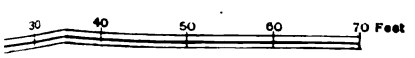

(Signed) Atwell Lake, Captain,
Civil Engineer. 2nd Division.

Photo-Print Survey, Office Madras.

1897.

order to render the rough dam as water tight as possible, clay will be thrown in front of the work as it progresses, and the sluices will be lined with cut-stone in chunam.

* * * *

"19. Two main channels must be taken off immediately above the work, and at the head of each there will be a sluice of 24 vents, 6 feet by 9, with a lock attached, and a bridge over all; but at present I do not propose the construction of locks into the river, as the traffic by boats is so very trifling, and there can be no doubt that, when the channels are excavated, it will be found better to take advantage of them than of the river below the annicut. On the Guntoor side, the present Toongabuddra channel, which has been lately completed and brought into operation, will, with very considerable enlargement, form the main channel to that district; and for the district of Masulipatam, a cut taken from immediately above the north wing wall, direct into the Boodemair, as shown in the plan, will be the main channel. There are, of course, many minor works connected with this project, which must be treated of in a separate place, particularly those for the better irrigation of the Deevy Pergunnah, in the Masulipatam district, the necessity and advantage of which will be fully explained hereafter.

* * * *

"22. I shall now proceed to the consideration of the benefits that will be derived from the project, and trust to be able to prove most satisfactorily, that they will be such as fully to warrant even a far greater expenditure. In discussing this portion of my subject, I necessarily lean a good deal upon the information afforded me by the Collectors of Masulipatam and Guntoor, who have, I am perfectly aware, taken no ordinary pains to furnish it in as correct a form as possible; but at the same time, my own personal observations, as well as the local information I have, from time to time, collected during the period I have held the appointment of Civil Engineer of this division, enable me to speak with a great degree of confidence, as to the favorable results to be expected from the construction of this most important work.

"23. In order to simplify my report as much as possible, I propose, in the first instance, to treat the two districts separately from each other; and I shall commence with that of Guntoor, as being the one which will derive the most benefit from the improved irrigation. The tract of land that will be brought under the influence of the annicut, according to the measurement taken on the map, may be said to contain about 1,100 square miles, or, deducting $\frac{1}{4}$th for waste land, sand drifts, &c., the extent of country to be irrigated may be taken, in round numbers, at about 500,000 acres, which agrees quite nearly enough with the returns furnished by the Collector. The revenue derived from this tract of land, under the great disadvantage of an irregular supply of water, averaged for the five years

almost preceding the famine, viz., from 1826 to 1830 inclusive, about 7,28,000 rupees, and for the five years immediately following the famine, or from 1833 to 1837 inclusive, the average collection was about 3,80,000 rupees, being but a little more than one half. The revenue for 1846 was about 6,56,000 rupees for the same tract of land, not even equivalent to the average collection of the five years preceding the famine, showing that the revenue has not yet recovered itself by 60,000 rupees per annum. The loss therefore of revenue, consequent upon one year of famine, up to the present time may be thus calculated :—

	Rs.
Average revenue, prior to the famine	7,28,000
Do. of the two years of famine	3,22,000
Revenue of the year, after the famine	2,48,000
Do. of the year, 1846	6,56,000
Loss of revenue in the 1st year, after the famine	4,80,000
Do. in 1846	72,000
Mean loss	2,76,000
Number of years since the famine	15
Rupees ...	41,40,000

showing a total loss of land revenue alone, within the tract commanded by the proposed annicut, of Rs. 41,40,000. To this should be added the loss in the other branches of revenue, which, of course, suffered in consequence of the impoverished condition of the people. But further, had this tract produced the crop which it would have done had the annicut been then in existence, it is evident that the famine, which raged throughout the whole of the upper part of the district, would have amounted to little more than a scarcity ; as that tract also would have been supplied with grain, at comparatively moderate prices from the alluvial country ; and thus the immense loss of revenue during the subsequent years, owing to the diminution in the number, and the impoverishment of the population in the upper tract, would have been almost entirely saved. This will be more distinctly shown by the actual total collections of the district during the period under review :—

	Rs.
Average total Revenue, prior to the famine	14,60,000
Do. do. of two years of famine	7,43,000
Do. do. of the year after the famine ...	5,77,000
Average of the four subsequent years	8,86,000
Do. four next years	10,65,000
Do. four do. up to 1846	11,36,000
Falling off of revenue in consequence of famine	8,83,000
Deficiency of revenue at the present time	2,24,000
Average loss of revenue during 15 years	5,53,000
Total loss up to 1846	82,95,000

"But it may be observed, that this is only a comparison of this period with that preceding, when under so imperfect a system of irrigation, and when the supply depended so entirely upon the high freshes of the river. It must, however, be also taken into consideration that, had the annicut been built at that time, the revenue instead of falling off, as it has done, would have undoubtedly been steadily on the increase up to the present moment, so that the total difference between the actual collections and what might have been fairly expected, would amount to not less than 120 lacs, or nearly a million and a quarter sterling. Supposing then, that 12 lacs of rupees would complete the project now brought before the notice of Government, half of that sum, or six lacs, the amount of expense that would be borne by the district of Guntoor, would have been sufficient to have made this difference.

"24. But of immeasurably greater importance than all this, is the fearful loss of life which took place during the famine in the Guntoor district, which would assuredly have been avoided, had the supply of water during that period been regular and sufficient; and I have every reason to believe that, though the river did not come down with its usual fresh, there was water enough to have been turned into the district, had it been dammed up by means of an annicut. In an interesting article written by J. F. Thomas, Esq., of the Civil Service, in the 'Madras Journal of Literature and Science,' dated April 1839, it is stated that, during the famine of 1832, more than one-third of the inhabitants of the Guntoor district, or upwards of 200,000 persons perished within a short period, out of a population of little more than 500,000. Mr. Thomas further adds that 'the returns of population in the year prior to the famine give 512,000, in the year subsequent, but one half or 255,000; and four years later, but 267,000; and it is asserted that there was little or no emigration. Previous famines have also been estimated to have destroyed one-third of the inhabitants of those districts in which drought was general, and we might perhaps fairly assume this proportion, as the ratio of mortality in famines in India, when they are left to work out their natural effects unchecked.' * * *

"25. I shall next endeavour to show the increase to the revenue in the Guntoor district which may be expected in consequence of the project now brought to the notice of Government. I have before stated, that the revenue which had so greatly fallen off in consequence of the famine, has not yet recovered itself. Last year's collection from the tract of country to which I am particularly alluding, viz., that which will be brought under the influence of the annicut, was about 6,60,000 rupees; and it will be seen by the Collector's statement in Appendix E, that the sist on the extent of land which may be brought under wet cultivation, calculated at the average price per acre for the present year, would amount to 29,00,000 (in round numbers). The increase, therefore, in revenue might be fairly

stated at 22,40,000 rupees, and this is calculated under supposition that the ryots get but one crop from their lands during the year, and that nothing but paddy is grown thereon. Whereas, there is no reason whatever, why, with the regular and plentiful supply of water, which they will obtain by means of the annicut, sugar-cane should not be grown, as well as a second crop of grain. The increase, therefore, under these circumstances, would be considerably above what I have stated; and perhaps in no part of the district can such rich land be found as in this very tract now alluded to.

"27. I now proceed to take up the Masulipatam district, and will endeavour to show the advantages it will derive from a better supply of water; and though the results may, perhaps, be not so favorable as those expected in the Guntoor district, they will still be most satisfactory. I must here remark, though I shall have to enter more fully on the subject before concluding my report, that the proposed annicut across the Kistnah must, of necessity, be looked upon as connected with the project on which the Civil Engineer of the 1st division is at present employed, namely, the construction of a similar work across the Godavery. This being the case, I shall not include in my project the whole tract of land in the Masulipatam district, which might be brought under the influence of the Kistnah annicut; as a large portion of it, that is to say, as far as the Colair lake, will be watered by the Godavery. The remaining part, as shown in the map, after deducting $\frac{1}{4}$th for waste land, sand-drifts, roads, &c., may be said to embrace a somewhat similar extent to that calculated on in the Guntoor district, or about 550,000 acres of very rich land. This, as in the portion of the Guntoor district alluded to, includes enam land which, properly speaking, should be deducted when calculating the total amount, as it yields no revenue to Government; but it might, at some future time, again revert to the Circar, and it forms, at all events, but a small portion of the whole in either district, being in Guntoor $\frac{1}{8}$th and in Masulipatam $\frac{1}{10}$th.

"28. The statement in the Appendix, marked G, shows the extent of land which was brought under cultivation last year, together with the average collections during two periods of five years each, prior and subsequent to the famine; and without entering into all the details which I considered necessary when reporting on the Guntoor district, I need only direct attention to the great fluctuation and falling off in the revenue, which will be seen clearly by a reference to the Collector's return above alluded to. The total extent of land in this district, which will be commanded by the annicut, amounts, as before stated, to about 550,000 acres, which, at five rupees, the average rate per acre for wet cultivation, would yield a revenue of 27,50,000 rupees. I am however inclined to think that this is probably a higher average rate than might at first fairly be calculated upon, although eventually a still higher one may reasonably be expected, when the irrigation is complete; but to avoid showing results greater than may possibly be

realised, I shall take the rate per acre at four rupees, which will make the total amount of revenue 22,00,000 rupees. The collection last year from this portion of the district was 4,66,000 rupees: if, therefore, the whole extent were brought under wet cultivation, there would be an increase in the revenue of nearly 17,50,000 rupees. Doubtless there are certain portions of this tract of land which it might be found inconvenient and unadvisable to cultivate with wet crops, and, under any circumstances, it must be a work of time to bring the *whole* of it under cultivation; but I trust that I have already shown enough to prove the immense advantage which would result from a plentiful and regular supply of water throughout the year.

"29. I now come to the Deevy* Purgunnah, a rich and formerly very fertile part of the district, the revenue from which has so greatly fallen off from the want of proper irrigation, that the collection last year only amounted to about 71,000 rupees. It will be seen by the statement that the area of the Purgunnah is estimated at upwards of 40,000 acres; and the average rate per acre being six rupees, this tract of land alone would, if all brought under wet cultivation, yield a revenue of two and-a-half lacs of rupees annually, or 1,84,000 rupees above last year's collection, making a total increase of revenue in the portion of the Masulipatam district which would be commanded by the annicut, of nearly 20 lacs of rupees. In this district the growth of sugar and indigo are altogether unknown, but, as in Guntoor, there is no reason whatever why both should not be generally cultivated. There are so many points of my subject connected with the Masulipatam district, exactly similar to those of the Guntoor district, that, were I to attempt to enlarge upon them in a like manner, I should be led into useless repetition. I may, however, observe that all I have said on the subject of the famine in 1832, as regards the ravages it made in Guntoor, is applicable to Masulipatam, though in a minor degree; and the necessity, therefore, of adopting measures for preventing, as far as possible, a recurrence of such misery is nearly as great in one as in the other district.

* * * *

"31. I trust that I have now fairly shown the advantages which, in a pecuniary point of view, are likely to arise from the construction of the proposed annicut. The estimate at present submitted, and for which sanction is requested, amounts to four lacs and 2,639 rupees, and provides for such works as are, in my opinion, necessary to be undertaken in the first instance: but further expenditure will, of course, be requisite for completing the project to the full extent contemplated. I have prepared a rough statement of the expense that will be probably incurred in excavating a channel from Baizwarah to Ellore, and another from Baizwarah along the

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* Divi Island.

banks of the Kistnah to the Deevy Purgunnah in the Masulipatam district, and for a channel from Seetanagarum, passing near to the town of Guntoor in the direction of Addunky, as also for one along the south bank of the Kistnah in the Guntoor district. I have likewise made an allowance for roads and bridges, as I consider that, in order to render the communication in the district perfect, it will be necessary to make branch roads both inland and towards the sea. As all the heavy traffic will be by means of the channels, I have only provided for such roads as will be required for foot passengers, light conveyances, cattle, &c. In making them, the drainage of the country will also be considerably improved, and the channels themselves will form the main drains. The following statement shows the probable amount of all these auxiliary works :—

	Rs.
300 miles of road at 1,000 rupees per mile	3,00,000
Detail irrigation works, such as channels, sluices, &c. ...	6,00,000
Aqueduct to Deevy Purgunnah and adjoining works ...	1,00,000
Bridge over annicut	1,00,000
Embankments, &c.	2,00,000
	13,00,000
Present estimate	4,00,000
Total for providing both districts with irrigation, internal navigation, roads, bridges and river banks	17,00,000

"In this statement it will be observed I have included the expense of the bridge across the Kistnah, and also that of building an aqueduct across a branch of the same river into the Deevy Purgunnah, the details of which important work I do not now enter into, but the sum allowed for it will, I am convinced, fully cover the expense of its construction.

"32. I must now take the opportunity of noticing the very great and valuable assistance I have received from Major Cotton, the Civil Engineer of the 1st division, in communication with whom my plans and estimates have been made out. * * * *

"33. It is proposed by Major Cotton and myself to connect the two rivers, the Godavery and Kistnah, by a channel meeting at or near Ellore; one half of the expense to be carried to the account of the Godavery project, and the other to the one now submitted." * * *

Sir Arthur Cotton's letter about proposed Kistna Anicut.

Before forwarding their report to Government, the Board of Revenue, on 21st February 1848, sent it for his "deliberate opinion on the whole project" to Major Arthur Cotton, then in the midst of the trials and anxieties of the early stages of construction of the great Gódávari Anicut, and his reply was as follows :—

"1. I have the honour to acknowledge the receipt of your letter, calling for my opinion on the projected Kistnah annicut, with reference to its probable stability, if constructed at Baizwarah.

"2. I beg to state that this subject has been frequently under my consideration during the last two years, that I have discussed it on the spot and repeatedly with Captain Lake, and also with others; and I beg to assure you that there is not left on my mind the shadow of any objection to the site, but quite the contrary, that I consider it an extraordinarily favourable one; and that if, in addition to its other remarkable advantages, it had the only other which might appear desirable, viz., that of a rocky bed, instead of a sandy one, it would in my view make very little difference, none at all as respects the stability of the structure, and only perhaps 50,000 rupees in the cost.

"3. There is so deep an impression in people's minds respecting a sand foundation generally, that it is most difficult to investigate the subject properly. There is certainly one defect in sand as a foundation, viz., that if running water comes in contact with it, it will be swept away; but this is the only one; in other respects it is the finest foundation possible; it is indestructible, and incompressible. Of the thousands of works which I have seen or executed on a foundation of pure sand I never saw the slightest sign of a settlement in any one of them. We must therefore take care to remember that there is only one thing to be guarded against in building in sand, and that so long as it is protected from the action of running water, no work resting in it can possibly fail; and the remedy for this one defect is as plain and easily applied in situations such as this, as could be desired; it is simply to cover the sand, where it would otherwise be exposed to the action of the current, with loose stone. With this precaution, where it can be used, I consider sand a perfect foundation, and in the present case, loose stones can be used in any quantity, at a cost that is not to be compared with the importance of the work. The size or the quantity of the stone must certainly be proportioned to the strength of the current: if this is great, and only small stones can be obtained, the quantity must be so increased as that the slope of their surface may make up for their want of size. In rivers like these, having a velocity of four miles an hour, at the utmost, the largest stone to be found in their beds does not exceed two or three ounces; and these often remain for years in the same place. If the surface of the stones had a slope of, suppose 20 to 1, they would require to be a pound or two in weight to resist the current; with a higher velocity and greater slope larger stones would be required; but with such velocities as we have to deal with in these rivers, unless we make the annicuts very high, very moderate sized stones would be sufficient, even with a considerable slope; while at Baizwarah any sized stones can be used, and in any quantities, at, as I have said, an expense not to be considered in a work of this importance. Captain Lake

has allowed 7½ annas per cubic yard for his loose stone, and perhaps this is not too much for the quantity he has allowed, considering that it includes the cost of apparatus; but I am persuaded that, if another lac of rupees were to be expended on loose stone, the additional work would not cost more than three annas a ton, so that 500,000 tons could be added for one lac. Captain Lake has allowed a base of 20 yards, to a height of 6, for the lower side of his loose stone work; if this depth extended across the whole breadth of the river, 500,000 cubic yards of stone would allow of the base of the slope being extended to 180 yards, or 30 times the height, and making the breadth of the whole base of the work 210 yards. I give these calculations to show what might be done at a comparatively trifling cost, if it were necessary; and I think it is scarcely possible for any person upon a little consideration not to be satisfied that, with such a breadth of stone work extended below the annicut, it would be impossible for the water to get at the sand on which the body of the work rested, so as to wash it away. And it is equally evident that, in such a project, a lac of rupees more or less in the cost cannot in the least affect the question.

"4. Any how, I should suppose that it must be allowed that it is simply a question of the quantity of loose stone, and nothing more; that is, that with a certain quantity of that material, the stability of the work is as certain as it could be on any imaginable kind of site; and further, that that quantity can be obtained at a comparatively insignificant cost.

"5. My own opinion is, that the quantity allowed by Captain Lake will be found ample: I should not be at the trouble and expense of filling up any hollows in the bed with stone, but would first bring it all to a uniform level with sand, and then throw the loose stone in an equal thickness all over the bed. For the sand is continually changing about, and where the hollow now is, in a year or two there will be a high bank of sand, and on that the annicut would be built. I should, therefore, level the bed with sand to near the summer level of the water, and then throw the mass of stone across, making it of course of a uniform height the first year, however low it might be.

"6. The Board desire my opinion respecting the depth of the sand over the rock, and the velocity of the river. It will be seen from the above remarks that in my view of the case the depth of the sand over the rock does not affect the question. I have no doubt that it is very deep, so deep that, if it were desirable to have the loose stone resting on the rock, the case would be hopeless; but it will be seen that I decide the question, according to my ideas, entirely independent of rock. With respect to the velocity, Captain Lake takes it at three miles an hour for the mean of the whole section, and though I have not taken it myself, I feel confident that it cannot much exceed this; my calculation of what it should be from the depth and fall per mile, gives a little more than this, about 3¼. That it is not much more is clearly seen by a mere examination of the section; if there was a

high velocity, it is impossible that the sand could stand in a great proportion of the breadth of the channel, from 2 to 16 feet above the summer level of the water, just as it does in all other parts of the river. Were there any thing like a high velocity, not a particle of sand could remain at a higher level than several feet below the summer level. Where the Godavery passes through the hills, there is not an atom of sand to be seen, and the water is 70 or 80 feet deep in the summer. The velocity over the annicut may be easily shown. The total section of the channel water in the highest floods is 12,000 square yards; the part of it obstructed by an annicut of the height proposed is 4,500 square yards, or about $\frac{3}{8}$ths of the channel will be obstructed; the velocity must therefore be increased as three to five, for the same quantity that now passes through five parts, must then pass through three; the velocity will consequently be increased from $3\frac{1}{2}$ to nearly six miles per hour, which will be the rate over the work when the river is highest. This, however, will not be the time when the velocity will be the greatest. According to my calculations, it will be about seven miles an hour when the water in the river below the dam stands level with the crown of the work, at which time I reckon that the water above will stand three feet deep over the top of the work; but as in this state of the river the body of water passing over the dam will be small, its effect upon the loose stone work will probably not be so great as when the river is higher, though the velocity will then be rather diminished.

* * * *

"9. I think these remarks are sufficient to explain my views respecting the proposed site. It will be seen from them that, after every consideration, I feel entirely satisfied that the objections to it are entirely imaginary, so far as the stability of the work is concerned, and nearly so as respects its cost; while on the other hand, the unlimited supply of stone on both sides of the river, at the very edge of the water, is such an advantage as would not be compensated by having a rocky bed, if the stone had to be conveyed one mile.

"10. In case I should fail to give to others the confidence I feel on this subject, I may mention one other point, viz., that as the rough stone dam must necessarily be executed in one season, and the building of the solid masonry in another, the effect of the current upon the work will be clearly seen in good time, and before the principal expense is incurred."

The Board took its time about the consideration of these reports, and did not send them on to Government till the following August more than a year after the date of Captain Lake's report. The Board's forwarding letter was chiefly a recapitulation of the reports, above printed, with an expression of opinion that it was "impossible to doubt that a work which will place under command of a plentiful irrigation about

a million of acres, must, besides immediate handsome returns, produce incalculable ulterior benefits," and it recommended that the plans and estimate submitted should be referred to a committee of Engineer and Revenue officers.

Committee appointed to report on Kistna Anicut project.

The Government accordingly appointed a committee composed of—Captain Buckle whose report ten years previously had brought the proposal for the anicut again to notice (see page 14); Captain Bell, then Public Works Secretary to the Board of Revenue; Captain Orr then carrying out the Gódávari anicut; Mr. Stokes, Collector of Guntur; and Mr. Forbes, Sub-Collector of Rajahmundry.

The Committee's report.

In January 1849 they sent in their report, this and the specification and estimate that accompanied it, are given below in full, as they form the basis on which the work was undertaken :—

"REPORT OF THE COMMITTEE UPON THE PROJECT OF AN ANNICUT ACROSS THE KISTNAH RIVER FOR THE IRRIGATION OF THE DISTRICTS OF MASULIPATAM AND GUNTOOR.

"1. In fulfilling the duty prescribed by Government, the Committee have had under consideration the following points :—

1st.—The general feasibility of the project.

2nd.—The returns to be expected.

3rd.—The site.

4th.—The plan and estimate.

Feasibility of the project.

"2. First, it is certain both from levels often taken, and from existing facts, that a very extensive tract on each side of the river may be irrigated by means of an annicut, placed in any situation, several miles above or below Baizwarah. The present channels, the Boodemair and Pulleiroo, on the left, and the Toongabuddra and Vellatoor on the right bank, already command a large extent of land, when the river rises to a certain height, and with the aid of an annicut to render their supply of water continuous, would of themselves add abundantly to the wealth and prosperity of the two zillahs.

"3. Secondly, as a work of engineering, the committee are of opinion that the annicut may be built in any part of the river with every prospect of success; the stability of such a work being simply a question of quantity and arrangement of material, though the facility of construction is dependent upon many variable circumstances.

"4. The only base for the foundation that can be obtained in any part of the river, is sand, upon which also the Coleroon and Godavery annicuts are built; and the only question, whatever site may be selected, is how this base may be effectually guarded from lateral disturbances, since it is immovable, or nearly so, by vertical pressure. The committee have no doubt that the object is attainable, even in the most unpromising sites, by the skilful disposition of the material, of which there is an inexhaustible supply in the igneous rocks of the vicinity.

The returns to be expected.

"5. These, in their full extent, depend of course upon the actual command of the annicut, a point to be hereafter discussed; but the committee propose in the first place to exhibit those profits which may be reasonably expected from an annicut within the limits of any sites or heights that have been or are likely to be suggested.

"6. In the statements already laid before Government, the committee observe that those of Masulipatam are deficient in specification of the sources of more immediate profit, and that those of Guntoor include lands which are on too high a level for irrigation, probably, within a considerable period. In both there is a want of discrimination between the existing wet and dry cultivation; at least with reference to the expected effect of the annicut thereupon.

"7. The committee have, therefore, after careful enquiry, prepared the new returns which are appended to this report, and upon which they beg leave to offer the following remarks:—

Appendices A and B.

"8. In Masulipatam, the highest revenue derived from the Boodemair and Pulleiroo in one year amounted, for both channels, to Rupees 68,183, when prices were somewhat above the average. The revenue will not, for the future, depend upon prices; but money rents are expected to the full amount of the best years when the channels are permanently supplied. The increase is therefore estimated at the amount of difference between the highest and average returns, that is, at 37,144.

Appendix A.

	Rs.
Boodemair ...	28,915
Pulleiroo ...	39,268
	68,183
Boodemair ...	13,129
Pulleiroo ...	24,015
	37,144

"9. The foregoing increase is calculated from the greatest extent of land under the channels hitherto cultivated, namely, 6,917 acres, and is therefore an increase from richer produce only: there are besides 11,535 acres in the Ayacut, of which three-fourths or 8,651 are expected to be immediately cultivated, and to yield Rs. 43,255.

"10. There are also 20,991 acres of wet land at present uncultivated in other parts of the district, favourably situated with reference to the annicut;

and from these an increase of Rs. 34,985 is expected in the first year after the construction of the annicut, 69,970 in the second, and 1,04,955 in the third and following years.

"11. An increase of Rs. 4,708 is calculated from difference of assessment on the present wet cultivation.

"12. On 33,000 acres of dry, 16,000 of which will probably be converted into wet cultivation, Rs. 12,000 are expected in the first, 24,000 in the second, 36,000 in the third, and 48,000 in the fourth and following years, after water has been supplied by the annicut.

"13. In a zufted estate, which will shortly become the property of Government, the increase is estimated at Rs. 9,690 in the first year, 19,380 in the second, 29,070 in the third, and 29,820 in the fourth and following years.

"14. The foregoing estimate has been purposely made at a low amount; but if the expected increase on dry land be deducted, on account of the possible difficulties of conversion at an early period, the profit in the first year will still be about 1,20,000 rupees, provided that proper means for distributing the water be employed.

"15. *Guntoor*.—In this district, the present irrigated lands lie in the Bopetlah, Repully and Ponnoor talooks, and amount, as it will appear by the annexed memorandum, to 36,117 acres, the average revenue upon which (a part only of course being cultivated), for ten years, amounted to Rs. 62,298, and the highest to Rs. 1,43,802; the difference, less the profit obtained from the Toongabuddra and Vellatoor channels, namely, Rs. 16,544, being expected as an immediate increase from the construction of the annicut. The revenue having hitherto been collected by shares, the extent of land cultivated in the best year is not known, but was, it is certain, considerably within the Ayacut; prices being high and the revenue large, proportionately to the cultivation. As it is expected that, by means of the arrangements for the field assessment just concluded, a fixed rate of Rs. 6 the acre will be obtained, the probable yield of revenue from the Ayacut will be 36,117 × 6 = 216,702, which, compared with the average return, gives an increase of Rs. 1,53,774 less 16,544, or 1,37,230 instead of 64,330.

Appendix B.

Difference	...	80,874
Deduct	...	16,544
Increase	...	64,330

"16. In the Repully talook, there are tracts of waste land favourably situated for irrigation, from which Rs. 77,860 are expected, as an early, if not immediate increase; and in the Tenally and Ponnoor talooks a large area now cultivated with red paddy will, it is believed on very good grounds, be quickly converted into wet land, and yield an increase of Rupees 1,86,528.

"17. The four talooks above mentioned are very favourably placed to receive water from the annicut; and the committee have no reason to

doubt that the expected increase therein will be quickly realized. It amounts altogether to Rs. 3,28,718, if the best yield only of the present wet lands be taken as the standard, or to Rs. 4,01,618, if the more probable return at the rate of the field assessment be admitted.

"18. In the Pruttepaud talook, a further immediate increase of Rupees 62,559 is expected; but regarding this the committee, considering the relative level of the lands, cannot record a decided opinion with the same confidence.

"19. The superiority of the profits expected from Guntoor to those of Masulipatam, is to be accounted for by the fact, that in the latter district no account has been taken of the Jary estates, which are in amount of acres as 244 to 118 of the lands in the possession of Government, and as 244 to 131 of the Government and zufted lands together, excluding from both reckonings the whole of the enams.

"20. Upon the arrangements to be made with the Zemindars, and with the Enamdars on the Government estates, the committee will offer some suggestions towards the close of their report. They now, having shown, as they trust, the more immediate profitable character of the project, observe that but a small portion of the returns that may most reasonably be expected from the annicut, as already proposed, has been exhibited.

"21. It has been the desire of the committee to show clearly the immediate advantages, because those which are more distant, though not less certain, cannot be estimated with the same accuracy, being in fact much dependent upon the increased resources which will be created by the annicut itself. At another part of the report the committee will treat of these later returns, with reference to the actual site and height of the work as proposed by them, and now to be discussed.

Site.

"22. The more important points considered by the committee, under this head, are—

Command.
Nearness of materials.
Safety and facility of construction, and expense of the work and its dependent channels.

"23. With regard to command, the committee are of opinion that that of the annicut, as already projected at Baizwarah, though sufficient for all the land included in the foregoing revenue statements, and probably far more, would not include the whole tract delineated on the map, and that to render it effective to the desired extent which it certainly ought to be, an additional height of four feet at the same site is requisite, to be diminished about seven inches for every mile higher up.

"24. In proximity of material the site of Baizwarah has a very decided advantage over every other; the hills on both sides, composed of rock excellent for the required purpose, being washed by the river even at its summer level. Between this site and Joopoody, eleven or twelve miles higher, there are no hills nearer to the river than one mile; and at the latter place, though there are rocky heights very near to the left bank, the hills on the right bank are at far too great a distance for the supply of material for the annicut.

"25. Loose stone will be greatly in excess compared with masonry in the proposed work, and lime-stone is therefore of secondary importance. It is found in the river bed in the form of kunkur * in different places at Wodaiswaram, two or three miles below Seetanagrum, which is opposite Baizwarah; and at Madaveram, about nine miles from Ibrampatam. It is doubtful whether sufficient quantities for the annicut could be collected from the river and at Wodaiswaram; and the committee have therefore allowed a price equal to the cost of lime-stone brought from Madaveram. With respect to this quarry, the site of Baizwarah has no advantage; but the cost of transporting the lime-stone to the river bank would be much in excess of every other charge, and would be the same for every site.

"26. With regard to safety of construction, no doubts are entertained of any site, but that of Baizwarah, to which therefore the remarks of the committee will be confined. They have already stated that a command of four feet, in addition to that of the annicut as proposed by Captain Lake, is necessary; that is, a work of 16 feet in height above the level of summer water must in their opinion be erected, if the site of Baizwarah be selected.

"27. It was remarked by Major Beatson in 1792 that the river had apparently 'forced its way' between the Baizwarah and Seetanagrum hills; and as this opinion stands recorded in Captain Lake's report, and might excite alarm as to the practicability of a safe construction at a spot where solid rock had yielded to the current, it may be as well for the committee to state that such an opinion is not in the least supported by the obvious physical facts. In the first place there is no 'chain' of hills lying across the path of the river, but on both sides, at no great distance, there are considerable gaps, through which the Boodemair and Toongabuddra channels flow, and either of which must have inevitably formed the bed of the Kistnah, ages before the river could work its way through the rock; and hence it is absolutely certain, that the passage between Baizwarah and Seetanagrum is as natural a one as either of the other two. Secondly, the same conclusion may be proved with nearly equal certainty from the fact that, below the rocks of which the hills are composed, nothing but rock is ever found in the earth, whereas at Baizwarah sand alone can be reached at

* Nodular lime-stone.

any fathomable depth; and on the hypothesis of the river having 'forced its way,' it must therefore be further supposed that it has cut away the rocks to an indefinite depth below its own bed; which, even allowing for the rise of the bed with the gradual formation of the Delta, appears impossible.

"28. The passage of the river is certainly much contracted at Baizwarah, and its velocity thereby augmented, from three miles, which it is in the broadest part above, to five miles the hour in the high freshes. But the latter velocity is by no means high, *per se*, being not more (probably less) than that of the Coleroon in Tanjore; and consequently the mean depth of the bed is scarcely at all affected thereby, and the deep pools are caused entirely by the relative positions of the hills. The current first sweeping round that of Baizwarah, and then driven upon that of Seetanagrum, forms a deep bed, constant at the former, but variable at the latter hill; yet this bed, at the site selected by Captain Lake for the annicut, is little deeper than the committee have found it to be in six other sections of the river recently taken; and hence they have no reason to suppose that, were the bed brought to a uniform level by an annicut designed on just principles, any dangerous hollows would be formed below the work.

"29. The stability of an annicut sixteen feet high, in this situation, will of course require peculiar caution in the construction, but, this being granted, may be reckoned upon with as much certainty as the nature of the case admits; but it remains for the committee to state what would be the effect of such a work in raising the level of the river water in the high freshes, which alone are of importance in the question. The afflux or rise by means of the work, they have calculated, by established data, would be only about 10 inches, if the natural depth were 35 feet above the summer level, the ordinary highest rise. In the extraordinary floods, which rarely occur, and rise three feet higher, the afflux would be somewhat less; and it is evident, therefore, that a weak embankment, carried along each margin of the river, would render any inundation by means of the annicut impossible, since no natural rise of the water within 35 feet overtops the present banks.

"30. The annicut will indeed probably have the effect of casting the current obliquely on different points of the banks above, and the more so in proportion to its height; but such points will be easily defended, and the current rectified by groins, for which there will always be an abundant supply of material.

"31. The committee have thus, they believe, shown that there would be no danger, either to the work or the country, from an annicut 16 feet high at Baizwarah.

"32. The facility of construction at any site (other things being equal), is great in inverse proportion to the length of the work. At Baizwarah, the

breadth is about one-half of that of any other favourable site; and though the difficulties are on the other hand increased by the presence of an equal body of water in a contracted passage, the committee are of opinion upon the whole that, considering the proximity of the quarries, Baizwarah would be found as convenient a site in this respect as any other.

"33. The last point for report, under this head, is the expense of the work and dependent channels at different sites.

"34. Between Baizwarah and Joopoody the committee have before stated that there is no favourable site with regard to the nearness of material, the expense of transporting which from any distance would add greatly to the estimate. Joopoody may therefore be taken as alone suitable for comparison with Baizwarah. Its advantages are simply that the requisite command would be obtained there by a work far less massive, and requiring less constructive skill. On the other hand, its length would be double, and material could be deposited from the left bank only; but the most serious disadvantage of this site is the increased length necessary for the irrigating channels. In point of expense, it is probable that this additional length, merely for the immediate irrigation required, would nearly, or even entirely, absorb the difference of cost in the two annicuts; and under this view the question would be narrowed to the relative difficulties of the construction, and chances of stability. But eventually the channels must be greatly enlarged, and would cost many lacs of Rupees before they could supply the whole of the culturable land in both districts; and what is of the most immediate importance, the lands from which the earliest increase of revenue is expected (the ryots being fully prepared to extend their cultivation), are the most distant from the sources of supply, which would consequently, in proportion to the distance, be most precarious where most required. The known difficulty of conveying water by high level channels to great distances in this country, when intermediate demands are to be satisfied, makes it, in the opinion of the committee, highly important that the immediate productiveness of the project should not be endangered by arrangements for which it appears to them there is no actual necessity.

Para. 24.

"35. They have therefore determined to recommend, in conjunction with Captain Lake and Major Cotton, the site of Baizwarah, as the most eligible under all the circumstances.

"36. That site, being under the line of the northern road, is farther highly convenient for the purposes of communication, whether by the annicut, or by a bridge over the work; and it is also a decided advantage, that the management of the annicut, when constructed, should be so much nearer to the control of the Collectors and Civil Engineer than it would be at Joopoody.

Plan of the work.

"37. In this the committee have followed generally the design of Captain Lake, but have proposed certain modifications, with reference to the varying section of the river. If the depth were even tolerably uniform, it appears to them that one form of section would suffice for the entire work; but under the actual circumstances it is necessary in one part to fill up the hollows with a mass of loose stone, and in another to build the work upon wells sunk, as far as possible below the summer level. This is the only arrangement that, in the opinion of the committee, will effectually overcome the difficulties arising from the constant passage of the water, which cannot be drained off without much greater difficulties.

"38. If every proper preparation were made, the committee would expect that the annicut might be built in the first year to the height (above the summer water) of five feet throughout, and the under sluices to a height sufficient to serve, in the second year, as drains, during the progress of the rest of the construction.

"39. The full height of the annicut would not be attained till the third year, nor perhaps even then, should circumstances render it desirable to maintain a lower height for any period; but such arrangements cannot be predetermined, and must be left to the judgment of the executive officer.

"40. In altering the plan, the committee have been guided by the highly important experience obtained in the construction of the Godavery annicut; an advantage which, it must be remembered, was not enjoyed by Captain Lake, who drew up his project before that work was commenced.

Estimate.

"41. The same remark applies to the estimate, the rates of which the committee have, considering the repeated injunctions of Government, felt it incumbent upon them to increase considerably, besides providing a large sum for the plant, which, with the particulars of the rates, is duly specified in the appendix to the estimate.

"42. The committee have endeavoured to prepare a liberal estimate, without indulging in mere conjectures; but they feel the responsibility of this part of their duty to be very great; and while they cannot undertake to certify the correctness of calculations, so liable to be disturbed by contingencies, they trust that they will be considered to have done all in their power to prevent disappointment in the cost of the work.

"43. The committee believe that no inconsiderable portion of the plant may be provided from that of the Godavery annicut; but they are unable to estimate this portion, and therefore make no deduction on its account. The cost of cut-stone may also probably be diminished by bringing it from the Condapilly fort, where a large quantity is ready for use; but here again, the

expense of transport being doubtful, they have thought it proper to fix the rates sufficient to prepare the material on the spot.

"44. The committee consider it essential that the work should be placed under the charge of an officer on the allowances of a Civil Engineer, since the Civil Engineer of the division could not attend to it, having at the same time the duty of superintending the Godavery irrigation. They have also provided for the pay of two First, and two Second Assistant Civil Engineers, though it is not certain that so many extra officers will be required.

"45. It is of great importance that contemporaneously with the preparation for the annicut, and its actual construction, surveyors should be employed in laying out the channels required for the distribution of water from the main ducts, the Bodemair and Toonabuddra.

"46. It is further the decided opinion of the committee that, if the work is sanctioned, a legislative enactment should be obtained, to enable the local authorities to obtain possession of property indispensably necessary for the prosecution of the work, and for the distribution of the water. The necessity of such a measure is particularly great at Baizwarah, where the annicut will touch the village, and where private property must be acquired to obtain room for working.

"47. The committee have now to recommend that if the work is sanctioned the Board of Revenue may at once be authorized to make known to the Enamdars on the Government estates in both districts the terms on which they may be supplied with water.

"48. The Zemindars of the Jary estates should, in the opinion of the committee, be invited to declare whether they will accept of the proposed irrigation upon certain terms, and should be cautioned that, in the event of a refusal, they will not be allowed the benefit at any future period.

"49. It should be observed that, in the calculations of increased revenue in Masulipatam, the Deevy Purgunnah, now under the management of the Court of Wards, has not been taken into account.

"50. In the estimated returns the committee have limited their observations to those immediately or early expected from the known resources of the districts, and the disposition of the ryots. They will now briefly add that the annicut, as proposed by them, will command in Guntoor about half a million of acres, and the same in Masulipatam * (of Government and other lands) exclusive of Deevy, and that the supply of water for this tract will be most abundant during the season of cultivation of paddy, and very considerable even in the lowest state of the river; so that there is every reason to believe that the whole will eventually be cultivated.

* Govt. lands.	130,000
Zemindary.	340,000
Enams ...	60,000
	530,000

"51. The level of the annicut has not been proposed without anxious consideration, and the committee have rather stated its maximum height, than fixed it at a definite point for the irrigation required. It will readily be

understood that the latter is a question of no ordinary difficulty, in a locality where nearly all the land is dry, or if wet has been hitherto, with small exceptions, supplied from the local rains. In Tanjore the height of the Upper Annicut was determined simply with reference to a mark on the Grand Annicut, at which it was known that the river furnished a full supply for all the irrigated lands; but in the case before the committee no standards of the kind exist, and a large system of levels, with minute calculations of the fall of water in the channels, would be necessary to enable them to predetermine the height of the annicut with any thing like perfect accuracy. They can, however, without hesitation declare, that should the maximum height be eventually adopted, there would be at least six feet water at the heads of the channels for 130 days in the year, which is considerably more than the period required to perfect a crop of paddy, and that there would almost always be an abundant supply for a large tract of sugar-cane, should that plan be cultivated.

"52. For, having measured the quantity of water now passing down the river, and from that estimated the quantity in the driest season, they find that there would be even then sufficient for about 100,000 acres of sugarcane.

"53. In conclusion, the committee desire to record their conviction of the very great importance of the proposed work, and of its early sanction. That it would, in all human probability, avert the possibility of a destructive famine in this region, seems an argument of the greatest possible weight, independent of profitable expectations, which are themselves most promising. Again, its early sanction is important to meet the expectations of the ryots, and the contingency of drought, and to hasten the profitable returns; in addition to which, the sooner the valuable experience acquired at the Godavery is brought to bear upon the Kistnah project, the more effective it will be.

"54. The loss of revenue by the famine of 1832–33 is estimated at least at one crore, the loss of property at a far greater amount, of life at 200 or 300,000, and of cattle at 200,000 (at the lowest) in Guntoor alone, besides the ruin of 70,000 houses. These facts will, the committee believe, bespeak more effectively than the most laboured arguments, the favourable attention of the Honorable Court of Directors, to the project now submitted, as one of indispensable and urgent necessity. The famine of the Northern Circars in 1833, and that of the North-West Provinces of India at a later period, prove with irresistible force that irrigation in this country is properly a question, not of profit, but of existence.

"The amount of the revised estimate is Rupees 7,49,165–4–2.

(Signed) E. Buckle.
(,,) J. H. Bell.
(,,) Charles A. Orr.
(,,) H. Stokes.
(,,) H. Forbes."

Masulipatam District,
Ibrampatam,
January 26th, 1849.

"APPENDIX A.

(COMMITTEE'S REPORT.)

Statement of expected increase of Revenue in Masulipatam.

Lands.	Present Revenue.	Expected increase.			
		1st year.	2nd year.	3rd year.	4th year.
	RS.	RS.	RS.	RS.	RS.
Boodemair, dug in Fusly 1249, when the revenue was	28,915				
In the seven years since the average has been	15,786				
Difference ...	...	13,129	13,129	13,129	13,129
Poolairoo, highest revenue in Fusly 1256	39,268				
Average of eight years since it was dug, or Fusly 1248, to 1255 ...	15,253				
Difference ...	...	24,015	24,015	24,015	24,015
Under the two channels are 18,452 acres, of which only 6,917 acres were cultivated in Fusly 1256. Remain 11,535 acres, three quarters of which or 8,651 acres will be cultivated at five Rupees the acre ...	...	43,255	43,255	43,255	43,255
Total wet land of the Government lands, acres	55,264				
Cultivated, Fusly 1256	22,738				
Remain ...	32,526				
Deduct accounted for under the channels	11,535				
	20,991				
Which will be cultivated at ⅓rd per annum or	...	34,985	69,970	104,955	104,955
Present wet cultivation acres 22,738 assessed in Fusly 1256 at Rupees 4-12-8 per acre, difference between which and five Rs. the proposed rate will be	...	4,708	4,708	4,708	4,708
Dry land, acres 33,300, of which one-half will be converted into wet land, say 16,000 acres, at five Rupees the acre.	80,000				
Deduct present dry sist at two Rupees	32,000				
	48,000				

APPENDIX A—*cont.*

Statement of expected increase of Revenue in Masulipatam—cont.

Lands.	Present Revenue.	Expected increase.			
		1st year.	2nd year.	3rd year.	4th year.
	RS.	RS.	RS.	RS.	RS.
At 25 per cent. per annum	...	12,000	24,000	36,000	48,000
Zufted estate which will be Government property in February—					
	ACSe				
Total Sarey land 12,868					
Wet land 6,018					
Remain dry ... 6,850					
Of which were cultivated in Fusly 1256 (1846-47) { Wet ... 654 / Dry ... 1,999					
The remaining wet land or acres 5,364 would be cultivated at ⅓rd per annum or 1,788 acres and at five Rupees the acre would give ...	...	8,940	17,880	26,820	26,820
And half the dry land at 25 per cent. per annum would be cultivated wet, and the difference of three Rupees the acre would give	...	750	1,500	2,250	3,000
Rupees ..	...	1,41,782	1,98,457	2,55,132	2,67,882

There are 58,000 acres of enam land in Masulipatam, and the committee would recommend that if the anicut is sanctioned the Board of Revenue should at once make known the terms on which Enamdars are to be given water from the channels."

(Signed) E. BUCKLE.
(,,) J. H. BELL.
(,,) C. A. ORR.
(,,) H. STOKES.
(,,) H. FORBES.

"APPENDIX B.

(COMMITTEE'S REPORT.)

Statement of expected increase of Revenue in Guntoor.

Comparison of 10 years' average sist with that of the best year in the Talooks of —

—	Average from Fusly 1246 to 1257.	Best year's Revenue.	Ayacut acres of the whole cultivable land.
	Rs.	Rs.	
Baputlah	27,846	66,378	9,162
Reypully	16,829	31,663	11,800
Ponnoor	18,253	45,761	15,155
	62,928	1,43,802	36,117
Deduct average sist from best year's revenue	...	62,928	...
Difference Rs. ...	...	80,874	...

But if the whole Ayacut were cultivated and assessed at six Rupees it would give	Rs.	2,16,702
From which deduct average sist as above	,,	62,928
Increase by cultivation of whole Ayacut	,,	1,53,774

In this the existing advantages of the Toongabuddra and Vellatore channels are not taken into account, which may be stated thus:

Average before Channels were opened.

—	Toonga-buddra.	Vellatore.	Total.
	Rs.	Rs.	Rs.
Average before famine	29,857		
Average after famine and before the channel was opened	13,750		
Rs. ...	43,607		
Mean of two averages ...	21,804	4,802	26,606

Average since the Channels were opened.

	Fusly. 1254 to 1257 average.	Fusly. 1249 to 1257 average.	
Rupees ...	36,656	6,494	43,150
Difference ...	14,852	1,692	16,544

Total average increase from existing channels ..	Rs.	16,544
If this sum is deducted from the difference between average and best year's revenue	,,	80,874
	,,	16,544
It will leave	,,	64,330
But if it is deducted from the assessment of the whole Ayacut lands, minus the average revenue ..	,,	1,53,774
	,,	16,544
It will leave for expected increase above the present revenue with the help of the channels	,,	1,37,230

In forming these averages seasons of drought have been omitted, and if these are taken into account, it will make the advantage derivable from the annicut appear much greater.

The assumed rate for irrigating land to be brought under cultivation is taken at Rupees six, which may be called the average of the present cultivation; but a continual supply of water should raise it above this, by enabling the ryots to get two crops of paddy in the year.

The low waste lands in Repully are expected to yield by conversion .. .. ,, 77,860

" Computed increase from the annicut irrigation of low lands now cultivated with red paddy.

Talooks.	Villages.	Last year's full.		Portion to be irrigated.		Magany sists taken of 3 times present sist.	Increase.	
		LAND. ACRES.	REVENUE.	ACRES.	Rs.	Rs.	Rs.	Rs.
Tenally	46	70,307	1,10,869	35,925	52,329	1,56,987	1,04,658	1,86,528
Ponnoor	59	48,576	80,633	25,126	40,935	1,22,805	81,870	
Pruttipaud	13	23,986	51,250	14,870	31,274	93,813	62,539	
Total ...	118	142,869	2,42,752	75,921	1,24,538	3,73,605	2,49,067	

Abstract of increase.

	Rs.	Rs.
From present wet lands the best yield being the standard.	64,330	...
Do. do. the field assessment being the standard	...	1,37,230
From Repully waste	77,860	77,860
From Tenally and Ponnoor red paddy lands	1,86,528	1,86,528
	3,28,718	4,01,618
From Pruttipaud red paddy land (doubtful)	62,559	62,559
Total Rs. ...	3,91,277	4,64,177

(Signed) E. BUCKLE.
(,,) J. H. BELL.
(,,) C. A. ORR.
(,,) H. STOKES.
(,,) H. FORBES.

"*SPECIFICATION of an Annicut and dependent works proposed to be erected across the Kistnah river at Baizwarah.*

"(1) The river at the proposed site is 3,860 feet across, on the crest of the annicut.

Amount of Estimate, Rs. 3,07,063-8-2.

"(2) Of this distance, the annicut will occupy 2,950 feet, the bridge abutments and piers 510 feet, and the sluices, including wing-walls, 360 feet.

"(3) The foundation of the annicut will vary with the character of the river section. Where the bed is deep, it will be filled up to the level of the summer water with rough stone, and where it is high, wells will be sunk in the front and rear of the work, as far as practicable, below the same level.

"(4) Upon these foundations the body of the annicut will be raised alike throughout, namely, with a front wall nearly perpendicular, and a rear curved slope, both of rubble masonry; the space between being filled with rough stone, and the crest covered in with rubble masonry, to be eventually, with the rear slope, capped with cut-stone.

"(5) The height of the annicut above the summer level will be 16 feet, the breadth of the crest 12 feet, and that of the slope (horizontally) 48 feet.

"(6) There will be an apron in rear of the annicut of 90 feet in breadth and 6 to 8 feet average depth.

"(7) The annicut sluices it is proposed to place, one at about 36 feet from each bank, with which and the head sluices they will be connected by wing-walls. The sluices are to have each 15 vents, of 6 feet in breadth, and from 10 to 15 in height. The floor is placed in the drawings at 9 feet below the crest of the annicut, but in the construction it must be fixed

Amount of Estimate for 2 sluices, Rs. 36,345-15-0.

SECTIONS FOR THE KISTN
AS PROPOSED BY THE COMMITTEE
SENT WITH THEIR RE

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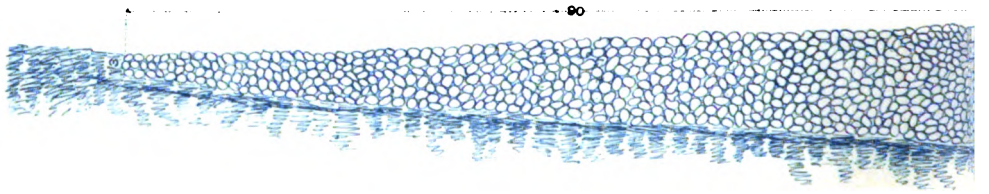

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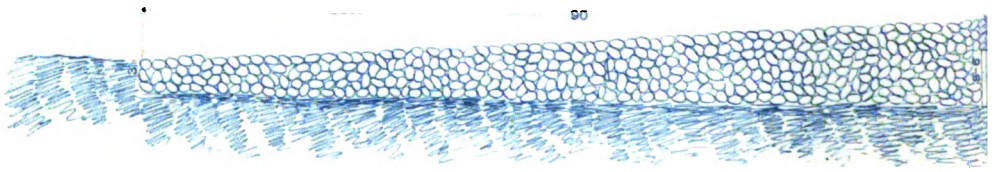

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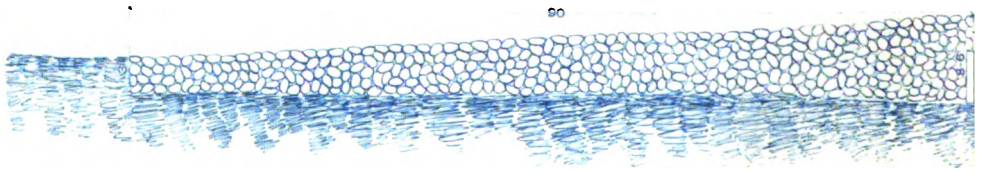
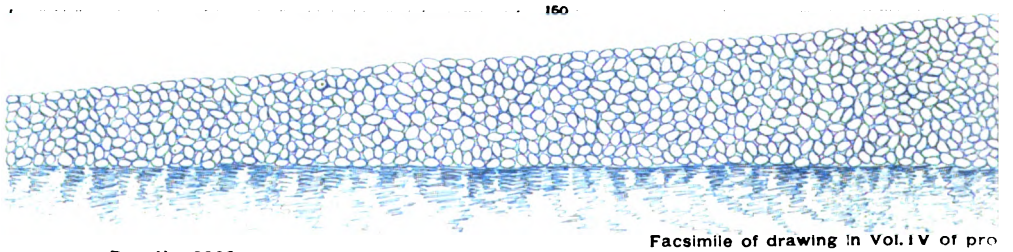




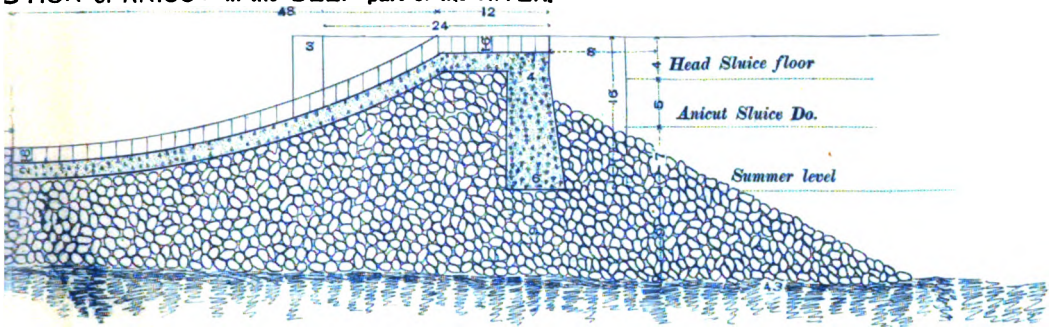
Facsimile of drawing in Vol. IV of pro

Reg: No. 3882
Copies 410

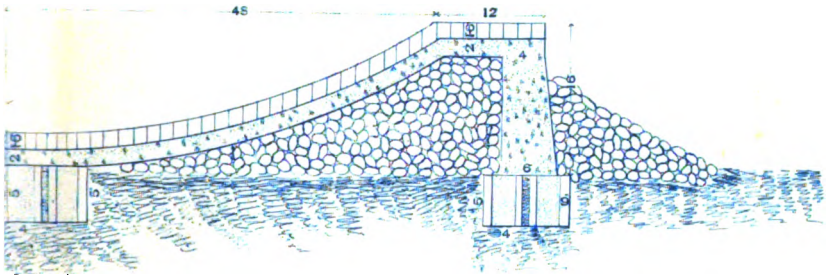
A ANICUT AT BEZWADA.

APPOINTED TO CONSIDER THE PROJECT.
>ORT OF 26TH JANUARY 1849.

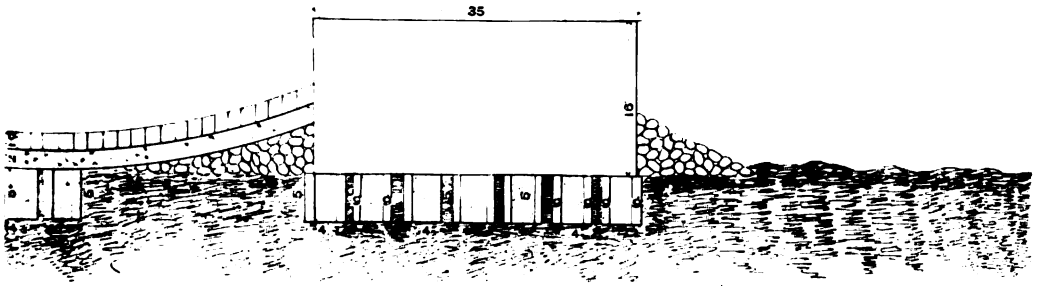
CTION of ANICUT in the DEEP part of the RIVER.



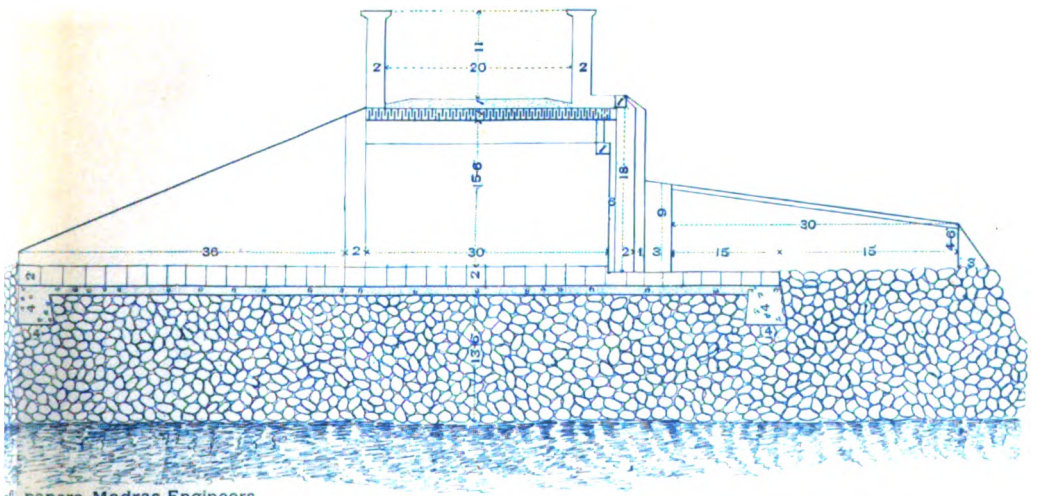
TION of ANICUT in the SHALLOW part of the RIVER.



CUT in the SHALLOW part of the RIVER showing a BRIDGE PIER.



SECTION of ANICUT, "UNDER," SLUICE.



papers Madras Engineers

Photo-Print., Survey Office, Madras.
1897

according to circumstances. The sluices will have front and rear aprons of cut-stone, and a rear apron of rough stone of 150 feet in width, and 10 feet average depth.

"(8) From above each set of sluices an inclined road will lead to the annicut, along which the communication will be carried with facility for the greatest part of the year, until a bridge is built.

"(9) The piers of a bridge of 49 arches, of 61 feet each, are proposed to be built to the level of the crest of the annicut: they will be each 10 feet thick, founded partly on rough stone, and partly on wells, and each abutment 15. The breadth of the bridge will be 24 feet, inclusive of parapets.

Amount of Estimate for 2 sluices, Rs. 34,565-15-2.

"(10) The two head sluices of the channels will be connected, as before observed, by wing-walls, with the annicut sluices on each bank.

"(11) The head sluices will have each 16 vents, in height from 7 to 9 feet, divided by 3 large and 12 small piers. There will be front and rear aprons of cut-stone, and a rear apron of rough stone as usual. The floor will be 4 feet below the crest of the annicut.

Amount of Estimate for 2 locks, Rs. 23,825-12-0.

"(12) Adjoining the head sluices, will be locks for the passage of boats into the channels, having chambers 60 feet long and 16 wide.

Amount of Estimate for locks, Rs. 13,627-1-10.

"(13) To enable boats to return into the river, a detached lock will be built at a convenient place in the Baizwarah channel bank. This work is of the usual description.

"(14) All the sluices and locks will be built of rubble masonry and cut-stone, as shown on the plans; the arches, parapets, &c., only being of brick in chunam.

"*N.B.*—The excess of the estimate above that of Captain Lake is owing principally,

First, to the increased length of the river section now proposed for the site of the annicut, amounting to 710 feet.

Second, to the increase (four feet) given to the height of the annicut, and consequently to its strength.

Third, to the increase of the prices, from 50 to near 100 per cent.

Fourth, to the increase of sundries, contingencies, and superintendence.

Fifth, to the provision of a plant.

"(15) It is farther to be remarked, that the estimate applies only to the same extent of works as that of Captain Lake, whose rough statement of the "probable amount" of "Detail Irrigation works," viz., six lacs, must be added

Report, paragraph 31.

to the estimate of the annicut; with the understanding that it will be very gradually expended; and the same may be said of the items for embankments, roads, &c., amounting to seven lacs more."

(By Order of the Committee.)

(Signed) J. H. BELL,
Brevet Captain of Engineers.

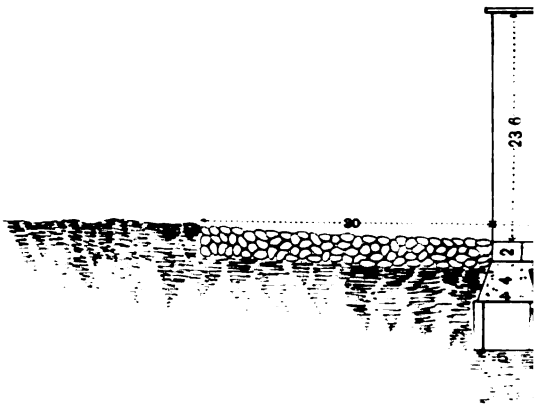
"*ABSTRACT ESTIMATE for the construction for an Annicut and dependent works for the Kistnah River at Baiswarah.*

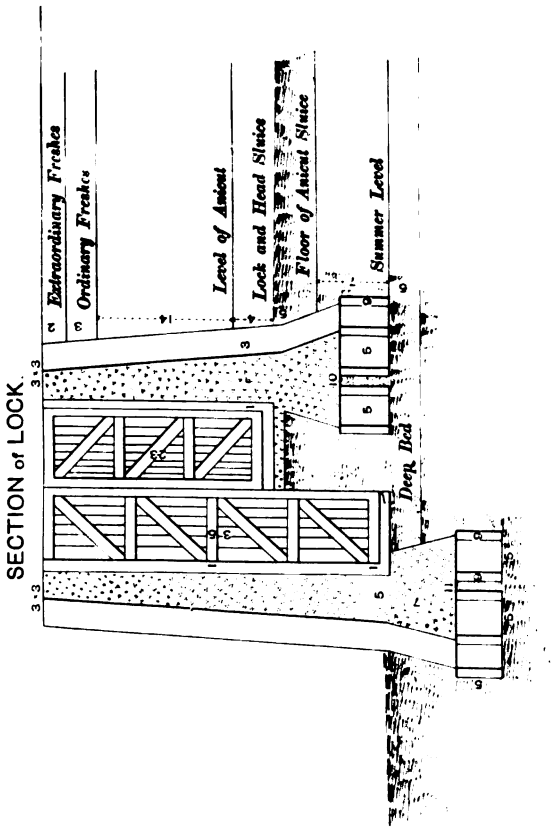
Quantities.	Description of work.	Rate.	Per	Amount.	Total.
	ANICUT.	RS. A. P.		RS. A. P.	RS. A. P.
219,529¼	Cubic yards of rough stone.	0 11 0	Cubic yard.	1,50,926 6 8	
32,404½	Cubic yards of rubble in chunam.	2 6 0	Do.	76,960 1 6	
11,345	Cubic yards of cut-stone in chunam.	5 0 0	Do.	56,725 0 0	
1,496	Wells	7 0 0	Each.	10,472 0 0	
	Grouting	...	...	5,000 0 0	
	Excavation	...	...	7,000 0 0	
	Total ...	...		.....	3,07,083 8 2
	ANICUT 'UNDER' OR 'SCOURING' SLUICE.				
3,744¾	Cubic yards of rubble in chunam.	2 6 0	Cubic yard.	8,893 12 6	
546	Cubic yards of partially dressed rubble in chunam.	3 0 0	Do.	1,638 0 0	
121¼	Cubic yards of archwork in chunam.	3 0 0	Do.	365 4 0	
338¾	Cubic yards of brick in chunam.	2 8 0	Do.	845 15 0	
1,096	Cubic yards of cut-stone in chunam.	5 0 0	Do.	5,480 0 0	
15	Shutters	30 0 0	Each.	450 0 0	
	Plastering and sundries.	...	...	500 0 0	
	Total ...	...		.....	18,172 15 6
	Total for another similar sluice ...	...	...	.....	18,172 15 6

PROPOSED KISTNA A

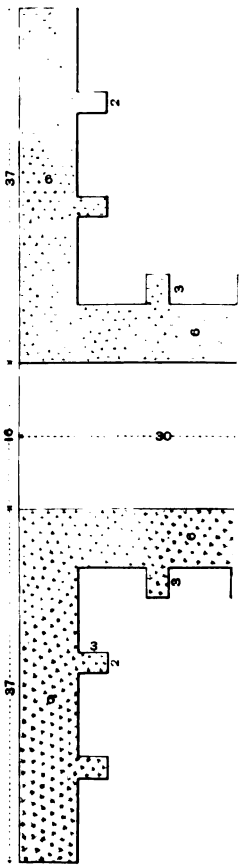
DESIGN FOR HEAD

Submitted by the Com
26th J





SECTION of LOCK.



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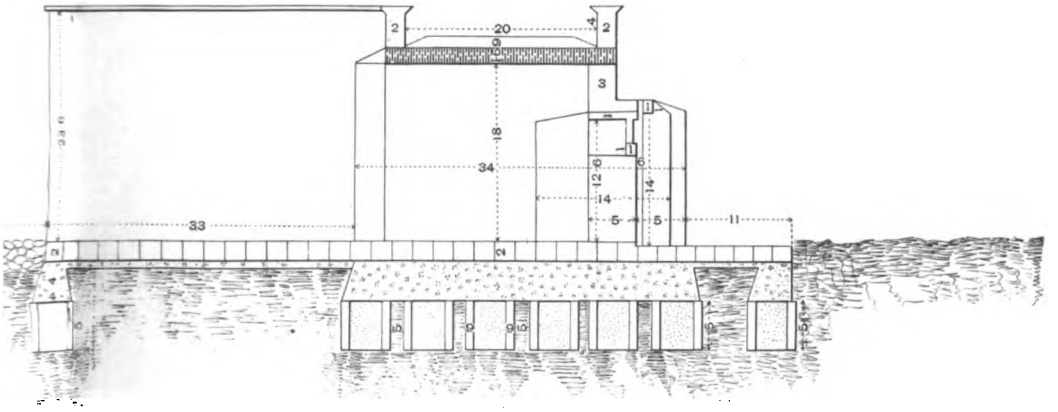
IA ANICUT AT BEZWADA.

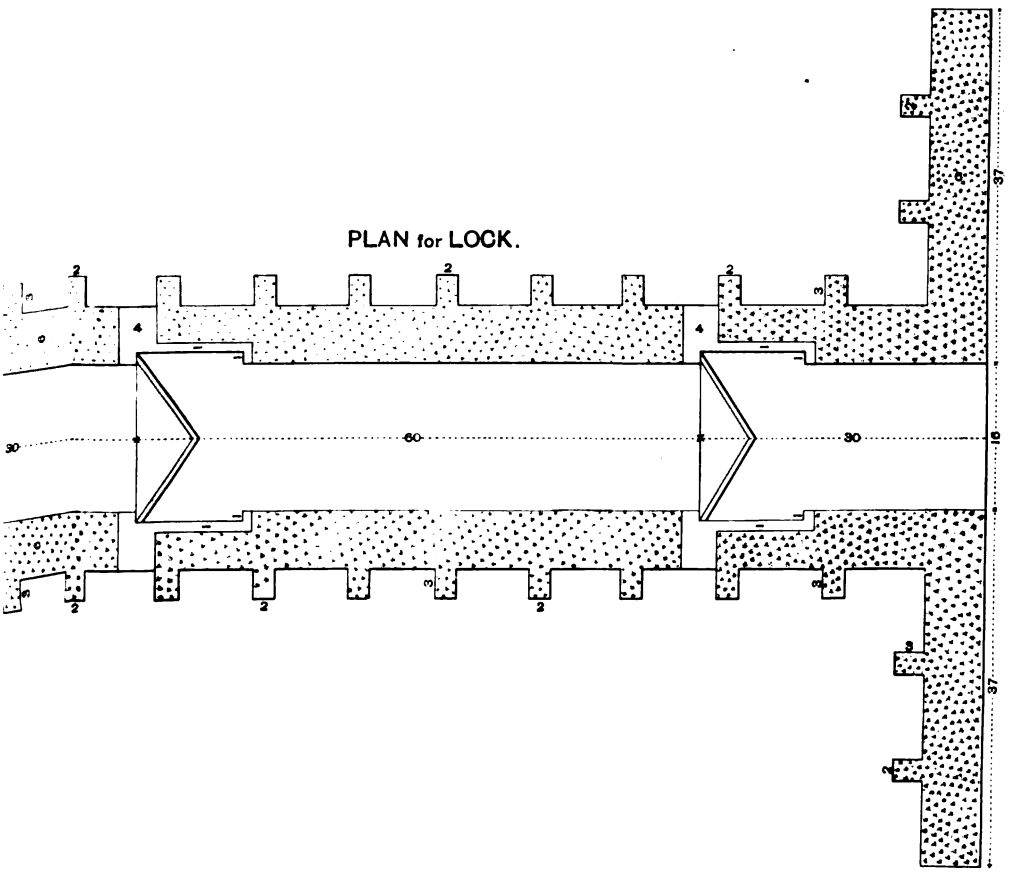
HEAD SLUICE & HEAD LOCK

by the Committee with their Report of 20th January 1849.

SECTION of HEAD SLUICE.



PLAN for LOCK.



om Drawing in Vol. IV of Profl. papers, Madras Engineers.)

Photo-Print., Survey Office, Madras.
1897.

"*Abstract Estimate for the construction for an Annicut, &c.*—cont.

Quantities.	Description of work.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.	Total. Rs.	A.	P.
	HEAD SLUICE.										
2,480¾	Cubic yards of rubble in chunam.	2	6	0	Cubic yard.	5,891	12	6			
270	Cubic yards of archwork in chunam.	3	0	0	Do.	810	0	0			
154⅞	Cubic yards of brick in chunam.	2	8	0	Do.	386	15	1			
850½	Cubic yards of cut-stone in chunam.	5	0	0	Do.	4,252	8	0			
277½	Cubic yards of cut-stone in chunam.	7	0	0	Do.	1,942	8	0			
91	Wells	9	0	0	Each.	819	0	0			
142	Do.	7	0	0	Do.	994	0	0			
900	Cubic yards of rough stone apron.	11	0	0	Cubic yard.	618	12	0			
3,000	Cubic yards of excavating foundation.	0	1	0	Do.	187	8	0			
	Centering to large arches.		...		...	400	0	0			
16	Shutters	30	0	0	Each.	480	0	0			
	Plastering and sundries.		...		...	500	0	0			
									17,282	15	7
	Total for another head sluice ...		...			.....			17,282	15	7
	LOCK ADJOINING HEAD SLUICE.										
2,826	Cubic yards of rubble in chunam.	2	6	0	Cubic yard.	6,711	12	0			
23⅓	Cubic yards of archwork in chunam.	3	0	0	Do.	70	0	0			
39	Cubic yards of brick in chunam.	2	8	0	Do.	97	8	0			
149⅛	Cubic yards of cut-stone in chunam.	5	0	0	Do.	748	2	0			
114	Wells, 4 feet in diameter.	7	0	0	Each.	798	0	0			
2	Pairs of gates with levers.		...		...	3,000	0	0			
3,000	Cubic yards, excavating foundation.	0	1	0	Cubic yard.	187	8	0			
	Plastering and sundries.		...		...	300	0	0			
									11,912	14	0
	Total for another lock.		...			.....			11,912	14	0
	DETACHED LOCK.										
3,408¾	Cubic yards of rubble in chunam.	2	6	0	Cubic yard.	8,095	12	6			
23⅓	Cubic yards of archwork in chunam.	3	0	0	Do.	70	0	0			
83	Cubic yards of brick in chunam.	2	8	0	Do.	207	8	0			
130⅔	Cubic yards of cut-stone in chunam.	5	0	0	Do.	653	5	4			
109	Wells, 4 feet in diameter.	7	0	0	Each.	763	0	0			
2	Pairs of gates		...		...	3,500	0	0			
15,000	Cubic yards, excavation.	0	1	0	C. yd.	937	8	0			
...	Plastering and sundries.		...		...	400	0	0			
	Total ...		...			.....			14,627	1	10

"*Abstract Estimate for the construction for an Anniout, &c.*—cont.

Quantities.	Description of work.	Rate.	Per	Amount.	Total.
	OPENING HEAD OF BAIZWARAH CHANNEL.	RS. A. P.		RS. A. P.	RS. A. P.
516,000	Cubic yards of earthwork.	0 1 0	Cubic yard.	32,250 0 0	32,250 0 0
	Total ...	...		.....	4,48,698 4 2
	OPENING HEAD OF TOONGABUDDRA CHANNEL.				
40,000	Cubic yards, sluice and lock.	0 1 0	Cubic yard.	2,500 0 0	
	Widening and deepening present channel.	...	...	5,000 0 0	
	Rough stone between head and anicut sluice and in other situations.	...	...	5,000 0 0	
	Temporary dams and sundries.	...	...	30,000 0 0	
	Embanking rivers ...	...	...	1,000 0 0	
	Plant	...	...	1,11,407 0 0	
	Opening quarry ...	...	...	7,000 0 0	
	Total ...	...		.....	1,61,907 0 0
	Civil Engineer's pay and tentage for three years.	821 12 5	Month	29,584 0 0	
2	First Assistant Civil Engineer for three years...	291 5 4	Do.	* 10,488 0 0	
2	Second Assistant Civil Engineer for three years.	191 5 4	Do.	* 6,888 0 0	
	Subordinate superintendence.	600 0 0	Do.	21,600 0 0	
	Contingencies	...	...	70,000 0 0	
	Total ...	...		.....	1,38,560 0 0
	Total Company's Rupees.	...		.....	7,49,165 4 2

(By Order of the Committee.)

MADRAS,
30*th April* 1849.

(Signed) J. H. BELL,
Brevet Captain of Engineers.

* *Note.*—These two amounts are miscalculations for double the amounts, viz., Rs. 20,976 and Rs. 13,776, respectively; this was pointed out in the Board's letter, No. 337, dated 25th May 1852, and in sanctioning the increase Government said (in its Minutes of Consultation, dated 11th June 1852), that the extra amount "added to the original estimate will increase it to Rs. 7,66,541-4-2, a sum which by proper management, it is hoped, will suffice for the due execution of the work."—G.T.W.

The Governor, Sir Henry Pottinger, wrote a minute supporting the project, and in July 1849 it was sent on to the Government of India with "Proceedings" No. 680, dated 20th July 1849.

The Government of India lost no time in sending the matter to the "Court of Directors." That body, however, did not hurry itself in dealing with the subject, and not till January 1851 was the following despatch sent:—

Despatch sanctioning Kistna Anicut.

DESPATCH No. 1 OF 1851, DATED 8TH JANUARY 1851.

Our Governor in Council at Fort St. George.

"The letters and paragraphs referred to in the margin relate to a plan for the construction of an anicut across the river Kistnah for the purpose of irrigating portions of the Guntoor and Masulipatam Districts which you have submitted for our sanction.

Letter, dated 20th November (No. 83), 1848, paras. 15 and 16.
Letter, dated 20th July (No. 37), 1849.
Letter from the Government of India, dated 18th August (No. 10), 1849.

"2. This project has been at various times under the consideration of Government since the year 1792, and although circumstances have hitherto prevented its being carried into effect, its feasibility and the great advantages which it would confer on the before-mentioned districts seem never to have been doubted. One of the principal considerations which deterred the Government from carrying the plan into execution was probably that both Guntoor and Masulipatam had been permanently settled, and there would have been difficulty in arranging with the zemindars for the reimbursement of the necessarily large outlay. That obstacle is, however, now removed, the whole of Guntoor and a considerable part of Masulipatam having reverted to the possession of Government.

"3. The present scheme is founded on a report by Captain Lake, the Civil Engineer of the Division, dated the 3rd July 1847. It had been examined and approved by Major A. Cotton, whose experience in such works in Tanjore is very extensive, and who was at the time engaged in superintending the construction of the anicut across the Godavery river.

"4. The plans and estimates were submitted to your Government by the Board of Revenue in the Department of Public Works with a strong expression of opinion in favour of the undertaking. Considering, however, that so important a work should not be commenced without the most rigid scrutiny, you appointed Major A. Cotton, Captain Buckle, Captain Bell and the Collectors of Masulipatam and Guntoor, a committee for that purpose, directing them to assemble at the site of the proposed anicut, and there to examine carefully the plans and estimates, both of expenditure and return, and report

fully their opinion of them, of the feasibility of the project generally, and of the eligibility of the proposed site or the advantages over it of any other they might consider preferable.

"5. The report of the committee is dated the 26th January 1849 and was submitted to you on the 30th April 1849. After having made a most careful examination into the whole question, the committee close their report with the following paragraphs:

[Here are quoted paragraphs 53 and 54 of the Committee's Report already printed; see page 39.]

"6. The question has again been carefully considered by your Government, and you have satisfied yourselves that, adding to the estimate of 7¼ lakhs given by the committee for the anicut alone, the sum of 8 lakhs as the probable amount required for 'Detail irrigation works and embankments,' the total cost of the work when complete will not exceed 15½ lakhs. The committee estimate 'the advantages of the work from the two districts' (by which terms, however, they mean the increase of revenue to be gained by the Government, alone, without including the benefits to be derived by the ryots) when the anicut and auxiliary works shall have been brought into full operation, at Rs. 7,32,059 per annum, or 48 per cent. on the capital expended according to the above estimate. Without going the full length of the committee's expectations, you state that you feel assured that 'a permanent increase of revenue will be gained from extended and improved cultivation which will not be short of 30 per cent. at the least.'

"7. 'The projected work,' you observe, 'thus promises on the lowest estimate to be a highly profitable one by creating additional revenue, and it will be still more so probably, by saving the public finances, and the inhabitants, from a recurrence of the enormous losses caused by the dearths which have afflicted the districts of Masulipatam and Guntoor.'

"8. You accordingly resolved to transmit all the papers to the Government of India with your earnest recommendation in favour of the project. That authority, in addressing us on the subject, state that the contemplated work has their entire approval, and submit their strong recommendation that the plan proposed by the committee should meet with our favourable consideration.

"9. The project has thus been submitted to the examination of those whose scientific acquirements, general experience, and local knowledge render them the most competent to form an opinion as to its merits, and has received the strongest recommendation from those authorities under whose consideration it has passed. We have carefully examined the papers submitted to us, and have satisfied ourselves that every possible means have been adopted to obtain the fullest assurance of the practicability of the proposed undertaking, and that the greatest care has been taken to prevent future disappointment in respect to the estimates both of cost and returns.

Under these circumstances, and concurring fully in the observation of Sir Henry Pottinger, that, independently of the undoubted benefit which must, in due time, accrue to the State by a great increase of revenue, it is 'a positive duty which the British Government owes to the inhabitants of the districts which the anicut is meant to fertilize, to adopt a measure which, under God's blessing, will for ever avert the horrors of famine under which they have before so deplorably suffered,' we readily give our cordial sanction to the undertaking, and trust that matters will be so arranged that the establishment employed on the Godavery Anicut may not be broken up and dispersed, but may be made fully available for the works on the Kistnah.

We are,
Your loving friends,

(Signed) JOHN SHEPHERD.
(,,) W. W. HOGG.
(,,) H. WIGRAM.
(,,) M. T. SMITH.
(,,) F. L. LUSHINGTON.
(,,) W. B. BAYLEY.
(,,) W. J. MELVILLE.
(,,) E. MACNAGHTEN.
(,,) R. MANGLES.
(,,) J. CAULFIELD.
(,,) J. OLIPHANT.
(,,) J. MASTERMAN.
(,,) J. PETTY MUSPRATT.
(,,) H. T. PRINSEP.
(,,) W. H. SYKES."

Delay in beginning work.

But though sanction had now come there was still to be considerable delay before the work was actually commenced. The Government in dealing with the despatch in its Proceedings, No. 31 of 1st April 1851, said: "The Governor in Council resolves to forward a copy of this despatch to the Board of Revenue in the Department of Public Works and to request them with reference to the resolutions of Government already communicated to them to report the measures they would propose for carrying the Honourable Court's intentions into early effect. The preparatory and preliminary arrangements for so extensive an undertaking must necessarily be considerable, and although these should not be made without full care and deliberation, the Governor in Council is of opinion that some advance in them may be effected during the present year so as to admit of the actual commencement of the work in the beginning of

1852, by which time the Godavery Anicut already in profitable operation may be expected to be approaching towards completion."

Colonel Cotton was then written to by the Board asking him, what portion of his Godavari establishment he could spare for the Kistna. In his reply of 31st May he expresses his willingness to spare Captain Orr and others for the Kistna works at once, but says "of course whatever officers are taken away from here will just so far delay the completion of this project, but there is no doubt that it is of more importance to commence the Kistna works than to hasten this." Government however decided that actual works at the Kistna should not be commenced till that at the Godavari was farther advanced. This decision was, strange to say, not communicated to Colonel Cotton, and the advisability of at once carrying on the "preparatory and preliminary operations" seems to have been lost sight of, and the whole matter allowed to drop till Colonel Cotton, whose eager temperament could ill brook the, to him, inexplicable delay, could no longer restrain his impatience, and on 7th January 1852 he sent to the Board of Revenue a very characteristic remonstrance from which the following are extracts:—

* * * *

"3. As the Government have not favored me with their views and intention on the subject, so that I have no official intimation what are the causes, that have led to this most dangerous delay, I am under the necessity of answering such difficulties as I have heard of or can suppose.

"The only difficulty that I have been privately informed has been allowed to prevent the commencement of the works, is the want of officers to superintend it. To this I have to answer that numbers of active, intelligent, able officers and others would be delighted to be employed on these works; there is nothing whatever to prevent one or two experienced Engineer Officers now employed on comparatively insignificant works being placed in charge of it, and if all India cannot furnish three or four others perfectly capable of superintending under their instructions either in the service or out of it, I am greatly misinformed . . . . I can only say that if the Government will place even three or four active officers who are no Engineers at my disposal and allow me to distribute my present Assistants as I may think necessary between the Godavery and Kistna works, I will undertake that the works shall proceed without a check, and with God's blessing be brought to a successful issue. Or if Government will merely order the execution of the work and allow me to find men to execute it, the works shall be carried on effectively.

"4. I may also suppose that it is still said that money can't be spared for it; I have lately in writing about these (Godavery) works, pointed out how completely such a difficulty is proved to be imaginary by what we here

see and I therefore will not repeat it but merely append the Statement of Revenue and Expenditure to show that so far from the general treasury having had to provide money for these works, the money has actually come in faster than it has gone out . . . . I assume therefore that with tolerably effective Revenue management an expenditure of 3 or 4 lacs a year will produce an immediate effect on the collections to the same or greater extent.

"5. Another objection may be, where can you find people enough? To this I answer first that this is a mere question of rate of progress; if we can't find so many people as we might like to employ we should certainly obtain a large number. But further I have reason to believe that employment for the people is the very thing that's wanted in these Districts on various accounts . . . . . I am convinced that nothing would be more beneficial at this moment than a large Government expenditure there. . . . . .

"6. I cannot imagine any more objections that required to be answered; whatever they are, they or others just as valid will be found whenever the work is talked of and I am certain if we wait for a convenient time, the works will never be executed.

* * * *

"8. As the local officer responsible for the state of the Division committed to my charge and therefore bound to lay before Government my views on any urgent matter in which I conceive the welfare of the Division is involved, so far as the case is within the limits of my peculiar duties, I should not perform my duty if I did not thus remonstrate against the delay of a work on which I am persuaded not only the welfare but the very lives of a whole population very much depend. Indeed I cannot exonerate myself from the charge of neglect in not having much sooner entreated the Government to consider this matter . . . . .

"9. Whatever may now occur I thus relieve myself from responsibility of being in any way a party to the further delay of a work so long ago ordered by the Home authorities and of such incalculable importance to a part of the country liable to such awful calamities as Guntoor."

Effect of Sir Arthur Cotton's remonstrance.

This woke everybody up: The Board of Revenue at once addressed * the Government urging the immediate commencement of the work; Government promptly gave the necessary authority, and everything was set going. It was decided that the actual carrying out of the works should be entrusted to Captain (afterwards General) C. A. Orr, who had been the chief † Executive officer in the construction of the Godaveri Annicut just completed.

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* Letter No. 26, dated 15th January 1852.

† See "The Engineering Works of the Gódávari Delta."

CHAPTER III.

KISTNA ANICUT AND HEAD-WORKS—SITE AND DESIGN.

BEFORE proceeding to an account of the execution of the Anicut and Head-works, it is advisable to give a brief description of their site and design.

Site of Anicut.

The site finally adopted for the Anicut across the Kistna was that at Bezwada, which had been almost unanimously recommended by the various Engineers who had considered the subject, and by the Committee whose report has been given in Chapter II. It lies between the two gneissic hills of Bezwada on the left bank, and Sítanagaram on the right bank, their distance apart at river level being only about 3,900 feet. The Anicut does not however run from the middle of the base of one hill to that of the other, but from just below the down-stream toe of the Bezwada hill to the up-stream toe of the Sítanagaram hill, the alignment having been governed by the advisability of placing the work as nearly as possible at right angles to the axis of the stream, and by the necessity for space for the Head-works required above the Anicut at its flanks.

The bed of the river at the place is of pure sand to an indefinite, and as yet unascertained, depth, and its surface was constantly changing, every flood moving the sand banks into new positions and leaving them when the water subsided, at different levels.

Captain Lake in his report of 1847, printed in last chapter, said, "the sections of the river at Baizwarah, taken at various periods, differ much each time; for at one time the deep bed was close to Sítanagaram hill, and in a year or two more it will have changed over to that of Baizwarah," and the Committee in its report (see page 35) says: "The current first sweeping round the Baizwarah hill, and then driven upon that of Sítanagaram, forms a deep bed, constant at the former but variable at the latter hill."

These two deep channels naturally marked the positions for the "Under" or "Scouring" Sluices, which being first built might be used for passing the dry-weather discharge of the river, so that for some five months or so in each year the construction of the Anicut itself might be gone on with untroubled by surface water.

Design for the Anicut and Head-works.

There were practically only two types of weirs possible for the Anicut at Bezwada, that with a vertical drop on to a rear floor, or apron, at or about the level of the bed of the stream, and that with a sloping apron starting from, or just below, the crest of the work. The former had been adopted by Arthur Cotton on the Coleroon, the latter on the Gódávari, both of them rivers with beds, like the Kistna, of pure sand.

When the weir is "drowned," that is, when the water in the lower reach is above the crest, there is not much to choose between the two types, but when there is great difference of level between the upper and lower reaches and the depth in the latter is but small, the case is very different; then the action of the water passing over the work is of great consequence, especially in streams with unstable beds, and it is a matter for anxious consideration whether the vertical overfall, or the sloping apron, form of work, shall be adopted. * With the former the disturbance caused by the impact of the falling water is very violent, but it takes place near the body wall and expends itself in a short distance from it; with the latter form, the water rushes down the slope and is delivered at the lower level with an action which, though it does not immediately cause such violent disturbance as in the case of the vertical overfall, throws the lower reach into a state of agitation, setting up complex under-currents, for a much greater distance from the work, rendering necessary a more extended protection of the bed below the work.

On this subject Major Cotton wrote: † "As in the Coleroon I would prefer building a work with a vertical fall as safer in a sandy river . . in any place excepting one similar to the Kistna, where there is an 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 (Gódávari) 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."

These considerations decided the question in favour of a work with a long sloping apron and extended talus of rough-stone, as shown in the

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* "The Engineering Works of the Gódávari Delta," Chapter III.

† Report on the Gódávari Anicut, dated 14th April 1852.

sections recommended by the Committee given on the drawing facing page 44. That design was however considerably modified in construction as will be seen on comparing it and the Committee's specification with the section given by Captain Orr when reporting the completion of the work (see drawing facing page 73) and with the sections given on plan No. 5, in Volume II.

The chief differences as regards the ANICUT itself were:

Modifications of sanctioned design.

(*a*) All arrangements connected with a masonry bridge over the Anicut were omitted.

(*b*) No portion of the body wall was founded on rough-stone thrown into the river, as recommended by the Committee (see paragraph 3 of its specification), but entirely on a double row of brick foundation wells 4½ feet internal diameter, sunk between 7 and 9 feet into sand, and capped with a 3-feet thick platform of masonry 12 feet wide. On this the body wall, 10 feet wide at base and 6 feet wide at top, was built of rubble masonry for a height of 11 feet and capped with cut-stone, 1 foot thick, making a total height from bottom of wells to crest, of 22½ feet.

(*c*) The *crest* of the Anicut was made at 15 feet above "*Summer Level*," or 20 * feet above so-called "*deep bed*," *i.e.*, one foot lower than originally proposed.

(*d*) Instead of a crest 12 feet wide with a curved *apron* from it of 48 feet length, covered with cut-stone, the apron was constructed horizontal for 20 feet from the rear edge of the 6 feet wide body wall (see (*b*) above), and then sloped down at 1 in 12 for 74 feet, *i.e.*, to 100 feet from front edge of crest; this apron was not covered with cut-stone as proposed, but with large-sized rough-stone carefully packed "*on end*"; at the rear edge of this apron a "bind" or "retaining" wall 5 feet wide was constructed in the mass of stone.

(*e*) The *Talus* beyond this apron retaining wall was continued with a covering of large rough-stone for another 100 feet, making, instead of 150 feet, as proposed by the Committee, a total width of 205 feet, and even this has been subsequently extended by from 40 to 50 feet, whilst the quantity of stone which has been used in the talus is enormously greater than that estimated for (see Chapter IV).

The "UNDER" or "SCOURING" SLUICES were placed at the ends of the Anicut in the positions and of the sizes recommended by the Committee. According to the specification their floors were to be 7 feet

* See Captain Orr's letter, No. 251, dated 9th August 1855.

above the "*Summer Level*," but this was modified by the instructions in the Board's letters of 18th October and of 10th December of 1852, to 1 foot lower or 6 feet above "Summer Level"; their sills are now 6 feet 9 inches above the old datum of "*Summer Level*," or 8 feet 3 inches below the crest of the Anicut as originally built.

The HEAD-SLUICES were not built in the alignment suggested by the Committee, the Eastern (Bezwada) Head-Sluice being placed at right angles to the Scouring-Sluices and close to them, whilst the Western Head-Sluice was placed at the head of the cut to the old Tungabhadra channel some 500 feet away from the Sítanagaram Scouring-Sluices. The sizes of the Head-Sluices were reduced from 16 to 15 vents of 6 feet wide. The level for their floors was according to the Committee's specification to be 12 feet above "*Summer Level*," or only 4 feet below crest of Anicut as then intended, but this was modified by the subsequent instructions referred to, to 3 feet lower or 9 feet above "*Summer Level*"; their sills (probably somewhat raised when new shutters were fixed to them) are now at Bezwada 9·75 feet, and at Sítanagaram 9·22 feet, above the so-called "*Summer Level*," or 5·25 feet and 5·88 feet, respectively, below the Anicut crest as actually originally built.

The LOCKS in connection with the Head-works recommended by the Committee were three, viz.: two Head-Locks adjoining the Head-Sluices, for the passage of boats into the canals, and one "detached lock in the Bezwada channel bank. . to enable boats to return into the river." The last of these was not built as it was evident that when the navigable canals were carried to tide-water as intended, there would be no necessity to provide for the seldom used and precarious river navigation below the Anicut. In the construction of the two Head-Locks the length of their chambers was wisely increased from 60 to 150 feet; it was a pity that the *width* was not also increased from 16 to 20 feet, that being now the width of all the other locks on the through line of navigation from Cocanada to the "Buckingham" ("East Coast") Canal, excepting the Ellore Lock which is only 15 feet wide. The lengthening of the Locks was doubtless due to the recommendation of Colonel Cotton, made when rebuilding the Vizéswaram Lock at the head of the Gódávari Western Delta Main Canal (see Extract from his Inspection Report printed on page 66 of "The Engineering Works of the Gódávari Delta").

Plan No. 5, Volume II, shows the positions of the Anicut and Head-works.

CHAPTER IV.

KISTNA ANICUT AND HEAD-WORKS—EXECUTION FROM COMMENCEMENT IN 1852 TO COMPLETION IN AUGUST 1855.

Captain C. A. Orr selected for carrying out the Kistna Works.

As already stated in Chapter II, the sanction of the Court of Directors was received early in 1851, and a year later, orders were issued for commencement of the work under the direction of Captain (afterwards General) C. A. Orr of the Madras Engineers. No better selection could possibly have been made, for he had just won his spurs, under Colonel Arthur Cotton, by successfully carrying to completion the great Gódávari Anicut, after a four years' fight against difficulties which at times appeared overwhelming, and the extensive experience thus acquired was of the very kind most needed for the Kistna work. This, though the Anicut was rather less than one-third the length of the masonry of its prototype, was a sufficiently formidable undertaking. It was no child's-play to have to construct on pure sand a masonry dam some 15 feet high * and almost three-fourths of a mile long, across the gorge of a river where high floods rose 40 feet and swept upwards of three-quarters of a million cubic feet of water per second past the place. Arthur Cotton had, by his Cauvery and Gódávari Anicuts, shown that such a work was quite possible and had settled the general lines on which it might be done, but to actually carry it into effect required Engineering skill, administrative and executive capacity, energy, and determination, of no mean order. It was because Captain Orr brought all these qualities, and extensive experience, to the direction of the Kistna Anicut that we find the history of its construction to have been, not indeed uninteresting or uninstructive but, comparatively uneventful, unmarked by the frequent occurrence of partial failures which so generally accompanies the execution of similar works.

Regularity of seasons on Indian Rivers.

The dealing with Indian rivers is facilitated by the regularity of the Indian seasons, which gives a considerable period in each year when but little water is flowing, and there need be no fear of floods. That period is shorter on the Kistna than on the Gódávari, because the large

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* See Chapter III.

southern affluents of the former river are reached by the South-West Monsoon rains earlier than are the affluents of the Gódávari, which lie some degrees further north. At Bezwada the "Working season" in the river could not be counted on as lasting more than five months, from January to May, and as Captain Orr did not assume charge of the Kistna works till March (1852), so much of the working season had passed that, especially as none of the preliminary arrangements had been made, it was impossible for him to commence any part of the Anicut or its "Scouring" Sluices in that year. The Board of Revenue however seems, now that the work was at last decided on, to have been in a hurry, for on the 1st July it called on Captain Orr for information as to "the description and extent" of his proceedings since he had assumed charge, and again on the 5th July for a description of the general plan of operations which he proposed to follow.

Operations of working season, 1852.

To the first of these letters he replied that the "operations have been directed to ascertaining the sources whence supplies of materials for present and future use may be obtained, to the providing of such as are required immediately, to the hutting of the small party of Sappers and Miners and of the people collecting at the works, to the clearing away of earth and rock for the laying down of railways into the quarries, to the removal of rock on the Seetanagram side to make room for the Under-sluice, and to the excavations for the Head-sluice, and Heads of channels"; and after giving some particulars of these operations he remarks: "The rate of wages has been fixed at two annas per diem for an able-bodied daily man cooly, and rupees four (per mensem) for the same description of men engaging to work permanently in the quarry. Notwithstanding this liberal scale of remuneration compared with the prices hitherto paid for labour in this part of the country, very few people of either the adjoining districts have come in." It is of interest to note that the wages now paid are fully double those considered "liberal" by Captain Orr forty-six years ago.

Captain Orr's letter about operations.

To the latter of the Board's letters he sent a reply from which the following is an extract:—

"With reference to your letter, No. 458, of the 5th instant, I have the honor to lay before the Board the following statement of the general plan of proceeding I propose to follow in the construction of the Kistnah annicut.

Captain Orr's letter as to general plan of proceedings, and questions of design and execution.

"2. On the subsidence of the freshes, the foundations of the head sluices and locks, on both sides of

the river will be excavated to their full depth, and the masonry of these works be commenced and carried on throughout the season, as far as the pressure of other more important objects will allow.

"3. The foundations of the under sluices, at each end of the annicut, will be laid as soon as the river shall have fallen sufficiently; and their construction will be pushed on as rapidly as practicable, in order that, if possible, the floors may be laid during the season, so as to allow the vents to be made use of the following year, as outlets for the river, while the body of the dam is in progress.

"4. It has been found at the Godavery, that, when the body of the annicut rested on a mass of loose stone thrown in to fill up hollows in the river bed, as at the sites of the various breaches that occurred during the progress of the work, it was not only difficult, but almost impossible, to render the dam water-tight; the leakage at those places being, not mere percolation, as along the rest of the work which was supported on wells sunk in the sand, but strong continuous streams flowing, at a great depth, through the large open interstices of the rough stones, as through inverted syphons. As there can be no doubt that the same thing would occur here, wherever the annicut should rest upon rough stone, thrown in to fill up the hollows in the bed of this river, it is my intention not to fill in these hollows on the line of the body of the work, but on that of the apron, and then to fill up in front to the proper level with sand, on which wells will be sunk, and thereon the annicut be built. In order to facilitate this mode of proceeding, the railways are intended to enter the bed of the river behind the under sluices as nearly on the level of their floors as possible. After the first year, the rails will be carried over the floors on raised temporary piers, to avoid causing any obstruction to the discharge of water through the sluices. These arrangements will of course be modified by the rate of progress, and other circumstances, as the works proceed. It is impossible to determine now the amount of work that it will be in our power to do the first season: I hope, however, to get down all the wells under the body of the work, and to raise that to a uniform height of a few feet.

"5. Except increasing the thickness of the rubble masonry covering of the annicut from two to four feet, I do not think of taking upon myself the responsibility of making any material alteration in the section recommended by the committee; but I am desirous that the question of the elevation to be given to the annicut, and the advisability of building into the body of the dam foundations for piers on which hereafter a bridge may be erected, should be taken into the reconsideration of the Board, and Colonel Cotton's opinion and judgment on these points be ascertained.

"6. From what I have seen of the tremendous power of the fall over the Vijaiswarum branch of the Godavery annicut, which is only about 16 feet above the bed of the river, at the shallowest part below, I cannot look

forward without misgivings to the effect of the somewhat more rapid stream of this river falling over a dam raised 20 feet above the bed of the river at the ford; and having observed some calculations lately made by Colonel Cotton, on the face of a memorandum of levels, that seems accidentally to have come under his notice, my doubts have been strengthened as to the practicability of maintaining in security, a work of such a height, except by the employment of a vastly increased amount of rough material, above that which has been calculated upon. Colonel Cotton there grounds his calculations of the relative command of this and the Godavery annicut, on the supposition that this annicut will be raised to a height of 16 feet above the bed of the ford. As it could scarcely have escaped his mind, that Captain Lake proposed to make the work 18 feet, and the committee 21 feet high, I am led to infer that he considered 16 feet to be the maximum elevation which could safely be given.

"7. Since the annicut, as recommended by the committee and sanctioned, will of itself obstruct so large a proportion as fully $\frac{4}{5}$ths of the bed of the river at the height of the floods, it seems to me out of the question that it can ever be advisable, even if practicable, to still further decrease the area of the remaining water-way by the erection of piers to carry a masonry bridge, grand and beneficial as such a structure would no doubt be. If there be any doubt, as I think there is, of the possibility of constructing, eventually, such a bridge as is proposed over the annicut, it will be well at once to consider the question, in order that, should it be decided against, the expense of the foundations of the piers within the body of the annicut may be saved, and in that case, that we may be freed from the difficult and tedious operation of building these foundations."

* * * *

In this letter it will be seen that Captain Orr deals with interesting questions of design and execution, and it will be convenient to state what was done about these before proceeding with the narrative of the progress of the work.

On the 18th October the Board, advised by the Engineer Officer who, in those days, it had attached to it as a Public Works Secretary, expressed to Captain Orr the following opinions:—

* * * *

Board's opinions on Captain Orr's suggestions.

"2. The Board fully approve of your intention to fill up the hollows in the bed of the river under the body of the annicut with sand instead of stone, but they do not perceive why those under the apron should not be filled up in the same way, and they therefore direct me to request that you will follow the same plan in this respect for the whole work. Should you however have objections to this mode of procedure, you are requested to state them, in order that they may be considered and answered.

"3. With regard to the height of the annicut, the Board direct me to observe in the first place, that you have reckoned it from the zero point of the register, instead of, as they believe it should be, from the mean bed of the river, which appears from the section to be five or six feet higher. If this opinion is correct, the true height of the annicut, as sanctioned, is only at the most 16 feet; but the Board are of opinion that the height to which it is eventually to be raised cannot be properly now determined. The work should be raised gradually, with rough stone on a continuous slope to the rear-most point of the apron, which it will probably be desirable to fix at a greater distance from the front wall than that which the committee have allowed. By proceeding in this way, the ultimate limit of height will be fixed after accurate observation of the effects of successive seasons of freshes; and the covering of masonry may be altogether, or for the most part, deferred to the same period.

"4. In order to allow for a low height of the work, should circumstances render it necessary, the floor of the annicut sluices should, in the opinion of the Board, be four feet above the summer-level or mean bed, and that of the head sluices and lock four feet higher. These levels, it is believed, will answer sufficiently well for any height that is likely to be determined.

"5. The Board agree in your opinion that the proposed masonry piers of the bridge should be omitted.

"6. In conclusion, they direct me to request that you will submit your opinion upon any of the foregoing suggestions, should you think it necessary to do so, or otherwise that you will conform your plan of operations thereto as far as possible."

* * * *

To this Captain Orr replied thus in his letter No. 203 of 5th November:

Captain Orr's reply.

"I have the honor to acknowledge your letter, No. 659, of the 18th ultimo, conveying the Board's opinion on the several questions mooted in my letter of the 30th July.

"2. The Board, while approving of my intention of filling up the hollows in the bed of the river under the body of the annicut with sand, instead of stone, remark, that it does not perceive why those under the apron should not be filled up in the same manner, and direct me to follow that plan for the whole work. My object in proposing to fill up, under the body of the work, with sand, is to prevent the great leakage that would take place, were the dam founded entirely on stone, thrown in to fill up deep hollows; but, as I consider that the stability of the structure will much depend upon the thickness of the rough stone along its rear, where the full power of the over-fall will exert its force, I think it most advisable, while guarding against leakage, by filling in with

sand under the body of the work, to fill in with stone behind. Whatever the section of the annicut may be, whether it be made as proposed by the committee, or of a uniform slope from the front wall to the rear-most point, I believe it so advantageous to get the rough stone to as great a depth as possible, towards the rear, that I shall venture to take upon myself to adhere to my original plan, unless the Board will issue to me positive orders to the contrary . . . .

"3. In reckoning the height of the annicut, I have followed the same course as was adopted at the Godavery, where the annicut has always been considered to be 12 feet above the deep bed, and not 12 feet above its mean level at the time of commencing the work; as may easily be seen by referring to one of the sections taken at that period . . . .

"4. In order to allow of a lower height of annicut than that proposed, I shall follow the Board's instructions, to make the floors of the under and head sluices, as nearly as possible, four feet, and eight feet respectively, above summer level. I beg, however, to point out that such an alteration of the levels of those floors, with a view to raising them hereafter, if it be found possible to build the annicut of the full height, will cause some increased difficulties of construction, owing to the greater trouble requisite to obtain adequate foundations, and to the necessity of waiting till the river has fallen to its lowest point before they can be commenced. As the sluice vents must be built to suit the higher level, the shutters and lock gates must be made four feet deeper than was intended, and by their greater height, and the greater pressure of water against them, they will be rendered more unmanageable than those of the smaller size, which are known to be sufficiently troublesome to work. If, in consequence of the annicut not being raised about 16 or 17 feet, the channels have to be cut down to the level on which the floors of the sluices are now ordered to be laid, an immense additional amount of excavation will be required; and, as was pointed out by the committee, a much diminished area of the delta will be irrigated. The uncertainty of the future level of the main feeders will also materially interfere with the prosecution of arrangements for the distribution of the water."

Alterations in levels of Head and Scouring-sluices decided on.

After considering this letter the Board modified its instructions as to the levels for the floors of the sluices, deciding that those of the "Scouring-sluices" should be at 6 feet above "Summer-level" and those of the Head-sluices at 9 feet above "Summer-level" or 3 feet lower than laid down in the "Specification" submitted by the Committee, but the Board adhered to its opinion as to the advisability of filling up the deep parts of the river under the apron and talus with sand and not with stone. The following is their letter on the subject:—

"1. I am directed by the Board of Revenue to inform you, with reference to your representation respecting the filling of the deep parts of the river at Baizwarah, that they consider,

No. 203, dated 5th November 1852.

"1st. That there can be no advantage in having one part of the apron thick, while all the rest is thin.

"2d. That the deep places are much deeper than there could be any advantage in filling with stone, even if it could be done the whole length of the work.

"3d. On this account it seems clear, that it would be quite a useless expense; and as the sums required to fill up this space with stone would be very considerable, it seems a point of some importance to avoid the expenditure.

"4th. The front part must of necessity be filled with sand as you propose; and it seems as if the loose stones in rear would, if they had any effect, preserve openings into which the sand from under the front of the work might be carried, and thus cause the front masonry to sink; so that it would certainly be safer for the whole work to rest on sand.

"2. After much consideration of your views on the point the Board, upon the whole, conclude that you should bring the whole bed of the river under the work to one uniform level with sand, before commencing upon the stone work. The Board are very anxious not to interfere with your own proposed plan of proceeding; but in this case it appears to them necessary to direct that, on the grounds stated, the work should be carried on as here shown.

"3. With respect to the levels of the floors of the sluices, the Board are of opinion that, to enable you to proceed with them at an earlier date, the floor of the head sluice may be laid one foot higher, and that of the under sluice, two feet higher than was fixed in their letter of 18th October, 1852, thus leaving only three feet between the levels of the floors of the two sluices.

No. 659.

"4. Should you have already commenced throwing in stone into the deep places, that work should be stopped, and the remainder should be completed with sand."

There can be no doubt that the Board was quite right in this matter and that it would have been a useless expense to have *filled* in the deep places with stone.

Till December (1852) no work was attempted in the bed of the river, and the operations consisted chiefly of getting together boats and other plant, opening quarries on the Bezwada and Sítanagaram Hills and laying down tramways in connection with them, collecting lime-stone and other materials, erecting buildings, and excavating the upper portions of the

Commencement of construction work.

foundations for the Head-sluices and Locks and parts of the channels leading away from them. Early in December, however, Captain Orr, thinking that there was no fear of the river rising again in that season, completed the excavations for the foundations of the Head-sluices and Locks and commenced all the masonry work. Scarcely had he done so when the river rose suddenly to a height most unusual at that time of year; it broke into the foundations and submerging the wells, put a stop to the proceedings for three weeks." Operations were resumed on the 5th January (1853), and during the ensuing working season the Head-sluices, Locks, and Scouring-sluices at the flanks of the Anicut, were pushed on with, and well advanced; and some of the foundation wells of the body wall of the Anicut itself were sunk, before the first freshes of the South-West Monsoon of 1853. Then, as though to give a foretaste of its power to those about to meddle with it, the Kistna came down in one of its greatest floods. On 20th July Captain Orr wrote thus:

Unusual flood in December 1852.

High flood, July 1853.

* * * *

"4. As the river has reached a height of about 39 feet on the Seetanagrum register,* this is a greater fresh than has ever perhaps been seen by any man now living. All our masonry has been overtopped by the water, but I believe no damage has been done. It is impossible to tell, till the river falls, what effect on the foundation of the Seetanagrum under-sluice and the portion of the front retaining wall of the annicut there commenced, is being produced by the excessive set of the current on that side of the river; but as the work is pretty well defended by rough stone, I hope no injury will occur.

"5. All the embankments of the river and the channels, throughout both districts, being topped and breached, the whole Delta is laid under several feet of water, and the inhabitants of numerous villages are driven to take refuge on the roofs of their houses, and on trees, where they have been obliged to remain for several days. I fear enormous damage has been caused to the public works, and that the people are suffering severe privations and losses, particularly of cattle."

Out of this trial, such works as had already been constructed came scatheless, but it was clear that the Committee had been mistaken in supposing that a very slight amount of embanking above Bezwada would suffice to keep the river in floods from there overflowing its margin and

* The zero of this "register" was evidently old "deep bed," or 5 feet below assumed "Summer-level."

sweeping over the deltaic lands. On the right side of the river, it is true, only a mile of embankment, to the Undavilly hill, proved sufficient; but on the left side an embankment in many parts of considerable height and section, had to be constructed for about 8 miles to Ibrahampatam, to prevent river floods from sweeping down the valley of the Budaméru; when they have done this even to a comparatively small extent, through breaches in the embankment, they have caused great damage to the Ellore canal and to the lands and works in the Gudiváda taluk.

The original cost of these embankments is not known. After the flood of August 1896 estimates were sanctioned of Rs. 12,200 and Rs. 63,200 for their repair and strengthening, the former sum being for the right, and the latter for the left embankment (see P.M.G., No. 1015 I, dated 13th November 1897).

During the flood season of 1853 the only masonry work that could be proceeded with on the Anicut and Head-works was the finishing off of the Sluices and Locks, but when the river was fairly low a considerable quantity of stone for the apron and talus was deposited in position. As soon as the next working season set in, operations were commenced along the whole length of the Anicut.

Work done to end of January 1854.

The following "Statement" shows the quantities of a work done compared with the estimate, up to end of January 1854:—

KISTNA ANICUT AND HEAD-WORKS.

STATEMENT *to show, in comparison with the Estimate, the amount of work done up to the end of January* 1854, *and its value calculated at the rates allowed in the Estimate.*

Description of work.	Estimate.*		Amount and value of work performed up to the end of June 1853.		Amount and value of work performed from 1st July 1853 to 31st January 1854.		Total amount and value of work performed up to the end of January 1854.	
	Cubic yards.	Amount.	Cubic yards.	Amount.	Cubic yards.	Amount.	Cubic yards.	Amount.
		RS. A. P.		RS. A. P.		RS. A. P.		RS. A. P.
Rough stone	228,602	1,57,164 14 8	34,000	23,375 0 0	122,923	84,509 9 0	156,923	1,07,884 9 0
Rubble	53,916	1,28,056 8 0	29,559	70,202 10 0	7,232	17,176 0 0	36,791	87,378 10 0
Cut stone	16,222 11/12	82,224 9 4	3,485	17,425 0 0	1,082	5,410 0 0	4,567	22,835 0 0
Partially dressed stone	1,092	3,276 0 0	1,803½	5,410 8 0	1,676	5,028 0 0	3,479½	10,438 8 0
Brick in chunam	2,000 29/36	5,428 12 2	1,407½	4,222 8 0	...	0 0 0	1,407½	4,222 8 0
Earthwork, excavating heads of channels, and foundations, &c.	775,000	48,437 8 0	5,38,414	35,683 0 1	252,906	16,430 1 0	791,320	52,113 1 1
Foundation wells	No. 2,299	16,457 0 0	No. 1,004	7,028 0 0	No. 654	4,578 0 0	No. 1,658	11,606 0 0
Temporary dams, contingencies, sundries, plastering, centerings, &c.	...	1,03,800 0 0	...	12,353 3 5	...	0 0 0	...	0 0 0
Plant	...	1,11,407 0 0	...	89,877 15 6	...	31,827 9 1	...	1,21,705 8 7
Pay of officers, superintendence, &c. ...	...	85,936 0 0	...	27,911 11 8	...	14,013 11 5	...	41,925 7 1
Grouting anicut	...	5,000 0 0	...	0 0 0	...	0 0 0	...	0 0 0
Opening quarry	...	7,000 0 0	...	7,303 7 7	...	0 0 0	...	7,303 7 7
Sluice shutters	No. 62	1,860 0 0	...	851 5 10	...	1,449 14 6	...	2,301 4 4
Lock gates	Pairs 6	9,500 0 0	...	0 0 0	...	7,793 6 0	...	7,793 6 0
Embanking river	...	1,000 0 0	...	0 0 0	...	80 4 3	...	80 4 3
Cash in hand, recoverable, &c.	...	0 0 0	...	7,148 1 7	...	21,467 7 5	...	21,467 7 5
Total Co.'s Rupees ...		7,66,541 4 2		3,08,792 7 8		2,09,763 14 8		4,99,055 1 4

* Includes the detached Lock to enable boats to return to the river, which was not built, see Chapter III, page 57.

The season of 1854 proved most favourable for work as during it the "Scouring sluices" were able to pass all the water which came down the river. Advantage was taken of this to push on with the Anicut, and so quick was the progress that by the end of March Captain Orr was able to report:—

Rapid progress in working season of 1854.

"3. The front retaining wall is now built quite across the river to a height of 15½ feet above the Seetanagrum Register, or one foot above the level of the floors of the sluices at the heads of the main channels. It is backed, throughout a great part of its length, with masses of rough stone sufficient, I believe, to protect that part against the action of the freshes; and if the other portions, now only scantily protected with stone, can be equally well backed up before the river came down, the whole work will, I think, be secure. All, therefore, now depends upon the quantity and distribution of the stone that can be quarried and deposited during the next two months."

The progress continued to be satisfactory for those two months also.

Despatch of Court of Directors about supposed disasters to works.

Just when everything was going on so well, the Court of Directors was having an attack of nervousness about the work, as will be seen from the following extract from its Despatch No. 15, 28th June 1854:—

"The Kistna Anicut appears to have been visited by a series of disastrous occurrences from its commencement. The rails and apparatus which were sent from England for the "plant" of the Anicut by the "Bidston," were lost by the wreck of that vessel; cholera broke out among the workmen and occasioned delay by driving them from the works, and on the 20th July 1853 a higher flood had occurred than was remembered by any living person.

"We have not received any professional reports showing the amount of damage done to the works, though the letters of the Collectors indicate considerable destruction of property.

"Up to the end of June last, the total amount expended on the Kistna Anicut was Rs. 3,08,792-7-8, but until the effects of the inundation are fully ascertained, it is impossible to hazard an opinion as to the present condition of the work, nor can it be known how much of the outlay has been wasted."

Of course the "Court" was speedily reassured on the subject and shown that instead of having been exceptionally unfortunate the work had met with fewer mishaps than is usually the case with such undertakings.

Work done in working season 1854.

The quantities of the chief kinds of work carried out in this season between the end of January (see statement printed above) and end of June were—

Rough stone	404,109	cubic feet.
Rubble	243,351	do.
Cut stone	15,255	do.
Brickwork in mortar	1,188	do.
Earthwork	112,118	cubic yards.
Foundation wells	No. 126.	

From the letter sent by Captain Orr with the statement from which the above quantities are taken, the following considerable extracts are given, because they deal with the interesting subjects of (1) great additional quantity of stone required for the Anicut talus, (2) the omission of the "cut stone" with which the apron was to be covered, and (3) the beneficial effects of the works even in their very incomplete state.

Extract from Captain Orr's letter, 272, 11th August 1854.

"5. The estimate, therefore, seems to be in a pretty satisfactory state; but as experience and an extended knowledge of the strength of the current of this river through the gorge where the annicut is placed, teach how extremely hazardous it will be to raise the work to the great height intended, unless at the same time an immense additional quantity of stone be deposited in extent equal perhaps to the allowance of it made in the estimate, a further heavy grant of money will be required, if it be considered indispensable to finish off the work with a covering of masonry and dressed stone; and in that case the estimate of the probable cost might be this,

	Rs.	A.	P.
20,000 cubic yards of Rubble Masonry at 2 Rs. 6 As.	47,500	0	0
15,000 cubic yards of cut stone casing at 5 Rs. ...	75,000	0	0
250,000 tons of rough stone in heavy masses at 10 As.	1,56,250	0	0
Superintendence	48,000	0	0
Sundries, contingencies, plant, &c.	60,000	0	0
Total Rs. ...	3,86,750	0	0

from which deducting money in hand, there would remain to be provided for by a further grant, Rupees 1,90,076, or say two lacs of Rupees.

"6. There appears to me, however, to be no actual necessity for giving a covering of masonry; and I think both it and the casing of cut stone may be omitted with advantage, at all events for some seasons till the body of the work, composed of rough stone, has had time to settle and become consolidated. The annicut, as it at present stands, consisting simply of a

substantial masonry wall, backed by rough stone only partially packed, is quite as effective as if it were covered with masonry, and is far safer, because the stream, instead of being precipitated over a smooth impervious surface, and thereby acquiring a force which on this river would be almost irresistible, is able, on topping the wall, to find its way into and through the interstices of the stone, in such quantities, as suffices to fill the bed below the dam, almost up to the level of the rear portions of it, before any heavy overfall can take place; and the roughness of the surface breaks up and impedes the velocity, so as thoroughly to destroy its power on the bed of the river below the line of the work. For these reasons, and because the masonry cannot be done till after the additional stone is deposited, from the want of sufficient labour to carry on and complete both operations simultaneously, I believe the prudent, if not the only possible mode of procedure for raising the annicut to its requisite height, will be to add to the elevation of the present wall, and to throw in behind it rough stone to the value of the whole of the money in hand; and in this way, as we possess the means of quarrying and transporting a quantity of stone, limited only by the amount of labour we can obtain, and can deposit it in ponderous blocks, we should have no difficulty in raising the present dam during the ensuing season at least four feet more, and in making it up with a section so stupendous as to render it perfectly secure against even the excessive force that the fall of this river, over such an obstruction as would then exist, may be expected to exert. As the raising of the wall might be done in a few weeks when the river has fallen sufficiently low, water would afterwards be retained at a level of five feet above the beds of the main channels, and thereby not only afford a supply for them throughout the hot weather, but also give us the means of transport for materials for the construction of the masonry works in the Delta, which might be commenced and pushed on rapidly, with the bricklayers and stone-cutters who would be available in consequence of the execution of the masonry covering of the annicut being dispensed with or deferred—and thus the earliest possible effect would be given to the project, and the most immediate benefits be derived.

"7. As then the completion of the annicut, according to the original plan and specifications, without an immense addition of the rough material on which the security of the work must entirely depend, is not in my opinion advisable or safe, and as a masonry covering, though it would add to the appearance and finish of the dam, would rather tend to weaken than strengthen it, and would not make it one whit more effective as a means of irrigating the Delta, I recommend that we be permitted to expend the balance, allotted in the estimate for masonry, upon the raising and strengthening the dam, as I have proposed, by simply increasing the height of the present wall, which is amply strong, and by the deposition behind it of as much rough stone as our means will allow.

"8. The excavations, to connect three of the principal existing channels with the annicut, having been so far advanced as to have been available on the filling of the river, a large quantity of water has been flowing into the districts for some weeks past, and all the tanks dependant on those channels, with only a few unimportant exceptions, have obtained a supply with which to enable the ryots to begin their cultivation under very favorable circumstances, although not at such an early period as usual, owing to the extraordinary lateness of the river. As the water admitted into the channels is now under regulation by sluices, and the supply, instead of being precarious and uncertain as heretofore, will even this year be continuous for some four months longer in consequence of the action of the annicut, in even its present state, our operations are already telling, and must be very beneficially felt in the country; as the rains have as yet been scanty and continue to hold off."

The Board of Revenue and Government dealt with the above in the letter and "Minutes of Consultation" from which extracts are given below:—

Consideration of, and decision on, points raised in Captain Orr's letter.

"3. Before, however, entering upon this point (of omitting the masonry covering of the annicut), the Board will notice, with reference to Extract from Minutes of Consultation of the 19th of April, 1854, the Civil Engineer's report upon the present state of the annicut, the actual outlay, and the probable amount required for the completion of the works.

"4. The annicut, it will be seen, has suffered no damage that can be perceived, from the freshes which have passed over it at all heights up to 31½ feet on the river register.

"5. The amount expended to the end of June was Rupees 5,69,867-2-1, and the balance of the estimate Rupees 1,96,674-2-1. To finish the annicut, according to the original design, with a complete covering of masonry would not cost more than the amount of the balance, were it not, in the opinion of the Civil Engineer, absolutely necessary that the work, when raised to its full height, should be very greatly strengthened by the addition of rough stone, at an extra expense of about two lacs. But the Civil Engineer finds the section of the annicut in its present state so favorable to its stability, that he strongly recommends the omission of the masonry covering, and the appropriation of the balance entirely to the completion of the front wall to the intended height, and to the addition of rough stone to the apron.

"6. The annicut in its present state exceeds in dimensions any work of the kind previously constructed in the same relative circumstances; and its form of section, which differs considerably from all hitherto used, has

succeeded so well as yet, that there is every reason to believe that it will prove equally suitable when the height of the work is increased, and its stability put to much greater trial.

"Under any circumstances the additional rough stone to the apron is absolutely necessary; and the prosecution of the operations of the present year till the requisite height and strength are attained, seems clearly the most judicious course. After another season of freshes it may be finally determined, from the observations then made, whether to complete the work with a masonry covering, or to leave it, as it now is, a wall with a rough stone apron. The Board, therefore, strongly recommend that the proposition of the Civil Engineer on the subject of the annicut section may be approved."

"*Extract from the Minutes of Consultation No.* 1263, *dated* 29*th September*, 1854."

"Under all the circumstances represented in Captain Orr's report on the Kistnah annicut, which forms the enclosure to the above letter, the Right Honorable the Governor in Council can see no objection to the proposal made by that officer, in consideration of the present state of the work being so favorable to its stability, to dispense with the complete covering of masonry contemplated in the original design as the finishing of the annicut, and, instead, to appropriate the balance * of the estimate to the raising of the front wall to the intended height with the addition of rough stone to the apron, especially as his Lordship in Council observes that Captain Orr justifies his proposal by solid arguments in its favor."

* Rs. 1,96,674-2-1.

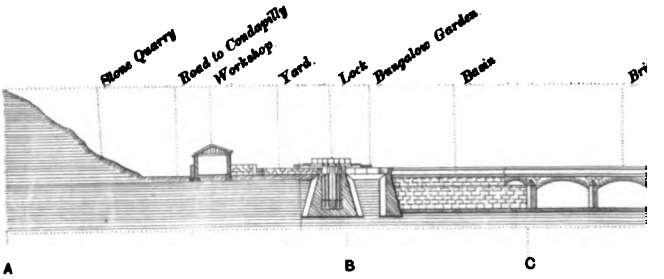
The course advocated by Captain Orr and approved by Government of dispensing with the cut stone covering of the apron did not prove in any way detrimental to the work; only on the top of the body wall 6 feet wide, was such covering (1 foot thick) ever carried out.

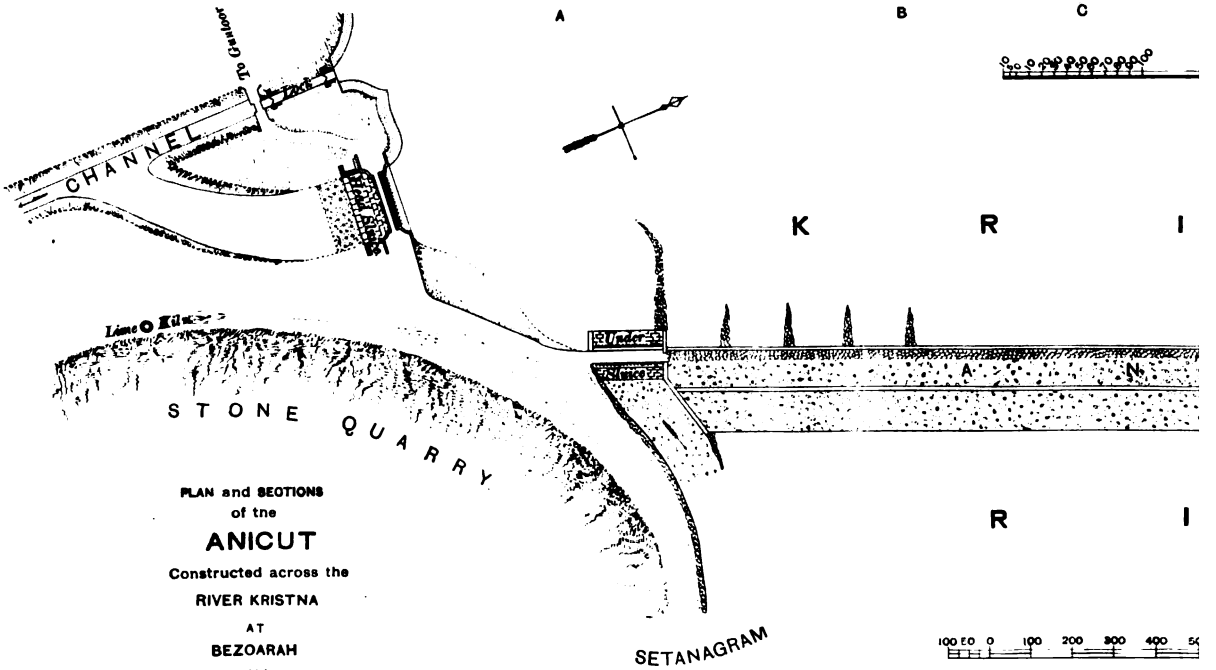
The great amount of stone required for the apron and talus in addition to that anticipated was in accordance with experience at all similar works (see Chapter III, "Engineering Works, Gódávari Delta").

Between July and December (1854) scarcely anything could be done to the Anicut, but about the middle of the latter month the river had fallen sufficiently to allow of the tramways being relaid in the bed of the river and work was resumed with vigour, every effort being directed to getting the Anicut completed in that working season (1854–55), and this was successfully accomplished.

By the end of May Captain Orr was able to report "the Anicut is now so nearly completed that I am bringing operations to a close for the

SECTION on the





PLAN and SECTIONS
of the
ANICUT
Constructed across the
RIVER KRISTNA
AT
BEZOARAH
IN
1853 1854 & 1855

{Submitted by Captain C A Orr with his letter No 251 9th August 1855}

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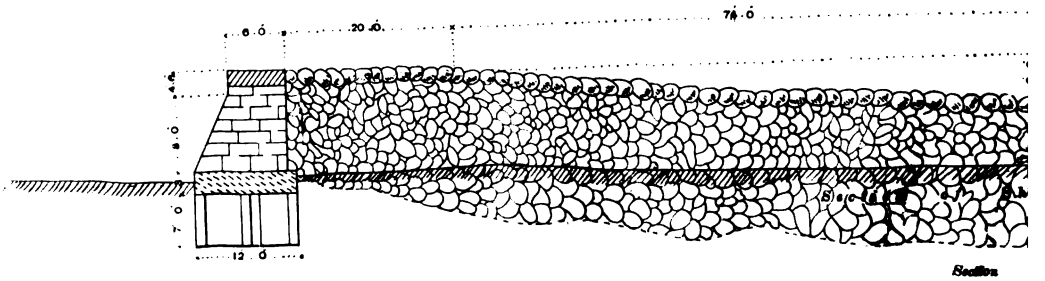

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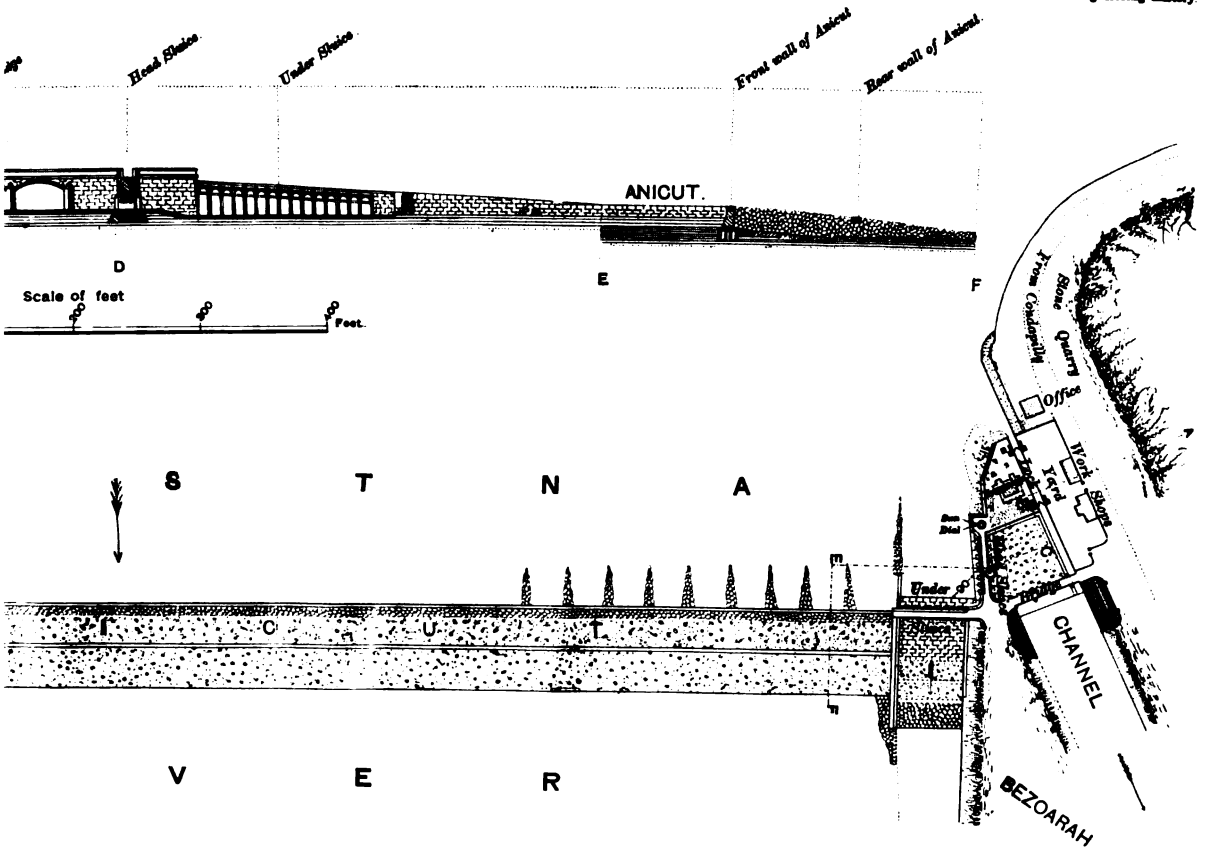
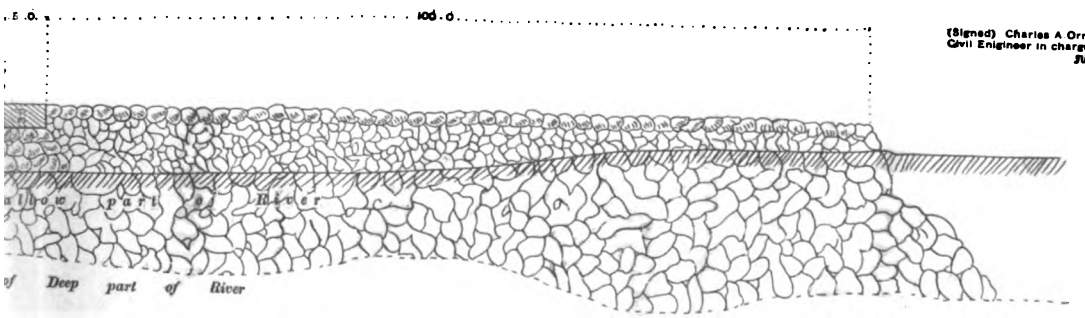
LINE . A . B . C . D . E . F . *looking East*.



Scale for General Plan.

Feet

TION OF ANICUT.



(Signed) Charles A Orr Captain
Civil Engineer in charge Kistna Division
June 29th 1855

Photo-Print Survey Office, Madras.
1897

season in preparation for the approaching freshes and in full expectation of their having no effect on the stability of the work" and, in letter 251, 9th August 1855, from which the following is an extract, he reports the completion of the work :—

Completion of Anicut and Head-works reported.

"*To the Chief Engineer in the D.P.W.,*
Madras.

SIR,

The receipts and expenditure on account of the Kistnah annicut up to the 31st July, 1855, are—

	Rs.	A.	P.
By cash received from the Collector's Treasury up to the end of June, 1855	7,31,789	0	3
By cash received during the month of July ...	16,975	13	7
Total Co.'s Rs. ...	7,48,764	13	10
Expended up to the end of June, 1855	6,88,616	8	0
Expended during the month of July, 1855	10,121	0	3
Advances	5,904	15	0
Articles remaining	15,170	7	1
Recoverable	20,074	12	3
Cash in hand	8,877	3	3
Total Co.'s Rs. ...	7,48,764	13	10

"2. In submitting the above statement I have the honor to report that the annicut has been completed to the extent, and in the manner proposed by me in my letter of the 11th August 1854, No. 272, and approved by Government in Minutes of Consultation, under date the 29th September 1854, No. 1263; that is, the front retaining wall has been raised to a height of 20 feet above the deep bed of the river, and has been backed by a large mass of rough stone consisting of more than half a million of tons in blocks of all sizes up to five and even to six tons in weight, forming altogether a dam nearly 200 feet in width. At 100 feet from the front a second retaining wall is built, having its top 6 feet below the crest; and between the two the surface of the work is roughly packed with stone on end, as tightly fixed together as possible by quarry rubbish rammed into the interstices. Behind the rear wall the dam is continued for nearly another hundred feet, by masses of the largest sized stone. Thus the form and construction of the annicut greatly differ from the more finished but infinitely weaker section originally proposed for it, as the covering of the top and a portion of the slope with masonry of rubble and dressed stone is dispensed with, and in lieu of it a vastly increased amount of material, in the shape of large blocks of rough stone, has been employed. As two freshes of upwards of 30 feet each have now passed over the work, its stability has been well tested, and

apparently with the most satisfactory results; for though the state of the rear portion of the dam cannot be judged of for some time till the river subsides, the crown and slope can be seen to be in good order, and with the exception of a stone displaced here and there, the roughly packed surface seems to stand extremely well. This proves that the masonry covering is not necessary; and therefore, as it can add nothing to the efficiency of the work, but would weaken rather than strengthen it, as shown in my letter above referred to, I would recommend its omission, and that all future outlay on the annicut be directed to the deposition behind it of additional quantities of stone in heavy masses, and to the puddling in front with clay. Some repairs and additions of rough stone will annually be required for some time to come; but the work being of a description to consolidate, and become more and more secure in course of time, the expense of its maintenance must ultimately amount to but a fractional percentage on its cost.

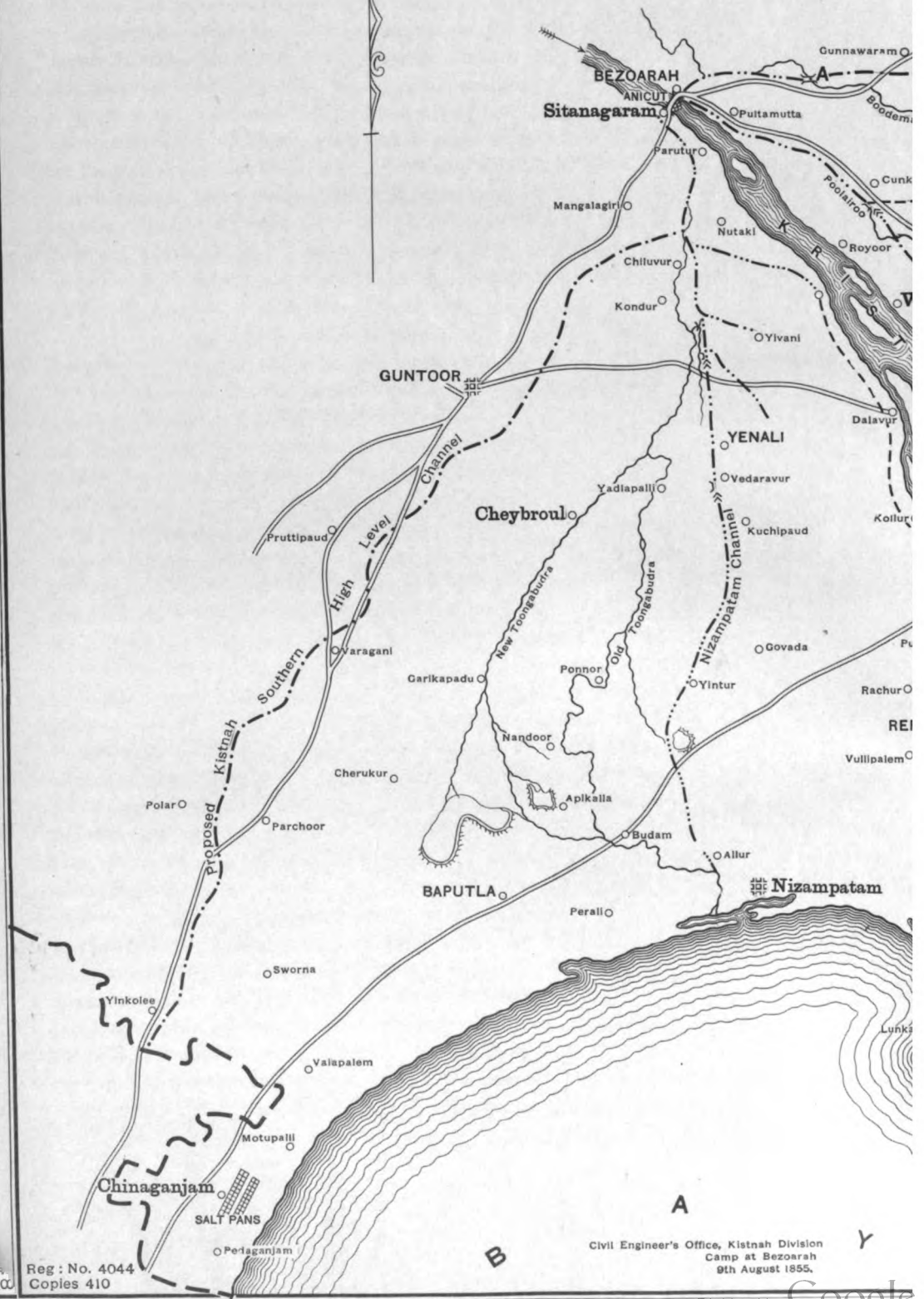
"3. The large sluices and locks adjoining the annicut being, with one partial exception, well and massively built, no apprehensions have ever been felt for their security. The exception is the Seetanagrum under-sluice, which, owing to the utter impossibility experienced in obtaining skilled laborers from the Guntoor district when these operations were commenced, was not so well constructed as the rest of the works, and being founded partly on solid rock, and partly on a mass of rough stone of great depth, shows the effects of unequal settlement, from a slight subsidence of the latter in consequence of leakage taking place through it, in spite of all the precautions adopted to prevent it. The settlement is so trifling as not to endanger the sluices; but the leakage is so serious an evil that it must be checked by extending the front apron several yards, and by puddling extensively all around.

"4. The plan and section accompanying this clearly explain the nature and arrangement of the works now so nearly completed as to be in full operation, filling all the channels that have as yet been connected with them, and conferring on portions of the country the immense benefit of an abundant and continuous supply of water. The accompanying sketch map of the Delta shows that by means of old channels which have been connected with the new main feeders, water from the annicut is being extensively diffused even this season, especially in the Masulipatam district by the many branches of the Poolairoo; but it at the same time shows how little has yet been done to extend irrigation by the formation of the necessary new channels. As the unusually heavy excavations near the annicut, which have involved immense labor and expense are finished, more rapid progress, than has hitherto been possible, might now be made with those channels, had the estimates for them, entered in my budget for the current year, been sanctioned instead of referred to England.

"5. The cost of the annicut and of the portion of the works already sanctioned, to give partial effect to it, amounts to nearly fifteen lacs of

SKETCH MAP
OF THE
DELTA OF THE KRISTNA RIVER
SHOWING THE PRINCIPAL LINES OF CHANNELS
FROM THE BEZOARAH ANICUT.

(Sent with Captain Orr's letter No. 251 9th August 1855)
(From Vol. IV Professional Papers Madras Engineers)



REFERENCE.

Natural and old channels where water is flowing ~~~~

Channels already newly formed, or improved. — · · —

Do. sanctioned, and under formation. — · · · —

Do. projected, but not yet sanctioned. — · — · —

Do. being laid out and estimated for. — — — —

A. Site of Boodemair Aqueduct.

B. Probable position of an Aqueduct to convey water in to the Divvy Purgunnah.

(Signed.) Charles A. Orr Captain
Civil Engr. in charge Kistnah Divn.

Photo-Print Survey Office, Madras.
1897.

Rupees. Fifteen lacs more will probably be required for the completion of the undertaking, and the faster it can be laid out the sooner will the country be benefited, and the treasury reimbursed; while on the other hand, as the improvement of the country is essentially dependent on the spread of irrigation by channels, and on the opening out of cheap communications by their means, any hesitation in sanctioning their extension, throughout every portion of the Delta, can only have the effect of withholding from the people the prosperity that is all but within their reach, and of depriving the State, first of the immediate returns it might obtain on the past outlay, and secondly of the permanent increase of revenue that would result from the speedy and thorough development of the projected irrigation scheme."

In dealing with this letter, two months later, Government remarked (G.O., No.641, dated 5th October 1855).

Orders of Government on completion of the work.

"2. The satisfactory completion of the Kistnah annicut, as now reported is highly gratifying to the Government, and they consider that much credit is due to Captain Orr. He has evinced great professional skill and judgment in conducting this vast and difficult work, and has set an example to the officers under him by his forethought, his constant attention to his duty, the systematic and judicious arrangements he has made, and the zeal and energy which have on all occasions characterized his proceedings; and the Government have much pleasure in recording their recognition of his valuable services."

Scant notice of successful execution of the works.

And so one of the boldest and most useful engineering works in India—a work which has conferred inestimable benefits on hundreds of thousands of human beings, and on which is now directly dependent a revenue of between 20 and 30 lakhs of rupees a year—was brought to completion without any flourish of trumpets, with merely a more or less perfunctory official acknowledgment of the services of the officer who had directed the operations, and without a word of commendation for the staff of officers and subordinates to whose energy and devotion was largely due the successful completion of the work.

Total cost of Anicut and Head-works.

The total cost of the "Anicut and Head-works," including the excavation of the heads of the two Main canals, was Rs. 7,72,186.*

* It is of interest to note that the Railway bridge, built in 1890–93, near the Anicut and of the same length as it, cost between five and six times as much as the whole Anicut and Head-works.

CHAPTER V.

THE ANICUT AND HEAD-WORKS SINCE CONSTRUCTION.

COMPARED with the Gódávari Anicut and Head-works, those of the Kistna had for many years after construction an uneventful history; none of them has ever been destroyed nor, till of late years, have any of them given cause for serious anxiety. Recently however they have fallen on troublous times which require notice; and there are also matters of considerable interest connected with them which it seems advisable to deal with in a chapter immediately following that which has given an account of the construction of the works.

Proposed Bridges over the Anicut.

AS REGARDS THE ANICUT ITSELF: It will be remembered * that provision was made in the sanctioned estimate for building with the Anicut, piers for a masonry bridge of 49 arches of 61 feet span over the whole length of the work, but that, on the recommendation † of Captain Orr, those piers were not built. In 1854 however he revived the idea of bridging the Anicut, but with a *timber*, instead of a masonry, structure, and with his letter No. 416, dated 20th December 1854, he forwarded plans and an estimate of 2 lakhs for the work, which received the sanction of the Government of India. Thirty bays were erected at an expenditure, including cost of timber obtained but not worked up, of Rs. 1,51,760, when further progress was arrested by the restrictive orders issued on account of the Mutiny. Before the work could be resumed it became evident from the effect of the portion which *had* been carried out that there were great drawbacks to such a structure; it was accordingly decided ‡ not to proceed with it and to remove what had already been done, selling the timber, or using it up on other works.

Proposal for timber bridge abandoned.

On this being reported to the Government of India it somewhat unkindly remarked "The Government of Madras subjects itself to a charge of inconsistency in having strongly recommended in 1855 a work which in 1859 and after considerable expenditure it declares to be needless and objectionable."

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* See Specification, clause (9), Chapter II. † See his letter, Chapter IV.
‡ See G.O., No. 1068, dated 16th May 1859.

The idea of a bridge over the Anicut was thus wisely laid to rest for ever, and till the construction of the Railway * bridge in 1893 all the traffic had to continue to be carried across the river in boats when the water was passing over the crest of the Anicut; during the "dry seasons" however, when water was below the crest, the Anicut itself was, and is, used as a roadway, its stonework being at such times protected by a thick covering of sand.

Anicut not high enough.

Within a very few years of the completion of the Anicut it became evident that it was not high enough, with reference to the level of the sills of the Head sluices and the "Main" Canals from them, to secure to the delta a sufficient supply of water when the season of floods was past and the river stood but little above the crest of the work. To meet this difficulty it became the custom at the close of each flood season to raise on the crest of the Anicut a rough stone wall 4 feet high and 6 feet broad; this was removed before the first freshes and the stone of which it was constructed was used in repairs of the apron or added to the "talus." This arrangement remained in force till 1891; the wall could not be put up till the river had fallen to but little over the anicut and then it took considerable time to bring the stone in boats and place it in position; also even when completed there was of course great leakage through it, so that at a critical time of year for the wet crops, there was a sad waste of much needed water. At last the wet cultivation dependent on the Anicut had so increased that it became evident that a more efficient arrangement was nvcessary and in 1890 the then Chief Engineer for Irrigation (Mr. Walch) wrote as follows in his Inspection Notes for January 1890:—

Raising Anicut by 1 foot solid, with grooved posts to take planks.

"The usual rough stone dam has been placed on the crest of the anicut to keep water as high as possible after the season of freshes, but of course it leaks much. It has long been recognised that as cultivation extended, it would be necessary to retain the water, in the season when there are no floods, at a higher level than is now possible. It is not advisable to permanently raise the crest by much, which would not only subject the work to more violent action but would also raise the level of the river above the work during floods and necessitate raising and strengthening embankments and head-works. Falling shutters which would remain on the work are not considered suitable, but I think that an adaptation of the system which, though somewhat rough, has been found perfectly efficient at the Gódávari

* With footway over top booms.

anicut may answer here. I propose to raise the anicut without disturbing the existing crest, by placing on it concrete one foot in depth (edged with rubble walls) in which will be embedded grooved cast-iron posts 2 feet 3 inches high, like those in use at Dowlaishweram, between which planks can be placed when necessary. The one foot of raising and the cast-iron posts will not raise the flood level very appreciably, and it would be only the concrete cap that would be at all disturbed if posts were knocked out by floating bodies, which is not likely to be more often the case than in the Gódávari, as it is not till the freshes have risen considerably above the level of the top of the posts that drift of any size or in any quantities comes down. I have given the necessary instructions for at once trying the system on a short length of the anicut and the trial will show if there is a fair prospect of success and will furnish data from which an estimate could be prepared."

In the following season the arrangements thus proposed were fully carried out. They answered well and in his Inspection Notes of March 1893 the then Acting Chief Engineer for Irrigation (Colonel R. R. E. Drake-Brockman, R.E.) reported thus: "The raising of the Anicut and the insertion of iron posts and planks has had a very beneficial effect in maintaining a full supply in the canals this season, which however was a very favourable one. The maximum flood (of 1892) rose to 16 feet on the crest. The lower aprons have suffered no abnormal displacement."

Removal of the grooved posts and planks and building up a further 2 feet solid.

In the following year (1894) however it was decided to "raise* the crest of the Anicut by a continuous wall of masonry to the level of the top of the existing shutters," and the work was at once carried out. The Anicut was thus raised to 3 feet above its original height, and the apron immediately in rear of the body wall, instead of being flush, or nearly flush, with the crest became 3 feet below it. No provision was made for so strengthening the surface of the apron as to fit it to stand the overfall which would thus be brought on to it at certain stages of the river, and no extension of the talus was carried out. The result was almost a foregone conclusion and deserves the careful notice of those who may be called on to deal with raising existing weirs. On the subsidence of the floods of 1894, in which year the raising had been carried out, the Superintending Engineer had to report as follows:—

Damage to Aprons and talus of Anicut in 1894.

* Note by the Chief Engineer for Irrigation, with Proceedings of Madras Government No. 330 I., dated 11th April 1894.

"I have the honour to inform you that the apron of the Kistna anicut has been seriously damaged during the last few months. The scours were noticed when the first heavy freshes came down the river in July last, and their position was located as far as possible by observations from the bank.

"2. The approximate dimensions of the holes have now been ascertained and plotted and an estimate is under preparation for the necessary repairs. The two largest holes are respectively 750 and 250 feet long, 20 feet wide and about 12 feet average depth. There is also a very deep scour hole below the under sluices on the Bezwada side, but not in a position to cause damage to the under sluices. The anicut body wall has also cracked in one place, but at present it is impossible to say whether this is due to settlement or not.

* * * *

"4. It has been found that the retaining walls, some paralled and some at right angles to the axis of the anicut, have stood well, and the first work I propose to carry out is to build a retaining wall parallel to the anicut and about 20 feet from the crest along those portions which have suffered most severely for want of such additional protection.

"5. The scours are due to the height of the crest above the apron, viz., 3 feet, and I propose, *if time permits*, to try the experiment of putting in one or two steps to reduce the present heavy fall on to the apron. It will, however, be very difficult to get the anicut put into proper order before next season and there may not be time to carry out more than a short length of these steps.

"6. The scour hole below the under sluices is due to the training bank of the railway bridge, but as it is on the site of one of the bathing ghâts to be built this year, I hope that when once we have repaired the damage and built the steps, the scour will be removed into the bed of the river and that there will be no serious damage in future years.

"7. I hope there will be no delay in obtaining funds, as, if not thoroughly repaired this year, the anicut will certainly be breached some time next year."

And in the Administration Report for 1894–95, the following appears:—

"Very extensive special repairs to the Kistna anicut were rendered necessary by the formation, during the 1894 irrigation season, of deep holes in the apron just below the crest, and in the river bed below the apron. These latter holes were filled in with sand. The scours of the stone apron immediately below the crest were very extensive, extending for an aggregate length of 1,320 feet and being of average section 20 × 12. The maximum depth of any scour hole was 18 feet below crest of anicut or 5 feet above the bottom of the foundation of the body wall. The apron was repaired with rough stone packing surfaced rubble masonry 2 feet thick.

In addition, a longitudinal retaining wall 20 feet from the crest and 4½ feet thick was built at the site of scour holes with cross or binding walls either of piles or masonry at 20 and 30 feet intervals . . . . The fact that injury to the Anicut apron had occurred was first noticed on the 16th July 1894 when the water was rising for the first and greatest * flood of the year."

These repairs proved sufficient for the following year when there was no considerable flood in the river, the highest having been only 12½ feet over the new crest.

Flood of 1896 and serious damage.

But the floods of 1896, which were exceptionally high, rising to 1'·26 above any previous record,† again proved the danger of the alteration made to the body-wall of the Anicut without sufficiently strengthening the apron and without adding considerably to the talus; the work was again seriously damaged and alarming holes formed in the bed of the river below it.

Damage thought to be due to Railway Bridge.

The Superintending Engineer (Major W. L. C. Baddeley, R.E.) was of opinion that by far the greater part of the damage was due to the Railway works below the Anicut, but to this the Railway Engineers strongly demurred, and a discussion ensued which is of such general Engineering interest, as well as of such importance in the history of the anicut, that considerable extracts will be given from the various reports, &c., on the subject. For a clear comprehension of them it is necessary however to first describe the positions of the Railway works with reference to the Anicut, and to state the considerations which governed their location.

Considerations which governed site and size of Railway Bridge.

When, in 1890, it was decided to build a bridge for the East Coast Railway over the Kistna at Bezwada, the site selected after careful consideration was 2,400 feet below the Anicut, this being as far down the river as was possible without forcing the Railway line into difficulties with the three Canals into which the Eastern Delta Main Canal branches at about 3,300 feet from its head. The Engineer-in-Chief of the bridge (F. J. E. Spring, Esq., C.I.E.) decided on spans of 300 feet and wanted to have only ten of them, but "in deference ‡ to the wishes

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* Only 14·5 feet above new crest, a very moderate flood.

† In July 1882 the river rose to + 66·29, in August 1896 to + 67·55, but in the latter year the Anicut had been raised 3 feet, so that the depth actually passing over the crest was 1'·74 greater in 1882 than in 1896.

‡ Mr. Spring's paper in "Engineering," July 3rd, 1896.

of the irrigation authorities . . . . . 12 spans were ordered by Government to be adopted" and the length of the bridge is practically the same as that of the anicut. The river, which is much narrowed at the gorge where the anicut is built, widens out immediately below it and was at the site of the bridge 4,920 feet broad, so that about 1,250 feet had to be closed by embankments blocking up some 18,000 out of 136,000 square feet through which a high flood before discharged. At first it was proposed to place the bridge symmetrically with the anicut, so that the centres of the two works would be opposite one another. This however would have necessitated the closing of much of the permanent deepest channel of the river which there ran near the right, or southern, bank, and the Engineer-in-Chief considered that it would be better to bridge the natural main channel than to close, or partially close, it, because "if a new deep channel should form and extending back to the rear apron of the anicut should find itself opposite a place where in the old days the river was shallow and the anicut consequently correspondingly weak, the consequences might be disastrous not only for the great irrigation interests, but for the bridge itself." The then Chief Engineer for Irrigation (Mr. G. T. Walch) agreed with this view and approved the newly suggested site for the bridge, which is shown on the "sketch" facing next page. As in the new position the training bank to the right abutment of the bridge was so retired as to hug the margin of the river, the other training bank had to be correspondingly advanced; the portion of the river bed blocked by this arrangement was between 18 and 19 feet above the low water level,* and therefore it was only in considerable floods that any water passed over it, and then with, of course, a less mean velocity than at the deeper parts of the river. The training bank was arranged with "easy curves tangential to the down stream masonry works of the north flank of the anicut" and it was thought that this would not result in any serious aggravation of the "swirl" which always occurred below the under-sluices when open whilst water was at the same time passing over the anicut. The training bank was constructed in the working season of 1892 and the bridge was opened for traffic in 1893.

Discussion of causes of damage to anicut.

Returning now to the discussion of the causes of the damage to the anicut, the following extracts are given from the Superintending Engineer's report, No. 1244-K., dated 13th August 1896, written immediately after

* See "Section," opposite page 84.

the high flood of 1896 and printed with Proceedings of Madras Government No. 789-I., dated 29th September 1896 :—

"9. The survey I attach to this letter shows how very much the river has been contracted by the bridge and north training bank, and when it is considered that the bulk of the water passes through the nine spans commencing from the northern side, the reason for the heavy scouring action that now is going on below the apron, near the Bezwada under-sluices, is not far to seek. The bridge has twelve spans,—the spans 1, 2, 3 commencing from the right bank, do comparatively little work ; 4, 5, 6, 7 and 8 pass the bulk of the water ; 9, 10, 11 and 12 do more than 1, 2 and 3, but much less than the centre spans.

The Superintending Engineer's views on the subject.

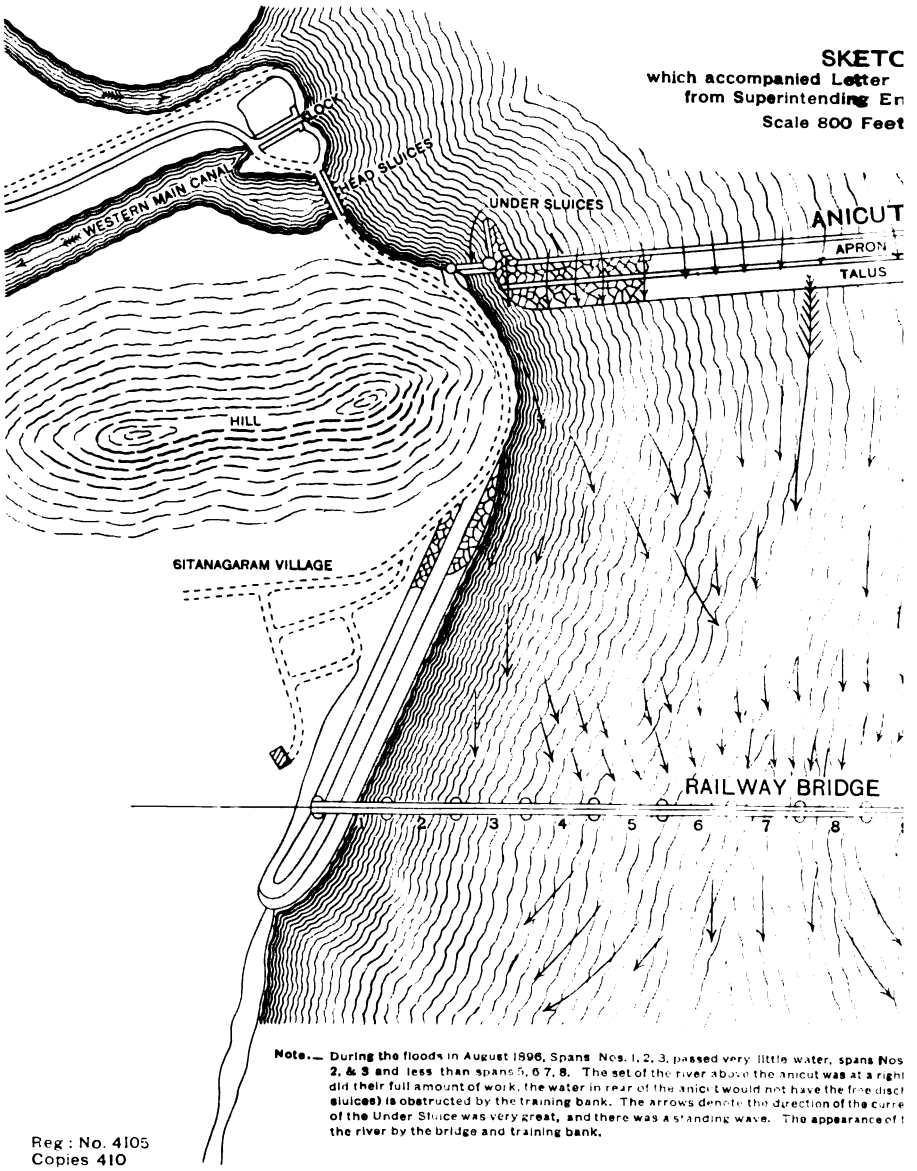
"10. It is an axiom for the proper situation of an anicut that there shall be the freest possible escape for the water in rear ; but what is the case at Bezwada ? The original spread of the river has been throttled by the bridge and training bank, and during the flood the velocity of the water passing through the centre spans of the bridge was so great that, looking down upon it from the bridge, the effect was not that of water passing rapidly under a bridge, but more like the effect observed when water is discharged through an under-sluice.

"The effect of this contraction is to produce back currents and whirlpools, which last year scoured out a hole 50 feet deep in the place referred to, and this scour hole will have increased this year, for, during the flood, the back currents and disturbance near the under-sluices were most marked.

"As a proof of the evil effect produced by the bridge and training bank, I may observe that, since the construction of the bridge, a shoal of sand has been steadily increasing in size close to the north protection bund.

"11. I must also point out that if the scour I allude to works back and takes down the under-sluices, it may cause a breach into the canal, which disaster would be equivalent to the failure of head works, and the consequences would be most serious as the Eastern delta system would be destroyed.

"12. It appears to me from an examination of the survey that the water passing over the anicut, which is 3,700 feet average length during floods, passes into a basin which is contracted at its mouth by the fact that the centre spans of the bridge pass the bulk of the water. How far this tends to raise the level of the water above the anicut I cannot say, but about the back currents and disturbance and consequent danger it causes to the anicut, there is not a shadow of a doubt in my mind. I may remark that this is no new theory of mine. I have considered the protection bund a danger to the anicut ever since I have been in charge of the circle, and the state of the river below the anicut on the Bezwada side during the flood was such as to convince me that the interests of the anicut demand a freer escape of water



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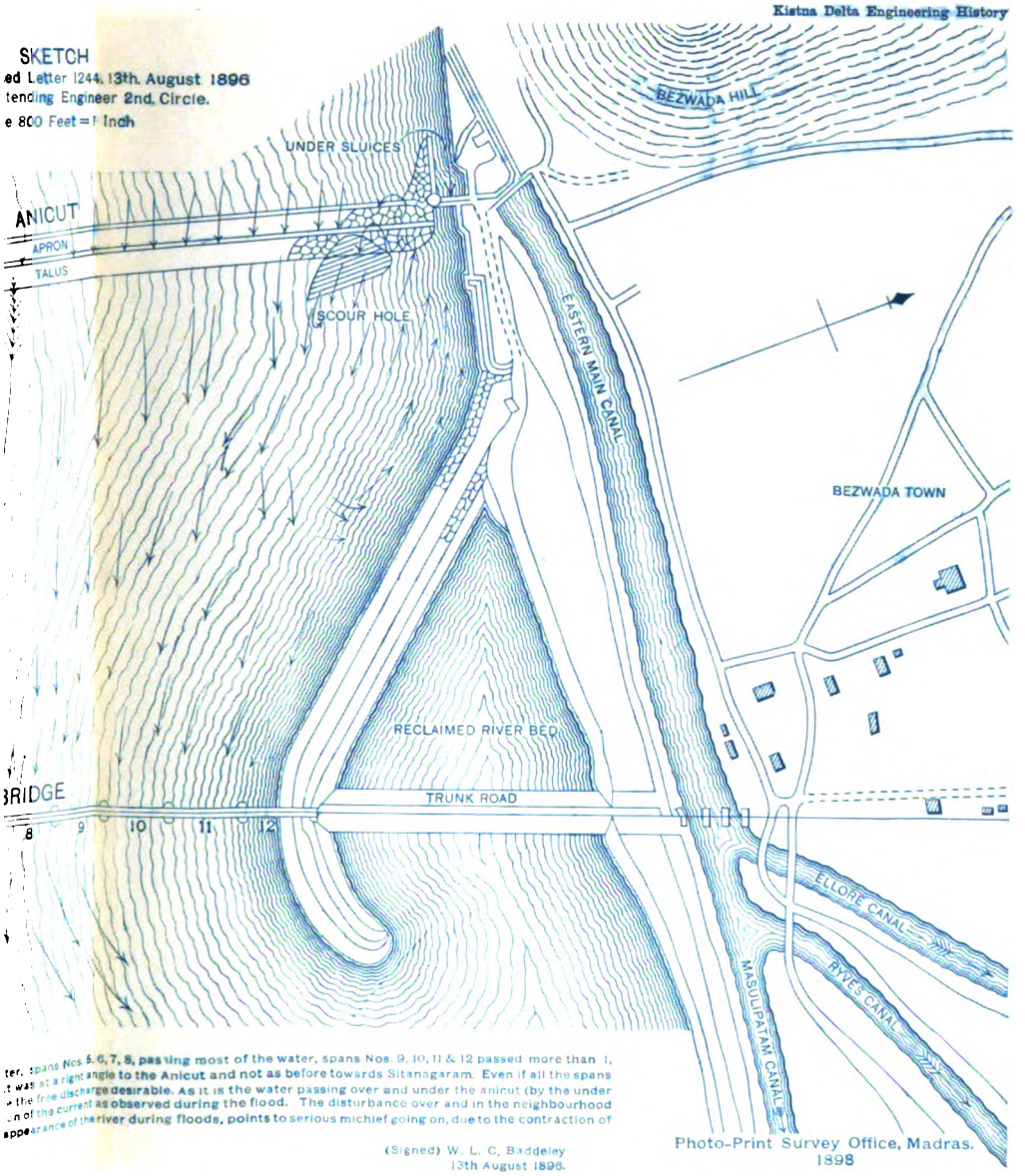
SKETCH
ed Letter 1244, 13th. August 1896
tending Engineer 2nd. Circle.
e 800 Feet = 1 Inch



ter. Spans Nos 5, 6, 7, 8, passing most of the water, spans Nos. 9, 10, 11 & 12 passed more than 1,
t was at a right angle to the Anicut and not as before towards Sitanagaram. Even if all the spans
the free discharge desirable. As it is the water passing over and under the anicut (by the under
on of the current as observed during the flood. The disturbance over and in the neighbourhood
appearance of the river during floods, points to serious michief going on, due to the contraction of

(Signed) W. L. C. Baddeley
13th August 1896.

Photo-Print Survey Office, Madras.
1898

in rear of it. The matter, in my opinion, is one that must be decided chiefly from the point of view of the responsible Irrigation officers. To allow the bridge to continue in its present state is to court disaster to the Eastern delta system. I must also state my earnest conviction that the danger is one that will increase every year so long as the bridge is allowed to remain as it is."

Mr. Upcott's views.

Government at once referred this to its Consulting Engineer for Railways (F. R. Upcott, Esq.), who visited the place and combated the idea that the railway works were responsible for what had happened, asserting that the increase in "the eddies and whirlpools at the junction of the anicut and under-sluice" was solely due to the recent raising of the anicut; this was also the view taken by Mr. Spring, who had now become Consulting Engineer to the Government of India for Railways, Assam, who wrote a long and interesting note on the subject, dated 5th December 1896.

Mr. Spring's Note.

He begins by pointing out that not the contraction of the breadth, but of the *area* of the river is the "true factor of the matter at issue;" that the bed under consideration being of erodible sand, "just ready to move with each instantaneous acceleration of velocity," the contraction of the breadth does not necessitate the reduction of area; that an extra depth * of 5 feet under the whole length of the bridge would provide a sectional area equal to that of the highest known flood before the construction of the work, and that, as a matter of fact, "as soon as the first moderate flood occurred after contraction," the deepening had been "equivalent to an extra 7,600 square feet of area of discharge channel, or to an extra depth right across the bridge of over 2 feet."

He then goes on to deal with the question of the "swirl" or "whirlpool" near the Bezwada under-sluices, asserting that "it has nothing whatever to do" with the bridge training works, this assertion being based on his personal experience of the swirl before construction of those works and on the fact that records show that it had been a frequent cause of trouble.

After consideration of the action of "swirls" and the best way of dealing with the holes caused by them he goes on to say:—

"The flood level of 1896 was about a foot higher than that of the highest previously known, viz., that of 1882. This would appear to show that there

* "I blocked up 18,000 square feet sectional area between river bed and high water level, leaving 118,000 square feet to carry the flood discharge which had heretofore passed through 136,000 square feet."—F.J.E.S.

is nothing exceptionally formidable in the flood of 1896 as compared with that of 1882, not much more indeed than can be accounted for by the addition of three feet to Anicut crest; and that, if on the subsidence of the floods it is found on measurement that the pot holes below the Anicut are larger and deeper than usual, some special cause for this result must be searched for. It seems to me that for such a cause we need not go further than the fact of the crest having been raised three feet, for it stands to reason that there must be very much greater erosive action at the tail of a rapid with a mean slope of 17 feet vertical in 250 horizontal than at the tail of a rapid with a mean slope of 14 feet vertical to 250 horizontal. The scouring action of the swirl under the extra foot of head through the sluices would also naturally be greater than had before been experienced."

Passing then to the form given to his training bank he says:—

"14. A swirl or whirlpool is the result of a current sweeping straight past a lump of dead water, or a comparatively slowly moving body of water, just as a peg top is caused to revolve by the acceleration due to the successive lashes of a boy's whip. Such a piece of dead water is created whenever a spur is projected out into a current. Should the spur on plan be more or less at right angles to the current there will be two such blocks of dead water, both of which will become swirls. When on the other hand the spur is at a comparatively acute angle to the direction of the current, tailing down-streamwards as usually constructed, there will be only one such lump of dead water, viz., that at the downstream side. This dead water will gradually acquire a velocity which may easily become sufficient to lift the material of the bed, and fling it out centrifugalwise to be carried away by the stream current. The result of the old fashioned system of keeping rivers within bounds by the use of spurs has over and over again proved disastrous, the holes which are caused by the resulting swirls being most voracious, eating up the heads of the spurs and continually necessitating repairs thereto. This will I think be testified to by the present Superintending Engineer of the Orissa Irrigation Circle.* But if, instead of protecting a natural or, as in the case of the Kistna north training bank, an artificial, bank by projecting a series of spurs out from it, the same material be applied in the form of a surface slope protection and an apron, along a straight or carefully curved river bank, the current will flow past smoothly and no swirl will be created.

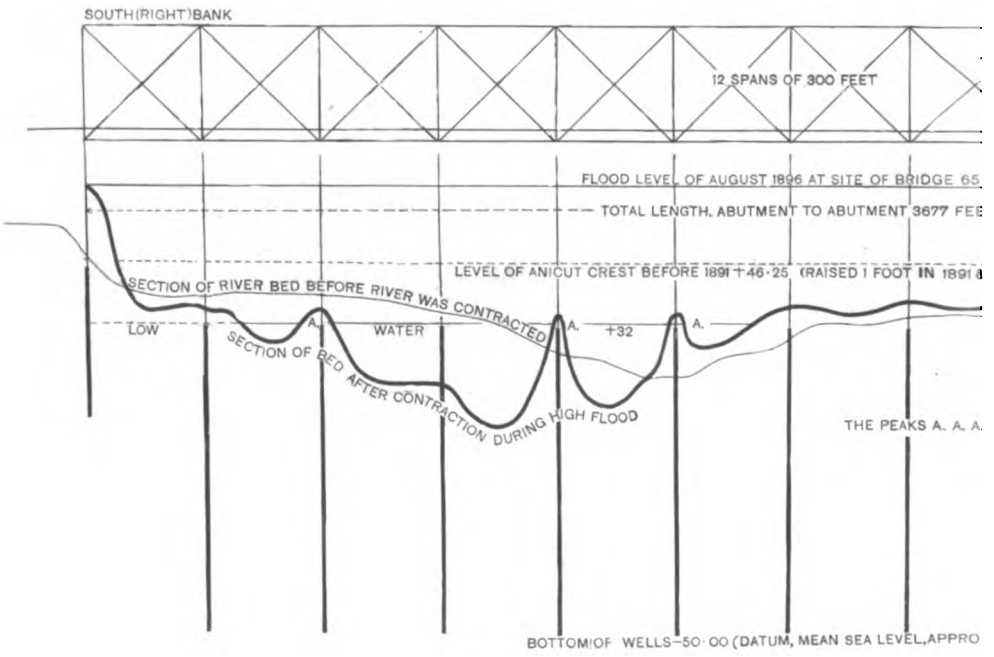
"15. It was for this reason that I so carefully curved the north training bank of the Kistna, leading it by easy curves tangential to the down stream masonry works of the north flank of the Anicut, in order that there might at least be nothing, in the form of the training bank on plan, which could

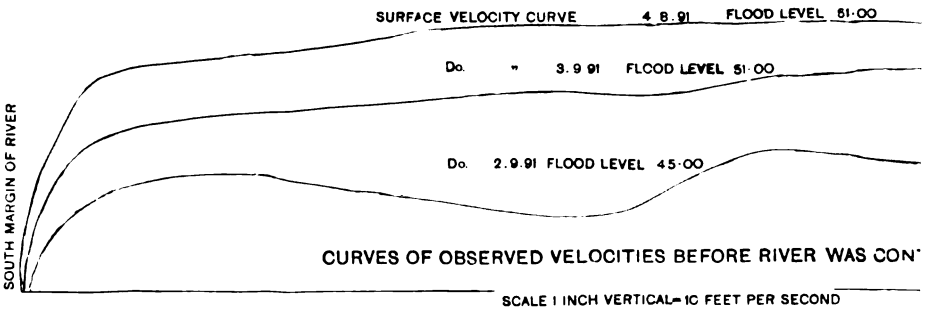
* And see page 50 of "Engineering Works, Gódávari Delta."—G.T.W.

KISTNA RIVER AT BEZWA

SECTION AT SITE OF RAILWAY BRI

Scales. Hor: 500 Feet. Vert: 50 Feet.—1 In





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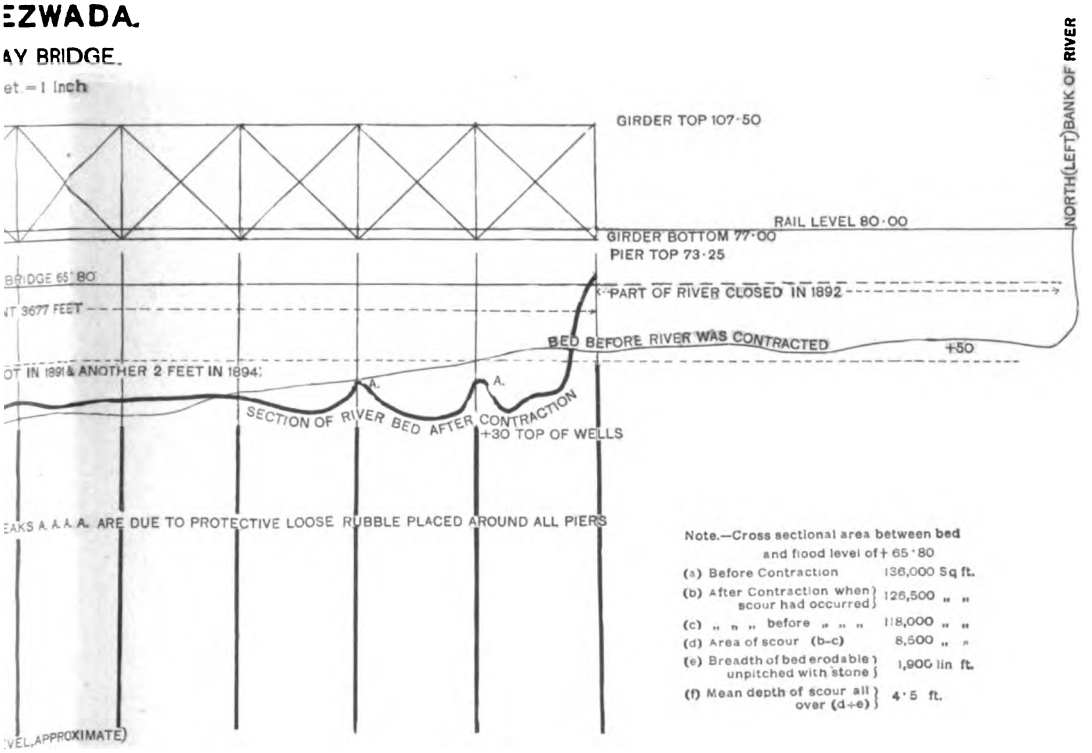
EZWADA.

AY BRIDGE.

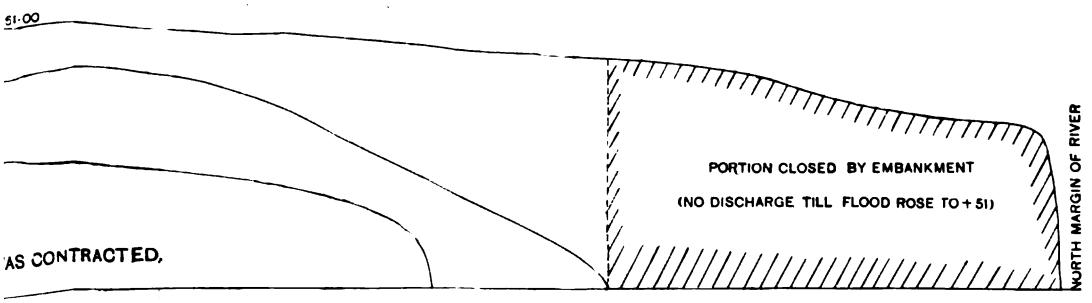
et = 1 inch



Note.—Cross sectional area between bed and flood level of + 65·80

(a)	Before Contraction	136,000 Sq ft.
(b)	After Contraction when scour had occurred	126,500 " "
(c)	" " " before " " "	118,000 " "
(d)	Area of scour (b–c)	8,500 " "
(e)	Breadth of bed erodable unpitched with stone	1,900 lin ft.
(f)	Mean depth of scour all over (d÷e)	4·5 ft.

(Signed)- F. J. E. SPRING
M. INST. C. E.
11-5-98



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1898

lend colour to any suspicion that the existing swirl, which was due to the strong current of the under-sluices, had been in any way aggravated."

As regards the question of the raising of flood levels by the bridge and its training banks, he says that "had the narrowing actually caused a backing up or afflux, the effect of such backing up would have been actually beneficial instead of injurious to the anicut as slightly diminishing the height of the over-fall," but that, as a matter of fact, no such backing up was caused, for—

"Were this the case there would be an afflux at the bridge, that is the general level of the area of water above bridge would be something distinctly higher than the general level of area of water below the bridge. Were there any such condition as this the difference of level would be something quite appreciable, and there would be such a local increase of velocity through the bridge as would, in a very few hours or minutes, lift the sand at the bottom and scour out such an extra depth all across as to speedily abolish the afflux, the bed not being of rock. Large photographs taken at or close to the top of the flood show that there was no such afflux. There was certainly a wave, perhaps 20 inches high, at each pier; but this wave is only the same sort of wave that is formed on the sides of a ship moving through the open sea, caused by surface or skin friction. A barge 14 feet broad, with a semi-circular bow and stern, forced at a velocity of 10 feet per second through the open ocean would have precisely such a wave on her sides as was seen by Mr. Upcott and by Mr. Eaglesome on the Kistna Bridge piers, especially if the skin of the boat were as rough as that of the pier masonry. But such a wave is a merely local effect and is a very different thing from an afflux."

Mr. Hughes' views.

Just before this "note" was written, the Chief Engineer for Irrigation, Madras (W. Hughes, Esq.) had decided that it had been "unwise to raise the anicut above the level fixed in 1891 and that it should be lowered to that level before next freshes, and self-acting shutters fixed as soon as possible," and this was also the decision come to by the Inspector-General of Irrigation who had been sent by the Government of India to advise them on the matter. Extracts from his summing up and disposal of the case are given below. It will be seen that he held the scales evenly between the Engineers who attributed to the bridge all, or nearly all, the mischief that had occurred, and those who went to the opposite extreme and pooh-poohed the idea that the "back swirl" near the Bezwada "Under-sluices" had in any way been affected by the training bank, though the Superintending Engineer and other competent officers had, from actual observation during the flood, been convinced that this was the case.

Views of the Inspector-General of Irrigation.

His "note" commences with a consideration of the levels of the high floods of 1882 and 1896, on which his opinion is that, though the 1·26 foot greater rise in the latter year "may be partly due to a fuller discharge, it must be attributed mainly to the fact that the crest of the anicut has been lately raised 3 feet which probably accounts for at least 1 foot of the increased afflux," and he goes on to say "There is a sheer drop of 3 feet on to the anicut talus * which has been neither strengthened nor lengthened to resist this heavy action."

He then deals at length with the conflict of opinion between the Irrigation and Railway Engineers as to the effect of the railway works on the anicut and the necessity for lengthening the bridge, and the following is a résumé of his views on this subject and his decision on the whole matter given in his own words:—

"I am therefore of opinion that any increase in the height of flood levels above the anicut, as compared with those of 1882, that was not due to an increase in the volume of the flood discharge, must be attributed entirely to the raising of the anicut crest, and was wholly independent of any obstruction caused by the bridge works.

"If this be admitted, the extent to which silt may have been deposited in any of the spans of the bridge or below the apron near the Bezwada under-sluices is immaterial. The only effect of increasing the number of spans would be either to increase these deposits of silt or to decrease the depth of scour in those spans on which the set of a flood may be heaviest. It has not, however, been stated that the maximum scour at the bridge was greater than was contemplated when the bridge was designed, nor is the safety of the bridge now in question. As regards the effect of the bridge on the flood levels immediately below and above the anicut, I have no hesitation in expressing an opinion that the water-way at present provided is sufficient.

. . . I see no reason for doubting the assertion of the very competent observers on the spot that, over and above these ordinary eddies, a great back-swirl was set up by the obstruction caused by the left embankment which might, if continued long enough, or if frequently repeated, endanger the safety of the left end of the anicut and under-sluices. The existence of such a swirl is clearly indicated by the levels, which show that the water on left bank below anicut stood 1·3 foot higher than on right bank. There is of course nothing extraordinary in the level on one bank of a river being slightly higher or lower than that on the other during a high flood, according to the position and volumes of the main currents, but in this case the levels upstream of the anicut were identical (in 1882 there was a difference of 0·66 foot) so that the discharge was as nearly as possible evenly distributed over

* "Apron."—G.T.W.

the whole length of the anicut. The great difference in the levels immediately downstream shows, however, how the water must have piled up above the left embankment, and is a measure of the violent eddies and swirls which must have occurred between the anicut and bridge. The remedy proposed by the Superintending Engineer, to remove the embankment and lengthen the bridge on the north end by three spans would, no doubt, reduce this action, but it is my opinion only on this account, and not because the water-way at the bridge is in itself insufficient, that the lengthening of the bridge can be recommended. The same object might be almost as effectively attained by removing two or three spans from the south, and adding them to the north end, though this would be open to obvious objections on other grounds.

"10. There is little doubt that this left embankment tends to set in motion new forces during the flood season which must be reckoned with by those responsible for the safety of the canal head works, but the question is whether the difficulties cannot be met by some less heroic and expensive measure than that of lengthening the bridge by three spans, which would probably cost something between 7 and 8 lakhs of rupees.

* * * *

" Although the downstream eddies no doubt tend to produce the scour-holes below the anicut, the severe action on the weir itself, due to the raising of the crest already referred to has probably been a far more important factor, and until this has been eliminated by cutting down the crest it cannot be said to what extent the action is due to the bridge training works."

* * * *

" My general conclusion therefore is that there has been no contraction of the water-way at the Bezwada bridge such as would affect appreciably the levels above the anicut. By lengthening the bridge the violent action which now occurs below the left end of the anicut would probably be materially reduced, but there is no evidence that this action has hitherto caused any serious damage, though it may do so in time and must undoubtedly be guarded against. I consider, however, that the safety of the anicut and under-sluices will be far more securely assured by cutting down the upper 2 feet of the present crest and strengthening the works in the manner proposed in paragraph 10 above than by lengthening the railway bridge, and this at less than one-tenth the cost, but the left training embankment should be made secure against over-topping by the highest flood and against the violent action that takes place along its water face."

Mr. Higham also recommended—

(*a*) Provision of falling shutters on the lowered crest of the anicut.

(*b*) Extension of the down-stream aprons.

(*c*) Raising and strengthening the left training bank above the bridge.

(*d*) The completion of the ancillary head sluice Western Delta (see page 90).

(*e*) The construction for the Bezwada Main Canal (Eastern Delta) of a lower or second Regulator of three 40 feet sluices (see page 89).

In reviewing Mr. Higham's "Note" the Government of India after noticing "with satisfaction the approval recorded of the good work done by Major Baddeley and his officers and subordinates during the recent floods" concurred—

"in the opinion that it is unnecessary to lengthen the Bezwada bridge, and they accept the view of the Inspector-General, as expressed in paragraph 10 of his notes, that the raising of the crest of the anicut has been a more important factor of the violent action that occurred below the anicut, and is more likely to cause danger to the work, than the left upstream embankment of the bridge, and that they are of opinion that the upper 2 feet of the raised portion should be at once removed and replaced by falling shutters, and that the apron of the anicut should be extended, as suggested in paragraph 10 of the notes.

"As regards the left embankment upstream of the bridge, it should be maintained at the height and section that may be advised by the Irrigation officers. The Government of India consider that the objection to increasing the height of crest of the anicut will apply with almost equal force to the Gódávari anicut, and that, as proposed in paragraph 3 of the inspection notes, shutters should be substituted for the extra 2 feet of masonry which was provided for in the estimate sanctioned by the Government of India in Public Works Department letter, No. 4 I., dated the 13th January 1896."

Removal of the 2-feet solid raising of 1894 and substitution of falling shutters.

Before the freshes of 1897 the 2 feet of the 1894 raising were removed and 170 running feet of experimental falling shutters were fixed. These having proved satisfactory, the remainder of the Anicut (excepting 353 feet at the ends which were built up solid to level of top of the shutters) has, in 1898, been fitted with shutters of the same, or very similar, pattern, drawings of which will be found in Volume II (No. 6). These shutters fall automatically when the river rises to from 1¼ feet to 1⅓ feet above their tops, and they are raised by hand when the river falls below 2⅓ feet over the masonry crest of the Anicut.

THE "SCOURING" OR "UNDER" SLUICES at either flank of the Anicut have not been appreciably altered since construction, except as regards their aprons which have been considerably extended and strengthened,

and as regards the means of regulating the discharge through the sluices. These used to be merely baulks or "Needles," lifted by a lever engaging with pins run through holes in the baulks, and driven down by mauls; these rough appliances have been superseded by gates worked by screw-gearing, those for the Bezwada sluices having been fitted in 1886 and those for the Sítanagaram sluices in 1891. (*See* Plan 8, Volume II.)

The Sítanagaram Under-Sluices were "founded * partly on solid rock and partly on a mass of roughstone of great depth" placed in the deep scour channel which there existed, and the consequence was, of course, unequal settlement which for some time caused anxiety, but has ceased to do so for many years.

THE HEAD-SLUICES.—These, like the "Under-Sluices," were originally provided only with baulk or "Needle" shutters, but in 1879–80 this rough and unsatisfactory arrangement was superseded, at both sets of sluices, by shutters with the screw-gearing, shown on Plan 10, Volume II, which not only render careful regulation possible, but enable water to be taken in at different levels when the river is high, so that as much sand and silt need not be swept into the canals as was the case when the water had always to be admitted from the bottom.

THE BEZWADA HEAD-SLUICES are subjected to alarming vibration due to the rush of water *through* the adjacent Under-Sluices when open, and the over-fall *over* them in high floods. At such times it has been customary to load the Head-Sluices with sand bags, and of this in the last floods the Superintending Engineer says "it distinctly reduced the shake and tremor in the sluice."

The advantages of the ancillary Head-Sluice built at Sítanagaram (see below) were so apparent in the floods of 1896 that it was proposed to have a somewhat similar arrangement below these Head-Sluices. The site, however, is peculiar and cramped and the details of the work would have to be very different from those of the Sítanagaram Sluice; would probably have to take the form of a Bridge of three or four spans across the canal, closed by gates of the "Stoney," or somewhat similar type. The matter is still under the consideration of the Inspector-General of Irrigation.†

THE SÍTANAGARAM HEAD-SLUICES had for years caused anxiety by cracks and signs of weakness, and in 1895 it was decided to build at

* See paragraph 3 of Captain Orr's No. 251, dated 9th August 1855, printed at page 74.

† It has been decided *not* to build an ancillary sluice, but to strengthen the existing work.

200 feet down the channel another set of sluices which would enable water to be held up between it and the old set and so lessen the strain on the latter in high floods, whilst the new work could take the place of the old one should that fail. The plan of this new work will be found in Volume II (No. 12).

Fortunately its construction was so far advanced before the great flood of 1896 that it could be brought into operation to the extent of reducing the head on the old sluices by 3 feet, thus saving them from the destruction which otherwise would have been almost a certainty; the new work has been finished in 1898.

THE HEAD-LOCKS remain as they were originally built except that their side walls and gates have been raised to meet the maximum floods now known. It has already been mentioned, in Chapter III, that these Locks have a width of chamber of only 16 feet, whilst all other Locks or important through lines of communication have a width of 20 feet, and it seems not improbable that they will, before long, have to be altered, or in the case of the Sítanagaram Lock, rebuilt in a better position.

CHAPTER VI.

WORKS IN THE DELTA—SANCTIONS—EXECUTION—COST.

Whole scheme expected to cost 15½ lakhs.

It will be remembered (see Chapter II) that, excepting two small sums for opening channels for a short distance from the Head-sluices, the estimate of Rs. 7,66,541 sent in by the Committee provided only for the Anicut and Head-works, but it was stated (see paragraph 15 of "Specification") that probably six lakhs would have to be added for "Detail Irrigation works" and "seven lakhs more for embankments and roads." In sending on the project Government considered that in addition to the 7⅛ lakhs for the Anicut and Head-works only "8 lakhs would be required for detail irrigation works and embankments, making a grand total of 15⅛ lakhs" and it was this sum which the "Court of Directors" sanctioned "in the full assurance that the greatest care has been taken to prevent future disappointment in respect to estimates both of cost and returns." What, one wonders, would have been the feelings of the "Honourable Court" could it have foreseen that the 15⅛ lakhs which then appeared so large a sum for the purpose to which it was to be devoted would be spent nine times over before the scheme then initiated could be said to be fairly developed.

Anticipated requirements for delta works, vague.

When first the works were started there was only a general and somewhat vague idea as to what would be required in the delta to enable the Anicut-water to be utilized, and it was not for many years, as will be shown, that any comprehensive scheme for the whole system was prepared. Meanwhile, estimates were submitted piece-meal for what from time to time appeared most immediately required, the first object being, as in the Gódávari, to get the water into the natural drainages and old channels and so in some way distributed quickly about the delta. Accordingly we find that the first estimates sanctioned were for making cuts to, and improving to some extent, the "Pulléru" and "Budaméru" in the Eastern Delta, and the "Tungabhadra" in the Western Delta.

The estimates sanctioned against the general provision of 8 lakhs for "Detail irrigation works and embankments" are given in the following statement:—

	Estimates.	Amounts.	Remarks.
	EASTERN DELTA.	RS.	
1853.	(1) Enlarging head of main feeder and cutting branch to Poolairoo.	68,462	Now "Main Canal."
	(2) Deepening and widening Boodemair for 9 miles to Kesarapilly.	40,278	Now upper portion of Ellore Canal.
	(3) Deepening and widening Poolairoo from Pattanata to Weyoor, 17 miles with Lock and Weir.	87,852	Now upper portion of Masulipatam Canal.
	(4) Bridge over the Boodemair for road from Ellore to Bezwada and Masulipatam.	7,585	
	WESTERN DELTA.		
	(5) Enlarging Toongabhadra for about 6 miles to Vadlapoodi; bottom width 15 yards.	56,460	Now "Main Canal."
1854.	(6) Widening, &c., Toongabhadra from Vadlapoodi for another 6 miles to Doogiralla and from thence excavating a new channel *vid* Tenalli, Sandole, and Alloor to the Nizampatam creek, with 3 sets of Locks and Weirs.	2,20,415	Now "Nizampatam Canal."
	EASTERN DELTA.		
	(7) Canal from Weyoor (see (3) above) to tide-water in the Pooligedde branch of river near Mopedevy with 2 Locks and Weirs, Under tunnels, and 150 irrigation sluices.	1,49,797	Part of this now "Bank Canal." (The Earthwork of this partly carried out for about 16 miles to Nadakudurru and then stopped, the unexpended balance being diverted to other works.)
	(8) Diverting Boodemair for about 3 miles and passing it under the Ellore Canal by an aqueduct.	22,020	Excess of Rs. 3,410 on this, reported in P.M.G., No. 836, 4th May 1858.
	GENERAL.		
	(9) Ten boats for conveyance of materials in connection with building the anicut.	14,301	
		6,67,170	
	(10) Besides the above there was sanctioned "a Channel from Ravendrapad to Vallabapuram in the Western Delta to take water from the Toongabhadra to a Channel already formed down west bank of Kistna."	14,332	Afterwards converted into the "Bank Canal." The earth from excavation of this Channel was chiefly used for the *River embankment* and appears not to have been charged to the Kistna system.
	There was also sanctioned in 1853 for River embankment—Bezwada to Ibrampatam.	22,675	

Towards the end of 1854, four more estimates were sent in, the amounts of which added to the Rs. 6,67,170 shown above would have considerably exceeded the 8 lakhs sanctioned, and consequently the estimates had to be referred to the Court of Directors, who accorded sanction to them in its despatch, 16th September 1856. These estimates were as follows :—

Estimates.	Amounts.	Remarks.
	Rs.	
(1) High Level Canal from the Boodemair at Késarapilly (see No. (2) of statement above) to Perikeed at 17½ miles.	79,550	Now the "Ellore Canal." (The portion between Dendalúr and Ellore is now considered to belong to the *Gódávari* system.)
(2) High Level Canal from Perikeed to Dendalúr (about 4 miles beyond Ellore) to there join the "Ellore" Canal from the Gódávari.	1,34,834	
(3) Extending canal from Weyoor (see No. (3) of statement above) to Masulipatam with 4 sets of Locks 105′ × 16′ and Weirs.	2,37,106	Now the "Masulipatam Canal." The size of the Locks was altered to 150′ × 20′ (see P.M.G., 30th September 1857). The total amount was increased to Rs. 2,53,294 in P.M.G., No. 712, 4th April 1860.
(4) Canal from Vadlapoodi (see No. (5) of statement above) for 20 miles to Inganapudi to eventually form portion of East Coast Canal.	1,46,787	This line proved to have been badly chosen and after considerable expenditure was abandoned in favour of the line now taken by the "Commamúr Canal."

Stoppage of works on account of the Mutiny.

The work on these estimates had scarcely been set thoroughly going when it had to be stopped in accordance with the restrictive orders * issued in June 1857 on account of the Mutiny. The great importance of one of the works from a Military point of view however soon became apparent, for early in November, during the North-East Monsoon rains, "Her Majesty's Royal Regiment of Foot" which had been hurried out from England at "3 days' notice" landed at Masulipatam with orders to push on at once to Hyderabad, and would have been able to do so had

* Resolution of the Government of India, 27th June 1857: "Having regard to the financial position of the Government, the Right Honourable the Governor-General in Council considers it expedient, that all Public Works of every description, except works in the Military Department, and inexpensive works of a very urgent nature, should forthwith be stopped at all the Presidencies, and that establishments of the Public Works Department should, without delay, be reduced to be lowest possible scale."

the Masulipatam Canal been finished; but it was open for navigation for only 24 miles from Bezwada, as far as Viranki, and for upwards of three weeks the regiment could not get over the 15 miles between Masulipatam and that place, the so-called road being a mere unmetalled track over soil which the Executive Engineer stated "becomes of the consistency of paste after heavy rain, and useless as a means of communication."

Completion of Masulipatam Canal specially sanctioned.

The Military, as well as the Civil, authorities therefore so strongly urged the necessity of completing the Canal as quickly as possible, that after considerable pressure, the Government of India allowed the work to be gone on with.

With this exception the Kistna Delta works were practically at a standstill for nearly 3 years. Between then and the sanction in 1864 of "Major Anderson's scheme" (to be dealt with further on) the sanctions for works to be actually carried out cannot be traced with certainty, as there then obtained a system by which "sanction once having been given for any work, the funds so obtained were available at the discretion of the local Government for any other sanctioned work," and works were frequently stopped or given up altogether to provide funds for other works which seemed more important, in a perfectly bewildering fashion. The following however seem to have been the chief works sanctioned for execution between 1858 and 1864 excluding such as appear again in, or were afterwards treated as sanctioned against, "Major Anderson's scheme" (see page 98) :—

		Rs.
1858.	Lock and Calingulah to Budaméru near Kesarapilly. Ellore Canal	13,660
,,	Draining country west of Commamúr Channel by diverting, &c., Nallamada; and Tunnels under the Channel	38,100
,,	Calingulah with sluices across the Tungabhadra at head of Commamúr Channel ..	2,800
1859.	Additional Lock and Weir at Intúr. Nizampatam Canal	34,600
1860.	For Channel—afterwards incorporated in Ryves' Canal	43,400
1861.	Extra for above and Channels from it ..	21,460
1862.	Extension of the Commamúr Channel for irrigation	21,580

		Rs.
1862.	Lock and Weir at Pamarru; new canal from 7½ miles below Pamarru to Bantumilly Saltkotars (now Bantumilly Canal); improving the Polraz-Kodu Channel; two new channels from the Púlleru	95,710
1863.	Constructing an additional Lock, Nizampatam Canal	15,965
,,	Two calingulahs and inlets and outlets, Ellore Canal	14,580

Captain Chambers' report.

In 1861 Captain Chambers made a report * on the state of the works, which may be condensed as follows:—

ON THE EASTERN SIDE OF THE RIVER.

The Main Canal (51 chains long) excavated with a bottom width of about 90 feet.

The Ellore High-level Canal.—Earthwork almost finished to Perikeed (at 26 miles); of a section much smaller than afterwards adopted; the masonry works which had been built on this canal were; bridge 60 feet span over it near its head; aqueduct 48 feet wide of 8 arches of 10 feet span by which the Budaméru after 3 miles diversion was passed under the canal; Lock (2nd class) at Késarapilly (11½ miles) into the Budaméru, along the winding course of which boats could struggle at certain times of the year to and from the Colair Lake and the Gódávari system of Canals; Weir, near the Lock, discharging into the Budaméru the water for navigation, and for the irrigation amounting to 20,000 acres; as there were not in that stream any means of holding up the water in reaches, far more had to be sent into it than the irrigation really needed and the result was extensive swamping of the Gudiváda taluk. To remedy this state of affairs to some extent a large artificial distributary, known as "Ryves' Channel," taking off from the canal just above the Weir and designed to carry 60,000 cubic yards of water per hour was under excavation.

The Masulipatam Canal, the prosecution of which, as already explained, was allowed to be gone on with, was, as regard its *earthwork* nearly completed, but was navigable only to end of its fourth reach at Akamarru

* With Proceedings of Madras Government, No. 1076, dated 11th June 1861.

(43 miles from Bezwada and 6 miles short of Masulipatam), because the Lock and Weir there were not finished. The area irrigated under this canal was 19,000 acres. Just above the first lock at Kankipad (12½ miles) a sluice of six vents 4′ × 5′ had been built, by which 40,000 cubic yards of water per hour could be sent into the "Pulléru," and by it 31,000 acres were irrigated.

The total area irrigated in the Eastern delta was thus 70,000 acres, of which 51,000 received their supply by the main natural drainages, the Budaméru and the Pulléru (see Chapter I).

On the Western Side of the River.

The Main Canal was opened to its end, 13 miles, though of course of a much less width than afterwards made.

The Nizampatam Canal was far advanced as regards its earthwork, but was open for navigation only to the end of its first reach (22 miles from head of delta) the Lock and Weir there, at Kuchipudi, not being finished; from that point the irrigation proceeded "by means of other channels still parallel to the canal and by sundry cuts some of them 8 or 10 miles in length," the whole area so irrigated being 18,000 acres.

The Bank Channel taking off from the left side of the Main Canal about 7 miles from its head (see No. 10 of statement on page 92) ran to "Vallabapuram on the edge of the Kistna where there is a masonry "Fall (or 'Weir') in full work. Over this some 15,000 cubic yards per "hour are sent down the remainder of the Bank Channel which is nothing "but a line of pits for the river embankment connected, so that water may "flow down them; its length from Vallabapuram to tide water is nearly "40 miles." From above Vallabapuram Fall "one main branch some "12 miles long is led capable of watering all the land between the river "and the Mirmunghi drainage, but as yet it is hardly used. Not till it "reaches Vellatúr (33½ miles), is the Bank Channel made much use of, "then it is repeatedly tapped by small channels which water 10,000 "acres in the Repalli taluk."

From the end of the "Main Canal" just above the head of the Nizampatam Canal was a "Masonry escape" by which "two-thirds of "the discharge of the Main Canal are passed into the old Tungabhadra "and taken down it for 12 miles when it is diverted by means of a rough-"stone dam into the Commamúr channel, a fine channel above 20 miles "in length, and 18 yards, and more, wide, originally made by Captain "Steele before the anicut was built; it is dropped over a low dam at "Chabroli, and it is then tapped for irrigation until it loses itself in the

"great Bapatla tank." By the old Tungabhadra and this Commamúr Channel 22,000 acres were irrigated.

From this report we see that 9 years after the commencement of the anicut there was not in the whole delta a single finished through line of canal or large artificial distributary, whilst so far from the drainage which it is so necessary should go hand in hand with irrigation, having been attended to, the natural surplus channels of the country had been seriously interfered with. Notwithstanding this, some 120,000 acres of land were being irrigated and protected from all fear of drought.

Works again taken in hand with vigour.

In 1860–61 matters began to improve and the works to be again taken in hand with some degree of vigour, but still in the old piece-meal, disconnected, way, and in 1862 the Government of India noticing this, requested that "a complete and comprehensive scheme of work remaining to be done in the Kistna District" might be drawn up. This was entrusted to Major J. C. Anderson, R.E., then District Engineer of the Kistna.

Major Anderson's proposals and estimate.

He does not seem to have been given any special establishment to carry out the very considerable investigations necessary for the elaboration of such a scheme as was required, and consequently the proposals made by him, in January 1863, were by no means complete, they dealt to a very imperfect extent with the distribution of irrigation water and almost entirely ignored the important subject of Drainage except in as far as it affected the proposed Commamúr Canal; they formed however a considerable step towards a proper appreciation of what was still necessary. The proposals and estimates (many of them merely approximate lump sums) are given in the following statement. On this is also shown what up to *September 1877* had really been done, or was in hand, towards carrying out these proposals:—

MAJOR ANDERSON'S SCHEME for "Completion" of the Kistna System of Irrigation and Navigation (see P.M.G., No. 430, dated 12th February 1864); sanctioned by the Secretary of State in December 1864;—with detail sanctions against same to September 1877.

Major Anderson's Scheme; sanctioned by Secretary of State.					Sanctions given by Government against the Secretary of State's sanction.				Remarks.
No. of item.	Canals, &c.	Description of Works.	Amounts.	Totals of Canals, &c.	Number and Date of Government Order sanctioning.	Description of Works.	Amounts.	Totals of Canals, &c.	
			Rs.	Rs.			Rs.	Rs.	
1	HEAD WORKS ... EASTERN DELTA.	Improving anicut	1,50,000	1,50,000	.....	.....	...	...	No estimate sanctioned.
2	MAIN CANAL ...	Improving head sluice	5,000		No. 1389, 20th May 1871.	Earthwork	44,076		
3	,, ...	Enlarging 900 yards from head sluice, east side.	37,020			Quay left side of canal ...	28,948		
4	,, ...	Enlarging 900 yards from head sluice, west side.	30,390			Compensation	4,500		
	,, ...	Altering Hyderabad road and compensation.	5,000			Roads and wall between bridges.	6,545		
				77,410		Revet, &c., right side of canal.	24,623		See remarks opposite "Ryves' Canal."
5	ELLORE CANAL ...	Enlarging to 8th mile	1,88,440			Sundries	4,838		
6	,, ...	Enlarging 8th mile to Perikeed.	31,000					1,13,530	
7	,, ...	Proposed branch channel ...	30,000						
8	,, ...	Branch of Budameru	5,000						
9	,, ...	Inlet from Budameru	5,000						
				2,59,440					
10	RYVES' CANAL ...	Enlarging	87,580		No. 2543, 20th Aug. 1867.	Head sluice and bridge at the new head on the Main canal.	13,000	...	These "Ryves' Canal" sanctions of the Government of India are in lieu of Items 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, and 17, Section I of Secretary of State's sanction; those items amount to Rs. 3,85,231.
11	,, ...	Enlarging head sluice	7,080		Do. ...	New cut from end of "Main Canal" for 7 miles to end of 1st mile of existing "Ryves' Canal" 90 feet bottom width.	2,79,880	...	
12	,, ...	Escape to Budameru	7,000						
13	,, ...	Calingulah at 7⅞ mile	7,000		Do. ...	Enlarging canal from end of 1st mile to Pulleru near Marrivada.	58,180	...	
14	,, ...	Under-tunnel	2,000						
15	,, ...	Enlarging branch channel ...	14,631		Do. ...	Enlarging Gudivada branch ...	26,800	...	
16	,, ...	Enlarging head sluice	2,000						
17	,, ...	Calingulah at 5th mile	3,500						
				1,30,791					

Major Anderson's Scheme for "Completion" of the Kistna System of Irrigation and Navigation (see P.M.G., No. 430, dated 12th February 1864); sanctioned by the Secretary of State in December 1864;—with detail sanctions against same to September 1877—continued.

Major Anderson's Scheme; sanctioned by Secretary of State.					Sanctions given by Government against the Secretary of State's sanction.				Remarks.
No. of item.	Canals, &c.	Description of Works.	Amounts.	Totals of Canals, &c.	Number and Date of Government Order sanctioning.	Description of Works.	Amounts.	Totals of Canals, &c.	
			Rs.	Rs.			Rs.	Rs.	
	Ryves' Canal—*cont.*				No. 2543, 20th Aug. 1867.	Alterations and additions to Komatiguntah calingulah, and Ryves' branch head sluice.	2,970	...	See remark above.
					Do. ...	Two calingulahs and bridges on Gudivada branch.	2,960	...	
					No. 348, 31st Jan. 1868.	Bridge of five arches 26 feet span at the Ellore road.	6,153	...	
					No. 2543, 20th Aug. 1867.	Two accommodation bridges ...	5,660	...	
					Do. ...	Accommodation bridge across Pulleru at Murrivada.	3,710	...	
					Do. ...	Three accommodation bridges on Gudivada branch.	3,780	...	
					Do. ...	Minor sluices and channels ...	5,000	...	
					No. 80, 7th Jan. 1870.	Iron punt	6,100	...	
								4,14,193	
18	Pulleru Canal.	Enlarging from Kankipad to Wuyoor.	32,310						
19	,, ...	Enlarging Wuyoor to Ryves' Channel.	3,560						
20	,, ...	Enlarging from Ryves' Channel to Pamarru.	17,070		No. 747, 17th Mar. 1865.	Widening and rectifying fall from Kankipad to Polrazkodu 26¾ miles.	76,150		
21	,, ...	Enlarging Pamarru to Polrazkodu.	12,988						
22	,, ...	Calingulah at Wuyoor	6,910		Do. ...	Calingulah at Wuyoor ...	5,600		
23	,, ...	Calingulah at Pamarru	14,420		Do. ...	Regulating bridge at Pamarru.	7,000		
24	,, ...	Channel to Aukumarru ...	7,721		Do. ...	Branch channel from Pulleru to Pamarru.	3,870		
					No. 3342, 19th Oct. 1866.	East side channel from Pulleru to Aukumarru.	15,610		

Major Anderson's Scheme for "Completion" of the Kistna System of Irrigation and Navigation (see P.M.G., No. 430, dated 12th February 1864); sanctioned by the Secretary of State in December 1864;—with detail sanctions against same to September 1877—continued.

Major Anderson's Scheme; sanctioned by Secretary of State.					Sanctions given by Government against the Secretary of State's sanction.				Remarks.
No. of item.	Canals, &c.	Description of Works.	Amounts.	Totals of Canals, &c.	Number and Date of Government Order sanctioning.	Description of Works.	Amounts.	Totals of Canals, &c.	
			Rs.	Rs.			Rs.	Rs.	
25	Pulleru Canal —*cont.*	Channel on to Masulipatam ...	10,000		.....	.....	...		
26	,, ...	Channel head sluice	2,150		.....	.....	...		
27	,, ...	Two calingulah bridges ...	2,690		No. 2211, 23rd July 1867.	Bridge of three arches of 20 feet span over Pulleru at Kankipad.	2,920		
					No. 3089, 5th Oct. 1867.	Bridge across the channel which connects the Masulipatam canal with Pulleru near Pamarru.	1,350		
28	,, ...	Bridge on Masulipatam road ...	1,000		.....	.....	...		
					No. 3028, 17th Dec. 1862.	Improving lower section of the Pulleru channel.	98,710		
					No. 126, 16th Jan. 1863.				
				1,10,819				2,11,110	
29	Polrazkodu Canal.	Extending to Ooputeru with lock.	30,000		No. 1703, 7th June 1867.	Irrigation channel from the 14th mile of Polrazkodu.	6,130		
					No. 3581, 27th Nov. 1865.	Regulating bridge across the head of the Polrazkodu.	4,120		
					Do. ...	Two additional bays to the escape calingulah at terminus of Buntoomilly canal.	1,220		
				30,000				11,470	
30	Masulipatam Canal.	Enlarging to 4th mile	1,54,000		No. 747, 17th Mar. 1865. No. 2308, 1st Oct. 1872.	Completing the sloping of banks of canal from 1st to 4th mile.	10,100		
31	,, ...	Enlarging to 13th mile	65,000		No. 747, 17th Mar. 1865.	Widening from 4th to 13th mile.	65,000		

***Major Anderson's Scheme for "Completion" of the Kistna System of Irrigation and Navigation (see P.M.G., No. 430, dated 12th February 1864); sanctioned by the Secretary of State in December 1864;—with detail sanctions against same to September 1877*—continued.**

Major Anderson's Scheme; sanctioned by Secretary of State.					Sanctions given by Government against the Secretary of State's sanction.				Remarks.
No. of item.	Canals, &c.	Description of Works.	Amounts.	Totals of Canals, &c.	Number and Date of Government Order sanctioning.	Description of Works.	Amounts.	Totals of Canals, &c.	
			Rs.	Rs.			Rs.	Rs.	
32	Masulipatam Canal—*cont.*	Clearing Agakodu and head sluice.	4,000		.....	.....	...		
33	,, ...	West side channel, 18th mile to Veeranki.	8,640						
34	,, ...	Side channel, 18th mile to Nidumole.	14,676						
35	,, ...	Side channel, 18th mile to Aukumarru.	5,570		No. 3342, 19th Oct. 1866.	West side channel from Kankipad to Agakodu.	49,860		
36	,, ...	Tunnels and calingulahs ...	8,000						
					No. 515, 14th Feb. 1868.				
					No. 3892, 14th Dec. 1868.				
					No. 383, 5th Feb. 1869.	Extending East side channel, 11 miles, to Gokaveram.	14,050		
					No. 1,412, 30th April 1869.				
				2,60,786				1,39,010	
37	Bank Canal ...	Head at 4th mile Masulipatam canal to Wulloorpolliem.	1,81,820						
38	,, ...	Head sluice	6,000						
39	,, ...	Rough locks	5,000						
40	,, ...	Continuation to head of Devi.	80,000						
				2,72,820					
41	,, ...	Probable expenditure on minor works and bridges.	...	4,00,000	No. 747, 17th Mar. 1865.	Minor branches and sluices ...	5,000		
					Do. ...	Compensation	5,000		
					No. 80, 7th Jan. 1870.	Constructing iron punt ...	6,100		
					No. 478, 25th Feb. 1874.	Rest-house at Gudivada ...	2,600		
								18,700	
		Total, Eastern Delta ...	...	15,42,066		Total, Eastern Delta ...	...	9,08,013	

Major Anderson's Scheme for "Completion" of the Kistna System of Irrigation and Navigation (see P.M.G., No. 430, dated 12th February 1864); sanctioned by the Secretary of State in December 1864;—with detail sanctions against same to September 1877—continued.

Major Anderson's Scheme; sanctioned by Secretary of State.					Sanctions given by Government against the Secretary of State's sanction.				Remarks.
No. of item.	Canals, &c.	Description of Works.	Amounts.	Totals of Canals, &c.	Number and Date of Government Order sanctioning.	Description of Works.	Amounts.	Totals of Canals, &c.	
	WESTERN DELTA.		Rs.	Rs.			Rs	Rs.	
2	Main Canal ...	Improving head sluice	5,000		No. 636, 7th Mar. 1865.				
3	,, ...	Enlarging to 8th mile	3,00,100						
4	,, ...	Do. to 12th mile	64,150		No. 2400, 30th July 1866.	Widening main canal ...	2,76,404		
				3,69,250				2,76,404	
5	Bank Canal ...	Enlarging to Kolloor	1,05,410		.....	.....	...		
6	,, ...	Do. to Vellatoor	11,626						
7	,, ...	Completing Vellatoor and improving Vellatoor and Iskapulli channels.	1,50,000		No. 2590, 17th Aug. 1866.	Drainage channel	10,460		
					No. 3232, 6th Nov. 1863.	Irrigation channel	6,779		
				2,67,036				17,239	
8	Nizampatam Canal.	East side channel to Koochipudi.	10,740						
9	,, ...	East side channel to Intoor ...	11,650						
10	,, ...	Head sluice and calingulahs ...	6,000		No. 3861, 6th Dec. 1866.	East and West side channels...	48,757		
11	,, ...	West side channel to Koochipudi.	8,620						
					No. 2359, 23rd July 1868.	Irrigation channel from Nizampatam canal.	2,825		
12	,, ...	West side channel to Intoor ...	11,260						
13	,, ...	West side calingulahs ...	1,500						
				49,770				51,582	
14	Commamur Canal.	Enlarging to 8th mile	39,243	...					
15	,, ...	Enlarging to Baputla tank ...	33,080		No. 3699, 15th Dec. 1863.	Continuation of Commamur channel from 28th mile from the head to the road from Inkole to Chinna Ganjam, with subsidiary works.	1,25,650		
16	,, ...	Enlarging to Inkole road ...	46,660		No. 1881, 24th June 1867.	Construction of rough stone rapid at Duggerala.	5,680		
					No. 545, 19th Feb. 1877.	Improvements to Commamur canal.	9,640		
17	,, ...	Head sluice and masonry works.	30,000		No. 1676, 21st May 1869.	Construction of a bridge over the Commamur canal.	8,030		
					No. 304, 30th Jan. 1873.				

Major Anderson's Scheme for "Completion" of the Kistna System of Irrigation and Navigation (see P.M.G., No. 430, dated 12th February 1864); sanctioned by the Secretary of State in December 1864;—with detail sanctions against same to September 1877—continued.

Major Anderson's Scheme; sanctioned by Secretary of State.					Sanctions given by Government against the Secretary of State's sanction.				Remarks.
No. of item.	Canals, &c.	Description of Works.	Amounts.	Totals of Canals &c.	Number and Date of Government Order sanctioning.	Description of Works.	Amounts.	Totals of Canals, &c.	
			Rs.	Rs.			Rs.	Rs.	
18	Commamur Canal—*cont.*	Drainage works	50,000		No. 2598, 31st Oct. 1870.	Budam project	46,420	...	Was to improve drainage of lower part of the Toongabhadra.
					No. 3900, 11th Dec. 1866.	Drainage channel	5,400		
					No. 2041, 26th June 1868.	Second-class lock at Jagerlamudy.	18,040		
19	,, ...	Locks	1,50,000		No. 3955, 18th Dec. 1868.	First-class lock at Duggerala.	33,570		
				3,48,983				2,52,430	
20	Guntur Canal ...	Adapting for Irrigation ...	15,000						
				15,000					
21		Bridges and minor works ...	3,50,000		No. 80, 7th Jan. 1870.	Iron punt	5,158		
					No. 3699, 15th Dec. 1863.	Surplus sluice in Bapatla tank and escape channel to the Nizampatam salt creek.	43,810		
					Do. ...	Longitudinal drain along the Romperu swamp for 15 miles to the Chinna Ganjam salt creek at Kadavakuduru bridge.	16,000		
					No. 1310, 1st May 1867.	Enlarging the salt creek ...	4,630		
				3,50,000				69,598	
		Total, Western Delta ...	...	14,00,039	.....	Total, Western Delta ...	...	6,07,253	
		GRAND TOTAL ...	...	30,92,105	.....	GRAND TOTAL ...	...	15,75,266	

The scheme was sent to the Secretary of State with a Government Order (No. 430, dated 12th February 1864) from which the following is an extract:—

"2. Taking the total area of the Kistna Delta to be one million of Acres, Lieutenant-Colonel Anderson assumes that only one-half consists of cultivable land, fitted by soil and elevation for being brought under wet cultivation by means of the Anicut at Bezoarah, of which half about one-fourth part only is as yet watered. Of these half million irrigable Acres, he assigns 270,000 to the Masulipatam side of the river, and 230,000 to Guntoor, and allowing 2 cubic yards per Acre per hour as the quantity of water required in those Districts for a rice crop, ... he explains the inadequate capacity of the channels, as they now exist, for the conveyance into the Delta of the quantity of water for which pressing, and yearly increasing demands are made, and suggesting some additions to the Anicut itself to improve the supply, he conclusively shows that to give full effect to that work for the benefit of the people and the augmentation of the revenue, a further outlay on enlarging, improving, and extending channels must be incurred of Rupees 30,92,205, of which Rupees 16,17,166 are required to be spent in Masulipatam, and Rupees 14,75,039 in Guntoor, in addition to the aggregate of Rupees 24,42,550 already expended on the general scheme up to the end of 1862-63.

"3. The extent of land brought under irrigation up to that date is stated at 1,90,000 Acres, which, divided into the expenditure give 12·14 nearly as the capital sunk per Acre; adding to the past expenditure the Rupees 30,92,205 which the works still require to be laid out on them to bring the whole 500,000 cultivable Acres of the Delta under irrigation, the average cost of watering each Acre will be not more than Rupees 11. If these calculations be at all correct, and there is no reason to believe that they are exaggerated, there can be no doubt that, beneficial and remunerative as the Kistna works are in their present unfinished state, they will be much more so when extended to completion, and that they will return a profit amply sufficient to justify the requisite expenditure upon them. The Government is satisfied that on financial grounds alone, if on no others, any outlay that may be required to extend irrigation from the Bezoarah Anicut to the utmost may be safely incurred, and it will be prepared to take into favorable consideration all such projects as may be submitted by the Superintending Engineer for the progressive development of the entire scheme as rapidly as funds can be made available.

"4. As regards the proposed additions to the Anicut of piers between which planks could, when required, be inserted to raise the level of the water and thereby throw a larger quantity into the channels than could otherwise be obtained at those times towards the end of the freshes when the river sometimes falls too low to furnish a full supply with the body of the

Anicut at its present elevation, the Government bearing in mind the great height of the work, as well as its peculiarly dangerous situation in a narrow gorge through which the river when in flood rushes with great force, is of opinion that any measures for even temporarily increasing the obstruction now offered by the Anicut ought to be taken with the greatest caution, and it fears that the adoption of the expedient suggested by Lieutenant-Colonel Anderson will not be unattended with risk, even if the work be strengthened as proposed, unless the means of rapidly removing the shutters at a few moments notice, either by day or by night be provided."

Anticipated total cost—
Rs. 24,42,550 already incurred.
Rs. 30,92,105 now proposed.
Rs. 55,34,655.

It will be noticed from the above that the total anticipated cost of the Kistna Delta works had now, since 1849, swelled from 15½ to upwards of 55 lakhs, but the assured success, financially as well as otherwise, of the Gódávari works, and the promising results of what had already been done in the Kistna, smoothed the way for favourable consideration of this greatly increased expenditure, and without demur the Secretary of State notified his approval, in his Despatch No. 33 of 9th December 1864. Thenceforward for several years all sanctions for the Kistna Delta system were treated as against the sum of Rs. 30,92,105, and as forming part of Major Anderson's programme, though in many cases they were modifications of, or even departures from, his proposals. What those sanctions were to 1881, when the new "Completion scheme" was sent in, cannot now be ascertained with certainty, but what they were to September 1877 will be found in the statement already given at pages 98 to 103.

Loans for remunerative Public Works.

In 1866 the Secretary of State sanctioned the adoption of the general principle of supplementing the ordinary resources of Government by loans for the construction of large public works expected to be remunerative; these were to be classed under the title of "Productive Public Works", and of course the Kistna system, in common with that of the Gódávari and the other chief irrigation systems of the Presidency, came into this category. From that time forward all grants, expenditure, and charges, on such works have been systematically recorded (which was by no means the case previously) and a much more elaborate system of charges against the works for estimated cost of establishments, share of leave and pension allowances, assumed expenses of collection of revenue in the Revenue Department, &c., &c., was adopted.

As large estimates were from time to time forwarded for sanction as part of Major Anderson's scheme though differing greatly from it, the Government of India in 1867 again pressed for a complete and comprehensive scheme for the whole delta, remarking in its letter No. 163-L, dated 25th October 1867 . . "In past years because of the difficulty of obtaining funds to carry out costly works, it might have been advantageous to break up such projects, and deal with them in fractions . . now when the difficulty in regard to the provision of funds no longer exists, there is still less reason why this course should be adopted," and it goes on to request "that steps may be taken for the preparation of a complete project for the whole system of works for the Kistna Delta based on a comprehensive view of the available water supply and of the lands that may be irrigated by that water." It took however many years before this request was fully complied with.

India again calls for submission of comprehensive scheme.

In 1874 Lieutenant (now Colonel) D. McNeil Campbell, R.E. (afterwards Chief Engineer, Madras) prepared * the "Completion estimates" for the Eastern Delta and the greater part of the Western Delta; these were reviewed and somewhat altered by Colonel (now General) J. Mullins, R.E., who was then, and for many years after, Chief Engineer for Irrigation, and they were, with some subsequently prepared estimates, sent on to the Government of India (see Proceedings of Madras Government, No. 3572, dated 19th December 1874, and No. 3528, dated 22nd December 1876). They were not however accompanied by the forecasts of returns and all the revenue particulars, required by the Government of India, who accordingly declined to forward them to the Secretary of State saying, "The Government of India much regret that it is unable even after this long interval to decide whether these works can be recommended to the Secretary of State for completion, chargeable to the Productive Public Works Grant, in the absence of definite recommendations from the Government of Madras in its Revenue Department."

"Completion Estimates."

Government of India letter No. 39-I., 4th March 1879, with P.M.G., No. 314-I., 5th May 1879.

At last in May 1881 the whole scheme was sent on in the way required, with a "note" by the Chief Engineer for Irrigation from which the following are extracts :—

Complete scheme submitted to India.

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* See Proceedings of Madras Government, No. 3572, dated 19th December 1874, and No. 601, dated 24th July 1878.

"2. The total cost of the system will be Rs. 1,38,99,784 for direct charges, or Rs. 1,66,70,813 including indirect charges as shown below :—

—	Expenditure to end of 1879-80.	Amount required to complete sanctioned works.	Delta completion estimates now submitted.	Total.
Direct Charges.	RS.	RS.	RS.	RS.
Works	38,92,360	69,167	66,00,000	1,05,61,527
Establishment	9,73,090	17,292	16,83,000	26,73,382
Tools and Plant	2,44,798	3,458	4,18,000	6,66,256
Suspense Account	55,315	— 55,315	...	...
Less Receipts on Capital Account.	— 1,381	...	...	— 1,381
TOTAL DIRECT CHARGES ...	51,64,182	34,602	87,01,000	1,38,99,784
Indirect Charges.				
Capitalized abatement of Land Revenue.	2,05,279	...	2,59,000	4,64,279
Loss by Exchange	...	...	20,000	20,000
Leave and Pension Allowances.	2,06,781	3,675	3,51,000	5,61,456
Simple Interest	51,294	...	16,74,000	17,25,294
TOTAL INDIRECT CHARGES ...	4,63,354	3,675	23,04,000	27,71,029
TOTAL DIRECT AND INDIRECT CHARGES.	56,27,536	38,277	1,10,05,000	1,66,70,813

"11. The ultimate area of irrigation is estimated at 470,000 acres, and the revenue as approximately estimated by the Board of Revenue is Rs. 13,94,000. Deducting the working expenses at 12 annas an acre, and the cost of collection at 7·2 per cent. on the revenue, the net revenue will be Rs. 9,41,132, * or 6·77 per cent. on the total direct charges of the system, or 5·65 per cent. including indirect charges. The above estimate of Revenue is however exclusive of Public Works Receipts, due chiefly to

Proceedings of Madras Government, No. 95-I., dated 8th February 1881.

	Rs.	Rs.
* Estimated Revenue		13,94,000
Working expenses—		
470,000 acres at 12 annas per acre ..	3,52,500	
Collection charges at 7·2 per cent. on Rs. 13,94,000 ..	1,00,368	
		4,52,868
Net Revenue ..		9,41,132

navigation, which already amount to a considerable sum, and will be made to cover navigation working expenses and interest on navigation outlay from 1870-71. These receipts are estimated at—

	Rs.
Navigation	82,500
Miscellaneous	13,500
Total ..	96,000

Adding this to the revenue realized in the Revenue Department, the total becomes 14·90 lakhs and the net revenue Rs. 9,92,132, or 7·14 per cent. on direct charges and 5·95 per cent. on direct and indirect charges. It may be noticed that the navigation mileage will be 348, and the receipts above estimated amount to Rs. 237 per mile. On the Buckingham Canal, a very recently opened navigation, the receipts for 1880 averaged Rs. 412 per mile, so there can be no doubt of the Kistna receipts realizing the amount stated."

Sanction of Secretary of State to "Completion Estimates."

In February of the following year the Secretary of State accorded his sanction to the scheme, in a despatch, an extract from which is here given :—

"Despatch from the Most Honorable the Secretary of State for India, to His Excellency the Most Honorable the Governor-General of India in Council, dated India Office, London, 9th February 1882, Public Works, No. 9.

"Your Excellency's Public Works letter, No. 40, dated 8th October last, submits for my sanction revised estimates for the completion of the Kistna Delta Irrigation and Navigation System.

"2. These estimates, so far as regards the probable revenue to be derived from the additional expenditure, are even now submitted in an imperfect shape, and have only been recently received by your Government from the Government of Madras, although that Government have been requested to furnish them since 1867.

* * * *

"4. The present proposals include a total direct outlay on the Kistna system of Rs. 1,38,99,784, or Rs. 83,65,029 in addition to the sum of Rs. 55,34,755, as originally sanctioned by Sir C. Wood's Public Works Despatch, No. 33, of the 9th December 1864. This further expenditure called for consists of fresh work, in order to supply new distributaries, which will nearly double the irrigated area, with extensive drainage and improvements of old work, for the purpose of securing existing irrigation from risks which have been brought to light by past experience. Expenditure of such a

description as this last tends, of course, to the increase of capital outlay without a proportionate increase in the actual direct returns from the work. Accordingly, the returns from the Kistna Delta System, which have hitherto averaged 9½ per cent., and even exceeded 12 per cent., will now probably be reduced to 7 per cent.

"5. The necessity, however, which exists for the proposed improvement and additions to the system is very clearly set forth in the papers transmitted with your letter, more particularly in the two notes on the subject by General Crofton and Colonel Brownlow; and I agree with your Government in considering that the estimates, as they stand, may fairly be approved. I accordingly convey my sanction to the direct outlay from productive funds on the Kistna Delta System being increased from Rs. 55,34,755 to Rs. 1,38,99,784.

"6. As these works have for many years past given a surplus net income in excess of the interest charge on the capital invested in them, no question of adding interest to the capital has in their case yet arisen, nor in view of the actual condition and prospects of these works do I consider that the proposed addition to the capital, on which their future profits will be calculated, will so increase the interest charge against the works as to affect their claim to be treated as Productive Works."

The summary of the new works to which this sanction was given is shown in the statement below, condensed from Appendix D with Proceedings of Madras Government, No. 321-I., dated 12th May 1881, as revised with Proceedings of Madras Government, No. 181-I., dated 28th February 1882. The anticipated cost of the *Works*, *exclusive* of "Tools and Plant," "Establishments" and all "Indirect charges" had now it will be seen mounted up to more than 105½ lakhs or nearly seven times the original forecast:—

Cost greatly beyond that originally anticipated.

Statement of the Kistna Delta Completion Estimates as sanctioned by the Secretary of State in his Despatch No. 9, dated 9th February 1882.

Particulars.	(1) Head Works.	(2) Main Canals and Branches.	(3) Distributaries.	(4) Drainage and Protective Works.	Total.
	Rs.	Rs.	Rs.	Rs.	Rs.
Head Works. Raising Anicut.	1,30,000	...	...	...	1,30,000
Eastern Section.					
1st Sub-section.					
Masulipatam Canal ...	...	2,13,520	30,000	...	2,43,520
Bank Canal	...	8,35,445	1,86,217	...	10,21,662
Drainages	...	...	...	...	48,653
2nd Sub-section.					
Ellore Canal	...	1,37,560	46,915	36,795	2,21,270
3rd Sub-section.					
Ryves' Canal	...	58,115	1,07,890	...	1,66,005
Pulleru Canal	...	36,965	73,805	...	1,09,690
Uppuluru Drain	...	...	...	28,725	3,78,096
Chendrayakodu Drain ...	...	...	...	1,43,402	
Polrazkodu Drain and Affluents.	...	...	...	1,87,130	
Kolleru Embankment ...	...	...	...	18,889	
4th Sub-section.					
Polras Canal	...	1,41,400	1,53,012	3,655	2,98,067
Lower Pulleru	...	...	48,660	...	48,660
Pullava Main Drain and Affluents.	...	...	...	20,080	1,63,215
Damidi Drain	...	...	...	3,209	
Peddakommeleru Main Drain and Affluents.	...	...	...	41,686	
Peddalunka Main Drain and Affluents.	...	...	...	98,240	
5th Sub-section.					
Pulleru Canal	...	...	1,58,200	...	1,58,200
Buntumilly Canal	...	1,30,180	15,350	...	1,45,530
Lasabanda Drain and Affluents.	...	...	...	2,19,034	2,56,545
Sultanagaram Drain ...	...	...	...	2,827	
Kanakavally Drain ...	...	...	...	27,184	
Gudur Swamp Minor Channels.	...	...	...	7,500	
Total, Eastern Section ...	...	15,52,605	8,19,549	8,86,959	32,59,113

Statement of the Kistna Delta Completion Estimates as sanctioned by the Secretary of State in his Despatch No. 9, dated 9th February 1882—continued.

Particulars.	(1) Head Works.	(2) Main Canals and Branches.	(3) Distributaries.	(4) Drainage and Protective Works.	Total.
WESTERN SECTION.	RS.	RS.	RS.	RS.	RS.
Main Canal	...	5,38,020	...	...	5,38,020
Bank Canal	...	2,68,040	1,41,470	...	4,09,510
Nisampatam Canal ...	...	10,645	4,940	...	15,585
Commamur Canal	...	7,47,880	1,71,010	...	9,18,890
Repalli Main Drain	...	...	...	2,51,087	
Bhattiprole Main Drain ...	...	...	...	47,853	
Minor Main Drains ...	...	...	...	11,929	
Tungabhadra Drain and Affluents.	...	...	...	6,15,191	11,10,160
Romperu Drain and Affluents.	...	...	...	1,84,100	
TOTAL, WESTERN SECTION.	...	15,64,585	3,17,420	11,10,160	29,92,165
Total ...	1,30,000	31,17,190	11,36,969	19,97,119	63,81,278
Unforeseen Expenses ...	...	...	...	...	2,18,722
GRAND TOTAL, I Works ...	...	...	..	...	66,00,000
Establishment, General Establishment at 25 per cent.	...	...	...	...	16,50,000
Survey Establishment at ½ per cent.	...	...	...	...	33,000
Tools and Plant, 2½ per cent. on the estimate for drains.	...	...	...	...	49,928
Tools and Plant, 8 per cent. on the estimates other than drains.	...	...	...	...	3,68,072
GRAND TOTAL, Direct Charges, "Completion Estimate."	...	...	...	...	87,01,000
Expenditure to end of 1879–80 and amount required to complete already sanctioned works.	...	...	...	...	51,98,784
GRAND TOTAL of Secretary of State's sanction for "Works" and "Direct Charges."	...	...	...	...	1,38,99,784

The following is a condensed description of the works for which the estimates provided :—

HEAD WORKS.

Raising Anicut by "building 3 feet in height of large blocks of cut-stone well clamped together over the front wall, the rough stone behind

being raised 3 feet, so as to retain the same slope as at present, and lengthening the apron by 50 feet," Rs. 1,30,000. In dealing with this the Chief Engineer for Irrigation said: "The crest should not be raised an inch higher than is necessary, and before the time for making an alteration comes there will be ample data to go on." What *has* been done is described in Chapter V.

EASTERN DELTA.

Masulipatam Canal.

(*a*) *Earthwork, Rs.* 1,74,660—*Widening, 1st Reach;* to a bottom width of 110′ to 115′ (depth of water 8′) to enable it to carry 1,912·5 cusecs * with a surface fall of ·33′ per mile, for 3½ miles to then intended head of the *Bank Canal,* and from there to end of reach at Kankipad Lock to a bottom width 61 to 76 feet (depth of water 7′) to carry 1,012·5 cusecs, of which 90 cusecs to be sent into minor distributaries, 502·5 cusecs to go to the Pulléru and 420 cusecs to a large distributary known as the "West-side channel," from just above the lock, leaving the other four reaches of the canal solely for navigation purposes, though it was noted that their "conversion into a still-water navigation will not prevent the use of the canal as a duct for the supply of irrigation water" should that prove advisable.

(*b*) *General Earthwork Improvements* to 2nd to 5th reaches, *Rs.* 12,000.

(*c*) *Alteration Veranki Lock, Rs.* 890.

(*d*) *New Lock at Nedumole, Rs.* 25,330.

(*e*) *Raising walls of Akumarru Lock, Rs.* 240.

(*f*) *Raising Chiritaguntapalem Bridge* so as to give 12′ headway, *Rs.* 400.

(*g*) *Lump sum* allowance for distributaries, *Rs.* 30,000.

Bank Canal.

Rs. 10,21,662.—As the proposals made for this have not been, and will not be, carried out (see Chapter VII), it will suffice to say that the general idea was to make a navigable canal to "afford water communication of a practicable but inexpensive kind" starting from 3½ miles of the Masulipatam Canal and running near the eastern side of the Kistna to the Puligadda branch of that river, over which water for irrigation of Divi Island was to be taken by an aqueduct estimated to

* Cusecs = cubic feet per second.

cost Rs. 3,58,000. The canal was to have only one lock, at its head, and a head-sluice to pass 900 cusecs. Its distributaries were to be numerous and expected to cost Rs. 1,86,217.

Ellore Canal.

(*a*) *Earthwork.*—Rs. 56,510 (of which Rs. 29,640 considered as belonging to irrigation and Rs. 26,870 to navigation) thus described in the note of the Chief Engineer for Irrigation with P.M.G., No. 3528, dated 22nd December 1876: "The canal as revised will have a depth of 8 feet and a bed and surface fall of 0·08 feet per mile from the head to the 11th mile; thence to the 20th mile the bed will be horizontal and the surface fall will be 0·228 feet a mile, the depth being thus diminished to 6 feet; from this point to the end at the Ellore Lock the depth will be 6 feet and the bed and surface fall 0·228 a mile. . . . The water surface is to be 60 feet in width as a minimum in the interests of the navigation, with however some diminution at old masonry works, which are serviceable and which it has not therefore been considered necessary to reconstruct. . . . The upper 35 miles of the canal are very irregular, and adjustment and the restriction of the water to its proper width, instead of allowing it to spread over the sometimes extensive berms on either side, are the alterations needed. In the lower few miles the lowering of the canal bed materially involves more earthwork."

(*b*) *Masonry.*—For improvement of tow-paths under bridges, Rs. 885.

(*c*) *Distributaries.*—Eight large irrigation channels, Rs. 46,915.

(*d*) *Cross Drainage Works.*—Rs. 80,165 made up of the following items, viz.:—

	Rs.
Improving existing Budameru aqueduct ..	1,880
Another Budameru aqueduct at Késarapally ..	28,000
Alterations to the West Tammiléru aqueduct ..	15,520
East Tammiléru outlet and an additional outlet.	17,230
One inlet and 6 outlets to pass minor drainages across the canal	17,535

Ryves' Canal.

(*a*) *Widening* the 2nd and 3rd reaches and building a bridge, Rs. 58,115.

(*b*) *Distributaries.*—For which it was said "the arrangements are not yet settled," Rs. 1,07,890.

Pullêru Canal (including "Lower Pullêru").

The provisions (which appear in the "statement" printed above, under three "sub-sections") are for—

(*a*) Main canals and branches, Rs. 36,385;

(*b*) Distributaries, Rs. 2,80,165.

No details were at the time submitted for these, but in May 1884 (see P.M.G., No. $\frac{455\ I.}{A}$, dated 3rd May 1884), the amount required for *Main Canals and Branches* was reduced to Rs. 22,385 which provided for the following works:—

	Rs.
Screw shutters to the two head-sluices at Kankipad	1,200
Screw shutters to the Weyûr Regulator ...	1,100
Bridge over Pamarru junction canal	7,650
Earthwork improvements	6,210
Cattle crossings	6,225
Total ...	22,385

For the *Distributaries* no complete scheme was ever prepared, but it was intended, as has been the case, that detail estimates for individual channels should from time to time be submitted.

Polraz Canal.

(*a*) *Earthwork* (least bottom width of canal to be 25 feet), three *second-class Locks*, two *Lock-weirs*, and the necessary *Bridges* and *Escapes* to make the canal a second-class line of navigation as well as to carry water for 20,000 acres, Rs. 1,41,400; and also (*b*) a lump sum provision of Rs. 1,53,020 for "Distributaries."

Bantumilli Canal.

The Rs. 1,30,180 provided for this were for (*a*) earthwork required to continue it as a navigable canal to the Upputéru; (*b*) three second-class Locks and Weirs; (*c*) one Bridge; (*d*) two Rest-houses; (*e*) nine "Cattle Ramps;" (*f*) compensation for land; and (*g*) improvement of an existing weir.

Rs. 15,130 were also put down as a lump sum for "Distributaries."

Drainage of Eastern Delta.

Rs. 8,86,959 were provided for the improvement of the drainage of this section of the delta, as shown in the following statement taken from Appendix F of P.M.G., No. 181 I., dated 28th February 1882:—

Statement showing the Estimates of the Drains of the Kistna Delta System, Eastern Delta.

Full amounts of Estimates.	Names of Drains.	Reduced amounts for entry in the "Completion" Estimates.		Remarks.
		Individual Drains.	Sub-section.	
Rs.		Rs.	Rs.	
57,960	Kanakala main drain	19,320		*$\frac{1,01,320-43,860}{3}$=19,320.
1,000	Devarapalli drain	333		
61,500	Taleru (Divi) drain	20,500		
25,000	Gudirmotu (Divi) drain	8,333		
500	Mopedevi drain ...	167		* *Vide* paragraph 19 of Note, Proceedings, Madras Government, No. 3528, of 22nd December 1876.
1,45,960	1st *Sub-section* ...	...	48,653	One-third of Rupees 1,45,960—*vide* paragraph 6 of G.O., No. 3528, of 22nd December 1876.
3,470	Viranki	} ...		Nothing sanctioned on the grounds that the lands which would be benefited were "zemindari."
2,06,790	Inampudi			
2,10,260				
		...	...	*Vide* paragraph 9 of G.O., No. 3528, of 22nd December 1876.
790	Nakalam drain	790		
300	Kesarapalli do.	300		
700	Avitapalli do.	700		
570	Athkur do.	570		
200	Potipad do.	200		
2,510	Ampapuram do.	2,510		
400	Viravalli do.	400		
830	Nellivagu do.	830		
2,175	Narasanapalam do.	2,175		
1,690	Canomole do.	1,690		
470	Perikeet do.	470		
140	Ramaleru do.	140		
60	Punnukollu do.	60		
8,260	Peddapad do.	8,260		
370	Wutlur do.	370		
2,800	West Tummeleru do.	2,800		
400	Jolipudi do.	400		
2,165	East Tummeluru do.	2,165		
1,845	Minor drains	1,845		
10,120	Minor improvements to masonry works ...	10,120		
36,795	2nd *Sub-section* ...	...	36,795	*Vide* paragraph 10 of G.O., No. 3528, of 22nd December 1876.

Statement showing the Estimates of the Drains of the Kistna Delta System, Eastern Delta—cont.

Full amounts of Estimates.	Names of Drains.	Reduced amounts for entry in the "Completion" Estimates.		Remarks.
		Individual Drains.	Sub-section.	
Rs.		Rs.	Rs.	
47,330	Uppuluru drain ...	28,725		
2,36,280	Chendrayakodu do. ...	1,43,402		
1,90,475	Polrazkodu do. ...	1,15,602		
1,02,335	Komaravole do. ...	62,109		
15,520	Palakodu do. ...	9,419		
31,040	Kolleru embankment ...	18,839		
6,22,980	*3rd Sub-section*	...	3,78,096	Appendix D printed with Proceedings, Madras Government No. 17 I., of 9th January 1879.
60,240	Pullava main drain and affluents	20,080		*Vide* paragraph 83 of note in Proceedings, Madras Government, No. 3258, 22nd December 1876.
9,625	Dammide drain ...	3,209		
1,25,058	Peddakomeleru drain and affluents ...	41,686		
2,94,720	Peddalunka drain and affluents	98,240		
4,89,643	*4th Sub-section*	...	1,63,215	One-third of Rupees 4,89,643—*vide* paragraph 13 of G.O., No. 3528, of 22nd December 1876.
3,655	Embanking Upputeru ...	3,655	3,655	*Vide* paragraph 11 of G.O., No. 3528, of 22nd December 1876.
1,87,250	Lasabunda drain ...	1,40,438		
49,755	Vadlamanad affluent	37,316		
8,630	Isukaparra do.	6,472		
46,410	Gokavaram drain	34,808		
3,770	Sultanagaran do.	2,827		
36,245	Kanakavally do.	27,184		
10,000	Gudur swamp minor channels	7,500		
3,42,060	*5th Sub-section*	...	2,56,545	Appendix D printed with Proceedings, Madras Government, No. 17 I., 9th January 1879.
18,51,353	TOTAL, EASTERN DELTA.	...	8,86,959	

WESTERN DELTA.

Main Canal.

Widening from Head-sluice to Duggirala Lock, 13 miles, Rs. 5,38,020.—Bottom width as far as Ravendrapad (head of Bank Canal), 230 feet, maximum depth 8½ feet, discharge 3,317 cusecs; * from thence to Duggirala Lock, 141 feet, maximum discharge 1,884 cusecs; side slopes 2 to 1; fall 0·27 per mile.

Bank Canal.

(*a*) *Earthwork, Rs.* 1,23,715.—To make it a second-class line of navigation through to the river, as well as to fit it to carry water for the irrigation of 70,000 acres—

For the first 13½ miles, bottom width, 75 feet;
For the next 20 miles, bottom width 70 to 49 feet; and
Beyond that, bottom width, 25 feet.

(*b*) *Masonry, Rs.* 1,52,325.—For (1) increase of size of Head-sluice from 5 to 8 vents; (2) five new Locks (second-class); (3) two new Lock Weirs and alteration of three others; (4) three Rest-houses; (5) Ramps; (6) five Drainage inlets in the first 7 miles; and (7) Kollipara *Surplus-weir* and channel.

(*c*) *Distributaries, Rs.* 1,41,470.—For 12 large irrigation channels with their branches and a lump sum (Rs. 30,000) for "Minor distributaries."

Nizampatam Canal.

(*a*) *Earthwork, Rs.* 10,645.—*Raising* and *strengthening* the banks to allow water to be held up at Kuchipúdi and Intúr locks for still water navigation, almost all irrigation water being conveyed by two large "Side channels" taking off from above the head lock.

(*b*) *Distributaries.*—Improving Head-sluice of the "West side" channel and extending it for 4½ miles; Rs. 4,940.

Commamúr Canal.

(*a*) *Earthwork, Rs.* 2,94,790 *and Land Compensation, Rs.* 5,480.—To make the canal a first-class line of navigation and to carry water for 80,000 acres of irrigation. Bottom widths, first reach, 130′—104′; second reach, 93′—89′; third reach, 81′—59′; fourth and fifth reaches, from which no irrigation proposed, 36′.

(*b*) *Masonry Works.*—Improvement of Head-sluice of canal—four new first-class Locks and Weirs—improvements of two existing Lock-weirs and one escape; four new Bridges; three Rest-houses; Cattle crossings, &c.

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* Cusecs = cubic feet per second.

(*c*) *Cross Drainage Works, Rs.* 2,49,350.—Of this, Rs. 1,88,250 for eight new Aqueducts (*Guntúr Nalla, Nakkavagu, Nallamada, Sakikalwa, Karenchedu, Swerna, Alleru* and *Emmilêru*), and the remainder for improvements to existing works, and for some 8,000 running feet of each "Inlets" and "Outlets."

(*d*) *Distributaries, Rs.* 1,71,010.—For 13 large irrigation channels and branches complete.

Drainages of the Western Delta.

For these Rs. 11,10,160 were provided as shown in the following statement taken from Appendix F with P.M.G., No. 181 I., dated 28th February 1882:—

Statement showing the Estimates of the Drains of the Kistna Delta System, Western Delta.

Full amounts of Estimates.	Names of Drains.	Reduced amounts for entry in the "Completion" Estimates.		Remarks.
		Individual Drains.	Sub-section.	
Rs.		Rs.	Rs.	
5,24,970	Répalle main drain ...	2,21,137		
5,440	Nandivelugu affluent ...	2,291		
3,105	Jagadigunta do. ...	1,308		
16,345	Gundera do. ...	6,884		
8,870	Lanjagunta do. ...	3,736		
27,345	Kavur do. ...	11,518		
4,205	Pemucalva do. ...	1,772		
5,795	Nagaram do. ...	2,441		
1,13,610	Bhattiprole drain ...	47,853		
7,295	Peddapalli do. ...	3,073		
21,025	Nizampatam do. ...	8,856		
7,38,005	*Répalle drain Sub-section*	...	3,10,869	Appendix D printed with Proceedings, Madras Government, No. 17 I., of 9th January 1879.
6,95,185	Tungabhadra main drain	...		
41,495	Kunderu affluent ...	...		
3,81,845	Kollimerla do. ...	...		
16,540	Doppalapudi do. ...	...	6,15,191	Do. do.
3,99,750	Nallamada branch drain.	...		
1,36,860	Pundla affluent ...	...		
1,85,690	Tenali branch drain ...	...		
18,67,365	*Tungabhadra drain Sub-section*	...		
3,36,100	Rompéru drain	1,16,230		
20,160	Bapatla affluent ...	20,160		
15,650	Karenchedu do. ...	15,650		
16,790	Parchurvagu do. ...	16,790		
4,400	Swerna do. ...	4,400		
10,870	Alleru do. ...	10,870		
4,03,970	*Rompéru drain Sub-section*	...	1,84,100	G.O., No. 286 I., of 3rd September 1877.
29,99,340	Total, Western Delta ...	...	11,10,160	

It will be seen that at last the *Drainage* question was receiving considerable attention, no less than Rs. 19,97,119 out of Rs. 63,81,278 (exclusive of "unforeseen works") being for that purpose. The general principles and system on which the discharging capacity for the drainage channels and the incidence of cost were fixed can be best explained by giving the following extracts from the "Notes" of the Chief Engineer for Irrigation (Colonel J. Mullins, R.E.) when reviewing the estimates, and from the Government Order dealing with them :—

Drainage.

"8. The drainage of the delta is a matter of great importance both as regards the well being and prosperity of this tract of very rich country, but also from a financial point of view. It became necessary to introduce some principle on which to base the designs of this class of work, and the arrangements prescribed are as follow. It was manifestly impracticable, in a country situated as is the delta, to dispose of rainfall drainage within the delta and that from the uplands after its entrance within the delta limits, as fast as it came down or accumulated, and it was believed also to be unnecessary that this should be done. Generally speaking standing wet crops would not be liable to injury from an excess of water during several days, or from submergence for a short period. It is, therefore, intended to dispose of the maximum estimated drainage of six days within that time. Moreover, as the amount of drainage is not in direct proportion to the area drained, and as it is believed that the real proportion is sufficiently closely determined by the formula $D = C \sqrt[3]{M^2}$, in which M represents the area drained in square miles, that equation has been made use of. For the determination of the actual discharge a standard area of 5 square miles has been taken, and C has been assumed for this particular part of the country to be 450 per cubic feet a second. On these data the maximum drainage from 5 square miles will be 1,314 cubic feet a second, equivalent to a little under 10 inches in the 24 hours. Six days have been taken as the time within which the lands are to be freed from flood waters, and in addition to the maximum rainfall drainage of 10 inches on one day, it has been supposed that 2 inches will be due to the other 5 days, so that altogether 12 inches will have to be disposed of in 6 days, or 2 inches a day from the area of 5 square miles. For other areas the relative drainage has been determined by the formula above given, and the results are as follow :—

Colonel Mullins' Note with P.M.G., No. 3572 dated 19th December 1874.

10	square miles; discharge due to a drainage from the whole area of			1·60 inches.
20	Do.	do.	do.	1·27 ,,
30	Do.	do.	do.	1·10 ,,
40	Do.	do.	do.	1·00 ,,
50	Do.	do.	do.	0·90 ,,
75	Do.	do.	do.	0·81 ,,
100	Do.	do.	do.	0·74 ,,
125	Do.	do.	do.	0·69 ,,
150	Do.	do.	do.	0·65 ,,

and so on for any other areas.

"This arrangement is applicable of course only to drainage within the delta, the area of which will be sub-divided by canals, channels, main and subsidiary drains, into a number of comparatively small spaces, on which drainage will accumulate after very heavy falls of rain, and thereafter be carried away as fast as the drains will allow.

"Upland, or extra delta, drainage will have to be disposed of, so far as passing it across the canals is concerned, as fast, or very nearly as fast, as it can come down. * * * *

"The drainage of the delta lands, so far as this may be connected with the disposal of surplus irrigation water, rendered necessary to admit of the extension of irrigation, or may be required for the benefit of lands already irrigated, is fairly chargeable to the general scheme of the delta irrigation. Beyond this it would seem that the irrigation works are in no way liable to bear the charge, and if any further works be debited to the capital account of the delta scheme, it should only be on the ground that if there be a likelihood of a return from irrigation considerably exceeding the interest on the money invested, some part of the capital represented by the difference may be invested in the general improvement of the condition and healthfulness of the country from which such revenue is derived. If so, it is of course surplus revenue only that should be applied to such a purpose.

"It has been supposed by the Government, in connection with the papers on the village drainage of the Godavery, that artificial irrigation is a principal cause of the need of drainage, but that this is not really the case may easily be shown. Very small drains comparatively will convey away all the surplus irrigation water. The total supply on this account is but a little over one-third of an inch in the 24 hours, and of this only a small fraction is surplused from the lands, because when there is heavy rainfall, and when consequently much water is not required on the fields, the quantity admitted at the head-sluices is diminished, and much of that which enters the canals is sent direct into the drains and natural streams. Probably, therefore, at the outside, one-fifth of an inch in the 24 hours would be the largest drainage due to the irrigation works, and as has been above shown this would be but one-tenth of the quantity due to rainfall. Natural causes render great drains necessary, and it would seem to follow that the irrigation project is not bound to pay more than a comparatively small fraction of the cost of providing them. * * * *

Colonel Mullins' Note with P.M.G. No. 3528, dated 22nd December 1876.

"The maximum falls are less in the latitude of the Kistna than further south, but 21 inches have been registered at Madras (in 24 hours) 13 to 15 inches have several times been measured in its neighbourhood, and 13½ inches were recorded at Nellore, less than 150 miles to the south of the

Kistna delta, in 1859. Such being the case, the provision intended to be made in the Kistna delta does not appear to be at all excessive.

"*Drains will be carried out gradually and tentatively.*—On the other hand, there is no intention of making these drains of the full size at once. This could not conveniently be done even were the dimensions known to be correct, but the advantage of providing for fairly ample dimensions from the first will be that embankments, infall works of branch drains, inlets, &c., will be placed at a sufficient distance from the centre lines of the main drains, and there will be no waste of money in removing them to a greater distance hereafter. The drains will be cut first to one-fourth then to one one-third, then, say, to half their full size, and so on progressively as labor may be available and as observation may show to be desirable. During the interval of some years that will elapse the data required for a correct estimate of the requirements of the country will be accumulating.

"4. The estimates include provision for the complete drainage of the country on a scale which has been designed to allow of all rainfall drainage being disposed of within a maximum period of 6 days. The data for deciding on the requisite capacity of drains for the relief of given areas are confessedly imperfect, and consequently it is proposed to cut them at first to from one-third to half of the designed dimensions, and thus to ascertain experimentally what is necessary for the efficient drainage of each particular locality. Another important point which has to be determined is the proper incidence of the cost of drainage works. It has been shown that the quantity of surplus irrigation water to be disposed of is small compared with the discharge due to rainfall, and, on the other hand, the irrigated area interested in the improvement of the drainage is only about 36 per cent. of the gross area. It will therefore not be proper to charge to the Delta system the whole cost of the drainage works, but at the present moment the Government are not in a position to arrive at a conclusion as to the proper distribution of the charge. The subject has for some time past been engaging attention, and it is thought that the best plan will be—

G.O., No. 3528, dated 22nd December 1876.

"1*st*,—to consider these drainage estimates as an approximate indication of the amount which may ultimately have to be spent for the improvement of the agricultural condition of this tract of country;

"2*ndly*,—to assume that about one-third of the amount of these estimates will require to be laid out concurrently with the extension of irrigation in order, first, to provide for the removal of the more prominent existing obstructions to effective drainage, and, secondly, to prevent all risk of deterioration of the condition of the country from the introduction by the canals of an increased supply of water;

"*3rdly*,—to take sanction for this one-third of these estimates as a lump sum provision for drainage, all proposals for expenditure being subsequently submitted for the specific sanction of this Government, so that improvements which may be shown to be necessary may from time to time be approved for execution;

"*4thly*,—to charge to the Delta system the cost of this partial drainage on the assumption that at least so much will be necessary either in the interests of the irrigated area, or to prevent increase of the inconvenience arising from defective drainage. By judicious arrangements it is anticipated that a good deal of subsidiary drainage will be secured without extra, or at a nominal, expense by forming catch-drains alongside distributaries when outside cutting is required to make up the channel banks to proper section. This arrangement has been provided for in laying out the distribution, and should be carefully borne in mind during the execution of the works."

The principles thus laid down have not been closely adhered to, but none better for the systematic treatment of the problem have yet been formulated. Much of the money spent on the large drainages of the Kistna Delta, especially in its Western section, has gone in cutting off loops and bends. There is apparently great difference of opinion as to the utility of such "Straight-cuts," but, in order to draw special attention to the subject in dealing with what remains to be done on the large drainages of the Kistna, the compiler of this history would record his conviction from experience, that "Straight-cuts" interpolated here and there along the naturally winding course of a delta stream, are useless as regards the object of getting flood water more quickly to the sea, whilst they so upset the natural régime of the stream as to make the state of affairs worse than before, especially at the junctions of the cuts with the natural stream. Of course these remarks do not refer to improvement of existing tortuous channels by adapting their capacities to requirements, and by judicious easing off too abrupt turns and bends; they refer solely to new cuts here and there along the streams.

Directly the sanction to the so-called "Completion Project" was received, the works were taken in hand with vigour, Mr. J. W. Rundall being then, and for several years after, the Superintending Engineer. No useful purpose would be served by following in detail the execution of these works, but in the "Statement of Expenditure on Capital Account," Appendix No. II, will be found the expenditure on them year by year. From this it will be seen that the year after receipt of the sanction, expenditure on "Works" rose to Rs. 3,13,761 and has since generally been between 3 and 4½ lakhs annually, whilst the *total*

expenditure, Direct and Indirect, has amounted to Rs. 1,31,91,665; more than that on the Gódávari Delta system.

The sanction of the Secretary of State in February 1882 to the "Completion Estimates," Rs. 1,39,19,784 (see page 108) had according to rules a currency of only five years; it was then renewed for five years more, and on the expiration of that time was again renewed to 1st April 1893, when again a further extension of another five years was allowed to 1st April 1898. On that date however it was decided "to close * the construction estimate" * * and to treat any subsequent outlay on works remaining incomplete on that date, and on all extensions and improvements which are found necessary for the extension of irrigation in the delta under the 'Open Canal Capital Rules,' each such extension and improvement being considered on its own merits." This has accordingly been done.

* See P.M.G., No. 540 I., dated 26th June 1896.

In carrying out the works of the "Project" there have been many deviations from its provisions, and it was hoped that the statement embodying all such changes, which will have to accompany the "Review" on the closing of the "Construction Estimate," would have been available for the purposes of this history, but this is not the case. The comparison of actual *expenditure* with the sanction under "Main" and "Sub-heads" is however given in the following statement:—

Statement of CAPITAL OUTLAY *incurred on the Kistna Delta System to end of* 1897-98, *compared by Main and Sub-heads with the estimate sanctioned by the Secretary of State in G.O., No.* 291 *I., dated* 28*th March* 1882, *and as modified up to* 31*st March* 1898.

Main and sub-heads.	Estimate sanctioned by the Secretary of State in his despatch No. 8, dated 9th February 1882.	Redistribution of the estimate sanctioned up to 31st March 1898.	Outlay to end of 1897-98.	Difference.	
				As compared with the estimate sanctioned by the Secretary of State.	As compared with the estimate as modified up to 31st March 1897.
1	2	3	4	5	6
DIRECT CHARGES.	RS.	RS.	RS.	RS.	RS.
I. Works—					
1. Head works—					
B. Land	...	5,875	9,593	– 9,593	– 3,718
C. Works	1,30,500	2,80,500	1,19,277	11,223	1,61,223
K. Buildings ...	...	93,250	94,533	– 94,533	– 1,283
O. Miscellaneous ...	...	3,615	4,339	– 4,339	– 724
Total ...	1,30,500	3,83,240	2,27,742	– 97,242	1,55,498

Statement of CAPITAL OUTLAY *incurred on the Kistna Delta System to end of* 1897-98, *&c.*—continued.

Main and sub-heads.	Estimate sanctioned by the Secretary of State in his despatch No. 9, dated 9th February 1882.	Redistribution of the estimate sanctioned up to 31st March 1898.	Outlay to end of 1897-98.	Difference.	
				As compared with the estimate sanctioned by the Secretary of State.	As compared with the estimate as modified up to 31st March 1897.
1	2	3	4	5	6
DIRECT CHARGES—*cont.*	RS.	RS.	RS.	RS.	RS.
I. Works—*cont.*					
2. Main Canals and Branches—					
A. Preliminary expenses.	...	1,160	1,203	– 1,203	– 43
B. Land	33,700	1,14,445	95,336	– 61,636	19,100
D. Regulators ...	65,050	75,520	1,81,544	– 1,16,494	– 1,06,024
E. Falls and weirs ...	11,530	17,288	18,152	– 6,622	– 864
F. River and Hill torrent works.	6,88,015	4,29,847	3,10,671	3,77,344	1,19,176
F. (1) Other cross drainage works.	36,129	49,692	51,234	– 15,105	– 1,542
G. Bridges	1,58,033	1,22,209	1,04,821	53,212	17,388
H. Escapes	24,260	10,591	10,022	14,238	569
I. Navigation works.	5,49,979	4,87,727	4,27,932	1,22,047	59,795
K. Buildings ...	26,813	54,939	59,240	– 32,427	– 4,301
L. Earthwork ...	22,07,221	20,50,828	19,62,239	2,44,982	88,589
N. Tanks and reservoirs.	...	...	780	– 780	– 780
O. Miscellaneous ...	36,815	1,03,364	1,12,073	– 75,258	– 8,709
P. Maintenance ...	32,000	...	...	32,000	...
Total ...	38,69,545	35,17,610	33,35,247	5,34,298	1,82,363
3. Distributaries—					
A. Preliminary expenses.	...	2,596	2,804	– 2,804	– 208
B. Land	99,160	2,08,919	1,33,131	– 33,971	75,788
C. Works	3,54,721	5,15,305	4,08,940	– 54,219	1,06,365
L. Earthwork ...	7,75,035	7,99,925	6,51,984	1,23,051	1,47,941
O. Miscellaneous ...	31,453	99,830	37,299	– 5,846	62,531
Total ...	12,60,369	16,26,575	12,34,158	26,211	3,92,417
4. Drainages and Protective works—					
A. Preliminary expenses.	...	2,329	803	– 803	1,526
B. Land	88,001	1,14,760	69,792	18,209	44,968
C. Works	3,37,616	4,74,158	2,48,323	89,293	2,25,835
L. Earthwork ...	15,37,633	17,08,119	12,70,655	2,66,978	4,37,464
O. Miscellaneous ...	37,386	48,526	22,316	15,070	26,210
P. Maintenance ...	...	5,000	97	– 97	4,903
Total ...	20,00,636	23,52,892	16,11,986	3,88,650	7,40,906
Provision for unforeseen works.	2,18,722	6,732	...	2,18,722	6,732
Total current sanctions.	74,79,772	78,87,049	64,09,133	10,70,639	14,77,916
Old outlay	30,81,755	30,81,755	30,81,755	...	...
TOTAL, WORKS ...	1,05,61,527	1,09,68,804	94,90,888	10,70,639	14,77,916

Statement of CAPITAL OUTLAY *incurred on the Kistna Delta System to end of* 1897–98, *&c.*—continued.

Main and sub-heads.	Estimate sanctioned by the Secretary of State in his despatch No. 9, dated 9th February 1882.	Redistribution of the estimate sanctioned up to 31st March 1898.	Outlay to end of 1897–98.	Difference.	
				As compared with the estimate sanctioned by the Secretary of State.	As compared with the estimate as modified up to 31st March 1897.
1	2	3	4	5	6
DIRECT CHARGES—*cont.*	Rs.	Rs.	Rs.	Rs.	Rs.
Brought forward ...	1,05,61,527	1,09,68,804	94,90,888	10,70,639	14,77,916
II. Establishment ...	26,73,382	25,61,898	22,14,258	4,59,124	3,47,640
III. Tools and Plant ...	6,66,256	6,88,829	6,60,944	5,312	27,885
III-A. Loss by exchange.*	20,000	...	...	20,000	...
GRAND TOTAL ...	1,39,21,165	1,42,19,531	1,23,66,090	15,55,075	18,53,441
Less receipts on capital account.	1,381	6,521	15,400	– 14,019	– 8,879
TOTAL, DIRECT CHARGES.	1,39,19,784	1,42,13,010	1,23,50,690	15,69,094	18,62,320
INDIRECT CHARGES.					
Capitalized abatement of Land Revenue.	4,64,279	5,52,200	4,53,037	11,242	99,163
Leave and Pension allowances.	5,61,456	4,28,960	3,87,938	1,73,518	41,022
TOTAL, INDIRECT CHARGES.	10,25,735	9,81,160	8,40,975	1,84,760	1,40,185
TOTAL, DIRECT AND INDIRECT CHARGES—CAPITAL ACCOUNT.	1,49,45,519	1,51,94,170	1,31,91,665	17,53,854	20,02,505
Interest on direct outlay while work is under construction.	17,25,294	...	...	17,25,294	...
GRAND TOTAL ...	1,66,70,813	1,51,94,170	1,31,91,665	34,79,148	20,02,505

* In the original statement sent to Government of India with No. 313, dated 12th May 1881, this "Loss by Exchange" appears under "Indirect charges."

The above deals only with the "CAPITAL" expenditure, but besides this there has of course been the continuous cost of upkeep of the works, establishment for the purpose, &c., known as "REVENUE" expenditure, which to end of 1897–98 has amounted to Rs. 2,31,85,707 as shown in the following statement:—

Statement showing the Expenditure and Charges to end of 1897–98 *on* REVENUE ACCOUNT, *Kistna Delta System.*

			Rs.
DIRECT CHARGES—			
Extensions and Improvements ... ... } Works ... ... {			2,92,223
Maintenance and Repairs ... ... }			58,10,025
		Rs.	
Establishment Charges to end of 1881–82		12,64,855	
Establishment Charges from 1882–83 to 1897–98—			
23 per cent. on expenditure (exclusive of land compensation)	Rs. 8,03,740		
10 per cent. on receipts in the P.W.D. ...	73,054		
6 do. on purely "Irrigation" revenue (this charge was first introduced in 1882–83 as a relief to "Provincial Funds") ...	14,78,128		
		23,54,922	
			36,19,777
Tools and Plant			8,29,447
		TOTAL, DIRECT CHARGES ...	1,05,51,472
INDIRECT CHARGES, VIZ.—			
Capitalized abatement of revenue on lands taken up for the works, and leave and pension allowances at 14 per cent. on establishment charges.			6,08,810
Charges for collection of Revenue by Civil Officers. (This is a percentage charge on all Irrigation Revenue; it has varied from time to time, is now calculated at 5 per cent.)			24,10,156
Interest calculated at 4 per cent. per annum on Direct charges of CAPITAL OUTLAY			96,15,269
		TOTAL, INDIRECT CHARGES ...	1,26,34,235
		GRAND TOTAL ...	2,31,85,707

It will be seen that by far the largest item in the above statement (Rs. 96,15,269) is the "*Interest charged on the Capital Outlay*"; this is still being charged, though nearly all of it might well before this have been extinguished by a sinking fund raised from the large surplus profits of the system. Another large item (Rs. 24,10,156) is the arbitrary charge for collection by Civil establishment of Revenue due to the system; this charge is now calculated at 5 per cent. on that revenue, and the better the returns the larger of course will be this charge. This is also the case with the charge, first introduced in 1882–83, of 6 per cent. on the purely Irrigation revenue for supposed *extra* cost, in dealing with such revenue entailed on the Public Works Department; this has amounted to Rs. 14,78,128. In fact the only item in the statement on which economy is possible is that for "Maintenance and Repairs" (upkeep and so on) of the works. Now, whilst no policy

could be more injudicious than that of so scrimping allotments for the working expenses or upkeep of the works as to lead to their deterioration, it is advisable to keep within bounds the natural tendency to extravagance in that direction, and the following facts bearing on the subject are worth considering:—

When the "Project" was sent on for sanction (see P.M.G., No. 312 I., dated 12th May 1881), the "Working expenses" were estimated at 12 annas per acre for works and repairs, establishment, and tools and plant, but exclusive of "Collection charges," or of "Interest." In 1885 this anticipated rate was increased to 14 annas per acre with the following remarks, which will be found in the Note of the Chief Engineer for Irrigation with P.M.G., No. 80 I., dated 29th January 1885:—

"The Superintending Engineer, II Circle, has suggested that the provision for working expenses should be increased from 12 to 14 annas per acre, as the average rate for the five years from 1878–79 to 1882–83 is Rs. 0·86, or nearly 14 annas per acre. The period adopted for deducing the average rate, however, includes years in which the cost of repairs was abnormally high, owing to damages caused by floods. The average rate does not include indirect charges, but includes all repairs both to Irrigation and Navigation works, while the estimated rate of 12 annas per acre is only for repairs to Irrigation works, the cost of repairs to Navigation works being separately estimated at Rs. 45,000. It was hitherto believed that the cost of maintenance would be reduced when the works were improved, but it is now apprehended by the Superintending Engineer that there will be a considerable increase in the rates for labor and materials, when the lines of railway now under construction are completed. The suggestion of the Superintending Engineer to increase the rate from 12 to 14 annas per acre is therefore approved, and the forecast statements have been drawn up accordingly. As the water in the Kistna canals is more highly charged with silt than that in the canals of the Godávari delta, the cost of maintenance in the Kistna delta is more than that in the Godávari delta, for which system the estimated rate is only 8 annas per acre." *

The Kistna system working expenses (exclusive of *Navigation* charges) have mounted up to almost 1 rupee per acre, not including any "Indirect," "Collection" or "Interest" charges.

* The "Working expenses" of the Gódávari system are now really from 12 to 15 annas per acre; see page 105, "Engineering Works of the Gódávari Delta," and Administration Report, 1896–97.

CHAPTER VII.

GENERAL DESCRIPTION OF WHOLE SYSTEM OF CANALS, ETC.

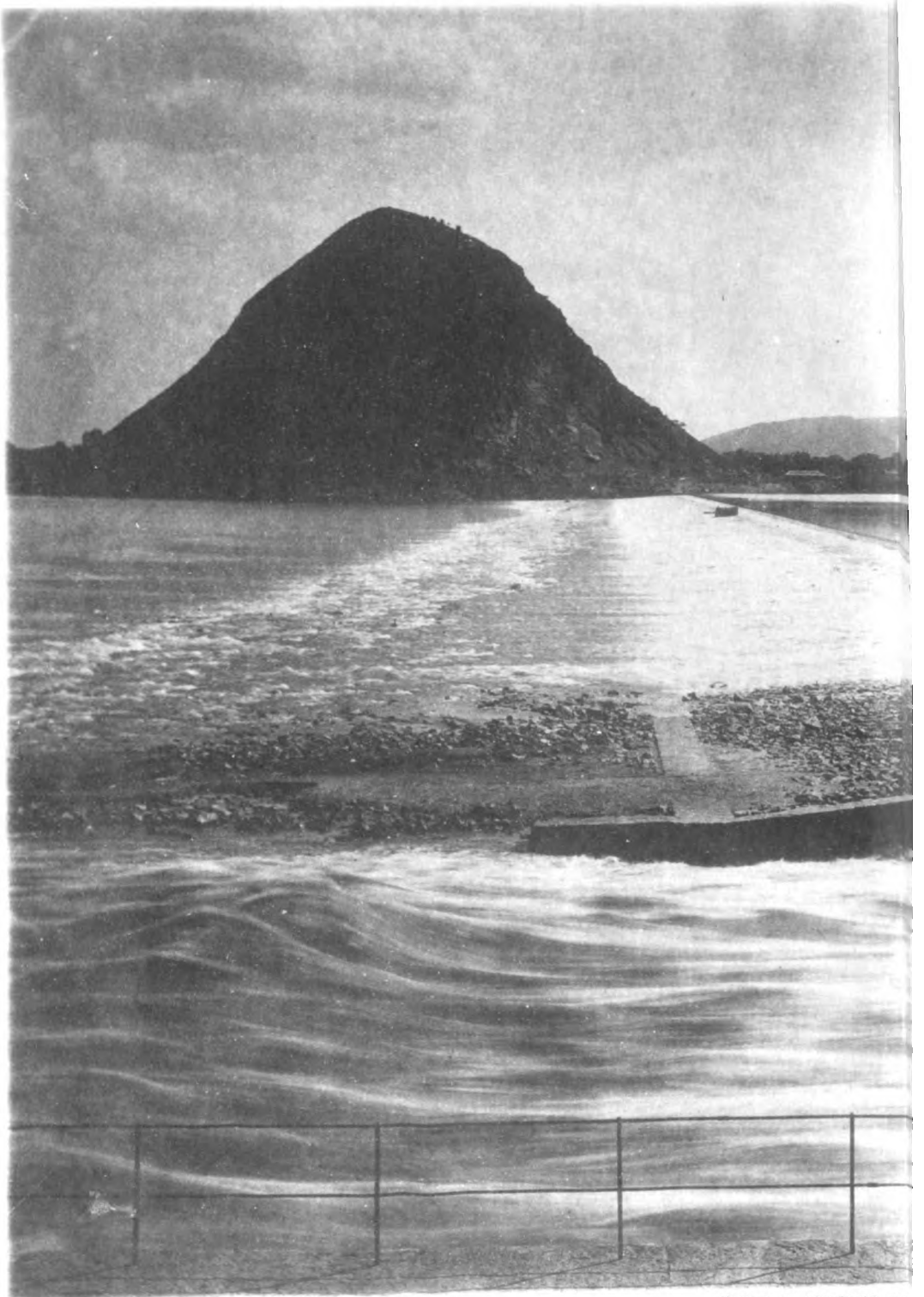
THE history of the construction of the works having been given, this chapter will be devoted to a brief description of their more important features as now existing; this, with the Sketch Map at the end of Chapter I and the larger scale maps in Volume II will, it is hoped, give a clear idea of the whole system.

First then, commencing with the ANICUT AND HEAD WORKS: The Anicut has a total length, inclusive of its Under-Sluices, of 3,714 feet. The foundations and section of the body wall are described in Chapter III and shown on Plan 5 of Volume II. The level of its crest as originally constructed was + 46·25 above mean sea-level (approximate) and is now, after the various alterations described in Chapter V, + 47·50. From 1 foot below the crest, or in some places where alterations have been made, from the crest itself, an "apron," the surface of which is carefully packed large stone grouted with, or in parts covered with, concrete, extends for 94 feet, the first 20 feet being horizontal, or nearly so, and the remainder sloping down to + 40·25, where there is a "retaining" or "bond" wall 5 feet thick; beyond this again there is a talus of rough stone extending for a length of from 120 feet to 150 feet, and sloping down to the river-bed. Along the crest of the Anicut there have now been fixed iron shutters * 3 feet high, so arranged as to fall when water tops them by from 1¼ feet to 1½ feet (see Chapter V); a drawing of these shutters will be found in Volume II, No. 6.

The views of the Anicut given in this Chapter were taken in 1893 when the crest was at + 47·25 and on it were grooved iron posts 2 feet high in which boards could be placed at will.

The highest floods since the construction of the Anicut have been that of July 1882 when the river rose to + 66′·29 or 20′·04 over the then crest, and that of 6th August 1896 when the level reached was + 67′·55 or 18′·30 over the crest as it was then; the discharge in the former of these floods has been calculated at 770,000 cubic feet per second. At

* This is their height above a depression of 4 inches in which the shutters stand, so that the top of the shutters is + 47′·5 — 0′33 + 3′ = + 50′·17.



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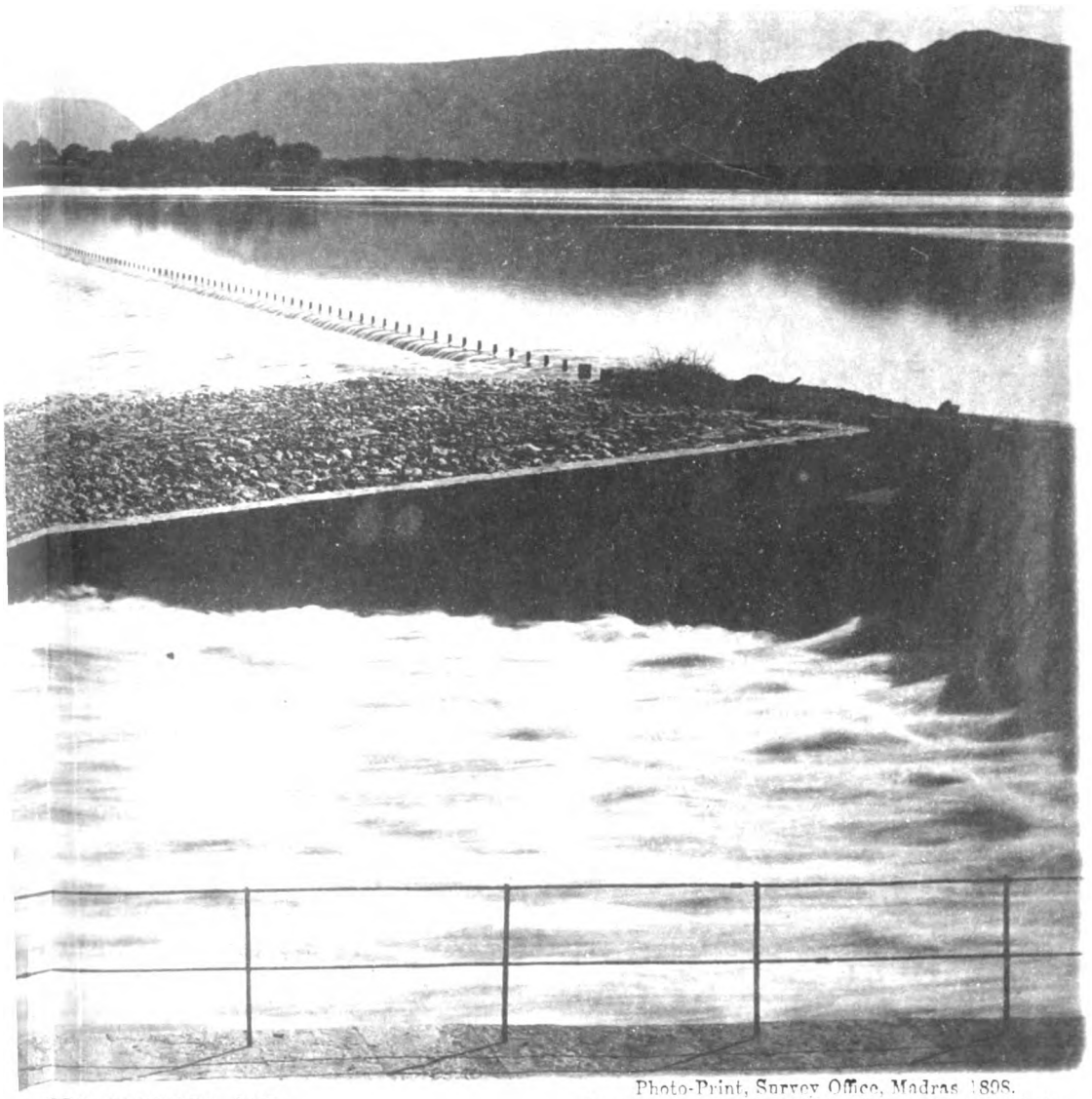
KISTNA ANICUT FR



T FROM BEZWADA END.

Photo-Print, Survey Office, Madras 1898.
from photo taken in 1893 by Messrs. Nicholas & Co.

the extreme left flank of the Anicut are the BEZWADA 'UNDER', OR 'SCOURING,' SLUICES of 15 vents, 6 feet wide and varying heights (see Plan 7, Volume II), the chief object of which is to prevent the accumulation of sand and silt in front of the Eastern Delta *Head-Sluices;* the relative positions of the two works, which are contiguous and at right angles to one another, have enabled this object to be attained. These "Under-Sluices" have their sills at + 38, or 9½ feet below present masonry crest of the Anicut, and are fitted with shutters actuated by screw-gearing worked from an overhead "trolly" or "traveller" (see Plan 8, Volume II) which can be run off the work into safety when floods pass right over the sluices.

As stated above, the chief use of these sluices is to prevent accumulations of silt and sand from interfering with the supply of the Eastern Delta, and is not to pass water during floods, when the discharge through them can be but a mere small fraction of that over the Anicut. From the violence of their action when discharging, which causes alarming vibration in them and the Head-Sluices, and from their effect in setting up serious eddies and "swirls" below them when water is passing over the Anicut, these Under-Sluices are sources of great anxiety. Their failure would certainly result in the destruction of the adjoining Head-Sluices and in extensive breaches between the river and the Eastern Delta Main Canal.

THE HEAD-SLUICES OF THE EASTERN DELTA adjoin the Under-Sluices and are at right angles to them. They have 15 vents, 6′ × 9′ high (see Plan 9, Volume II), and are fitted with shutters in three tiers, actuated by screws working in screw boxes fixed on a platform above flood level, in front of the bridge which crosses the work (see Plan 10, Volume II). The sills are at + 41 or 6½ feet below the present masonry crest of the Anicut, 9·17 feet below top of falling shutters.

THE HEAD LOCK OF THE EASTERN DELTA is the full length, 150 feet, now adopted for such works on first-class canals, but is unfortunately only 16 feet wide instead of 20 feet. It is situated 320 feet down a channel, the open head of which is 510 feet up the river from the Head-Sluices. This is so far away from the Scouring-Sluices that it is not appreciably affected by them and consequently shoals in front of the entrance, and silt in the channel, are frequent hindrances to traffic. Below the Lock a masonry-lined tail channel, 210 feet in length, leads to the *Main Canal* under the BRIDGE which spans it immediately below its head (see Plan 32, Volume II). Along the sides of the Lock

and its channels lie the District Workshops, timber yards, &c., of the Public Works Department.

Passing now to the works on the right flank of the Anicut:

THE SITANAGRAM 'UNDER' OR 'SCOURING SLUICES' situated at the extreme end of the Anicut are so similar to those at Bezwada that no separate description is necessary.

THE HEAD-SLUICES OF THE WESTERN DELTA are 500 feet away from the Under-Sluices—an arrangement which makes the effect of the latter of little value. These Head-Sluices are of the same size and in general arrangements similar to those of the Eastern Delta, but their sills are nearly 8 inches lower. It has already been noted in Chapter V that in the channel 200 feet below the original Head-Sluices of the Western Delta, a second or auxiliary set has been constructed (see Plan 12, Volume II).

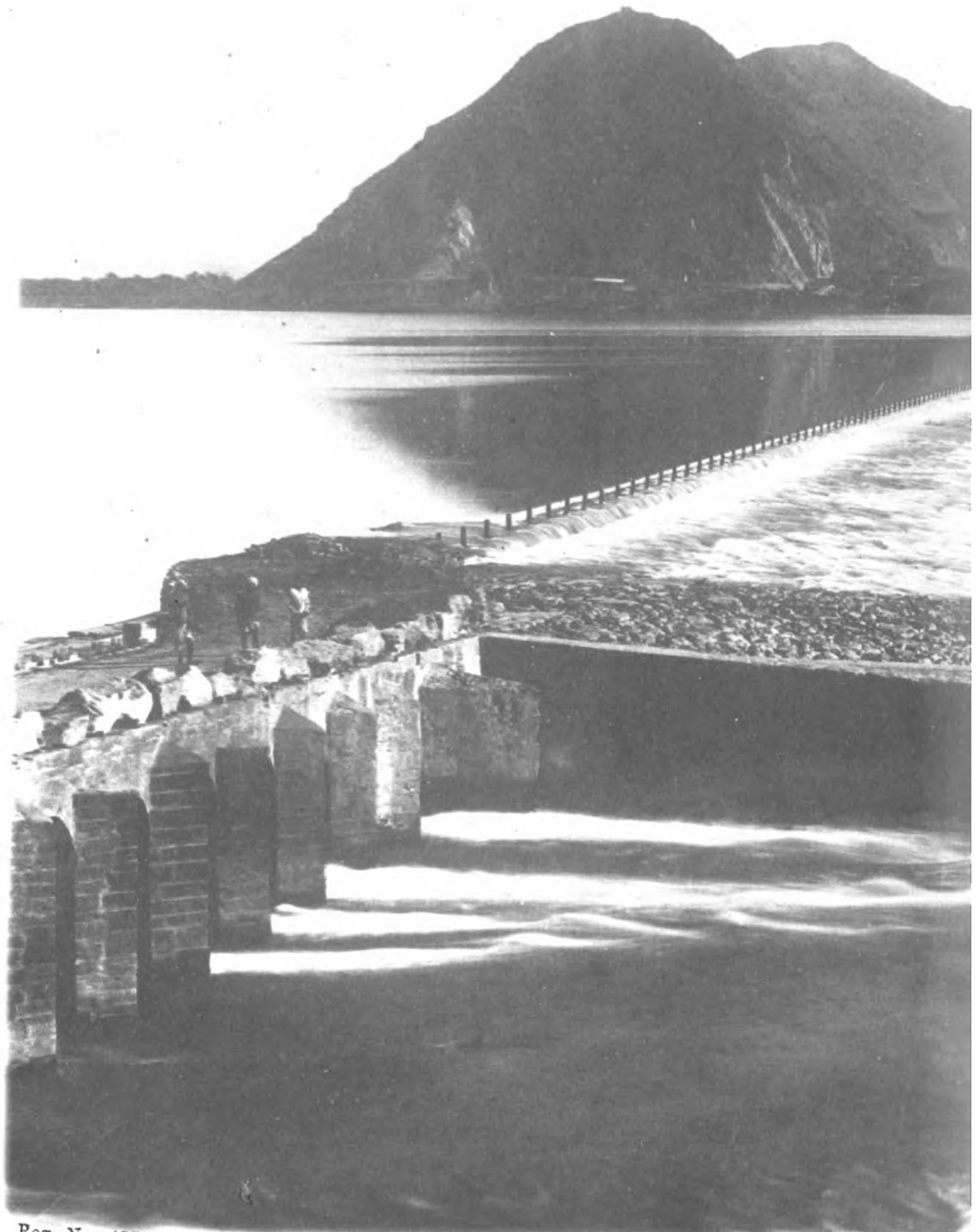
At 230 feet higher up the river than the Head-Sluices is the HEAD LOCK, of the same size as that of the Eastern Delta; it is slightly recessed from the margin of the river, shoals in which often make access to it difficult.

Passing now to the works in the two sections of the delta:

EASTERN DELTA.

The water admitted through the Bezwada Head-Sluices has to at once turn abruptly to the right to pass into the MAIN CANAL—an arrangement necessitated by the cramped nature of the site between the steep Bezwada hill, the Town, and the River. In order to provide communication between the town and the Anicut, the canal is at its immediate head spanned by a Masonry Bridge of three arches of 40 feet and one of 16 feet. Two flights of masonry landing steps lead down to the canal in connection with the wings of the bridge (see Plan 32, Volume II). For nearly its whole length, 53 chains, this canal skirts on its left side the main street of the large and rapidly increasing town of Bezwada with upwards of 20,000 inhabitants, whilst on its right side the canal is separated from the river by only a very narrow strip which carries the great bank due to the "spoil" from the excavation of the canal.

For 600 feet the left side of the canal is lined by a handsome masonry "ghât," with steps, ramps and platforms arranged for the convenience of the large boat-traffic, which makes this its terminus or its calling place. It is always a busy scene, scores of boats taking in or discharging cargo, whilst others are arriving from, or departing for, Madras, Cocanada, Masulipatam, or other places which lie along the



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KISTNA ANICUT FRON

T FROM SITANAGARAM END.

Photo-Print, Survey Office, Madras 1898.
from photo taken in 1893 by Messrs. Nicholas & Co.

East Coast Canal or the various canals of the Kistna and Gódávari Deltas. Near its end, where it trifurcates into the Ellore, Ryves' and Masulipatam Canals, the Main Canal is crossed by the East Coast Railway bridge of three spans of 100 feet.

THE ELLORE CANAL on leaving the end of the *Main Canal* turns abruptly to the east and, with a fall of only from 1 to 2 inches a mile, runs in an unbroken reach of 40 miles to the large town of Ellore (30,000 inhabitants), just beyond which is a Lock with a drop of 12'·65 to the *Gódávari* "Ellore Canal"; this, together with the Main Canal of the Gódávari Western Delta, completes the 87 miles of inland navigation between the two great rivers, with only one Lock besides those which connect the canals with the rivers themselves. The Ellore Canal has been run, with the small fall above mentioned, at as high a level as possible and lies above the alluvial tract of the "Delta"; there is consequently but a very small amount of irrigation possible on its left side; to its right however it throws off numerous distributaries which irrigate in all some 48,000 acres. The canal starts with a bottom width of 60 feet and ends with that of 36 feet, whilst its full supply depth diminishes from 8' to 5'·9" (see "Condensed Sections," Volume II). As it runs right across the watershed of the upland country, the drainage of 1,174 square miles have to be passed across it, of which 540 square miles are served by the Budaméru; that river, as stated in Chapter I, has been the cause of frequent damage to the canal, which bars it at an inconvenient level. The works to pass the Budaméru waters are spread over some 5¾ miles (from 7 to 12¾) and consist of (*a*) cutting down the canal banks for a mile or so to only 1 foot above canal full supply level, so that some of the flood waters may there spill into and out of the canal when the masonry works do not prove sufficient; (*b*) two large *Aqueducts* ("Budaméru" and "Késarapilly") with an aggregate area of vents under the canal of 1,151 square feet; (*c*) three *Under-tunnels* (or small Aqueducts) with openings of 135 square feet; (*d*) one small escape (formerly Ryves' Canal Head-Sluice) of three vents of 6'×6' each; (*e*) 290 running feet of Aqueduct walls over which excess water that has come into the canal can flow out of it.

Between 12 miles 60 chains and 37 miles 40 chains the streams which have to be passed are individually small and the works provided for dealing with them do not require separate notice; they will be found detailed in P.M.G. No. 446-I., dated 25th May 1891. We then come to the Tamiléru, a stream which drains some 367 square miles of upland and at times brings down a very large quantity of water. About a mile

before it reaches the canal it separates into two branches which run on either side of Ellore; the western one strikes the canal at 37 miles 40 chains where originally there was an Aqueduct, under which part of the flood water was supposed to go, whilst the remainder was to spill into the canal over the left wall of the Aqueduct and pass out through openings, which could be opened or closed at will, in the right wall; the levels were such that this arrangement never answered, the vents under the Aqueduct getting entirely blocked with sand, all the flood-waters then coming *into* the canal and blocking it for considerable distances with great accumulations of sand and silt. The work was then remodelled and made into an "*Escape*" with vents down to nearly the bed of the canal closed by screw-gearing shutters to be lifted at flood times to let the water pass across the canal, "stop-gates" being provided in the canal above and below the escape to prevent the flood waters from running up and down the canal and silting it up. These arrangements are not entirely satisfactory, but the conditions to be dealt with are highly difficult.

The other branch of the Tamiléru passes round to the east of Ellore and falls into the canal just above the Lock which connects the Kistna and Gódávari Canals. To pass the flood waters which thus enter the canal, out of it, there are provided an "*Escape*" of eleven vents of 7′ 6″ wide each, and an "*Outlet*" of eight vents 20 feet each; here also the conditions are such as to preclude an entirely satisfactory arrangement; the canal is frequently so silted up as to impede traffic and parts of the town of Ellore are at times flooded. Were it not that the important traffic along the canal has to be considered, and that therefore no "super-passage" with less than 11 feet clear headway under it is permissible, the difficulty might be met by diverting the Tamiléru and taking it *over* the end of the *Gódávari Canal* about a mile east of the Lock.

As regards traffic the Ellore Canal is one of the most important in the whole Kistna system, for not only does it serve the local traffic between the two large districts of Gódávari and Kistna, but it forms a portion of the through line which extends from Madras to Cocanada, a distance of 385 miles.

The traffic on this canal has of course been affected by the East Coast Railway which runs alongside it, and was opened in 1893. The Chief Engineer for Irrigation in his "Note" with P.M.G. No. 319-I., dated 18th April 1898, states that the goods carried on the canal fell from 170,620 tons in 1893–94 to 87,039 tons in 1896–97, whilst the number of passengers who travelled on it fell from 75,754 in 1891–92

to 65,925 in 1892–93, in which year the railway was opened, and has now fallen to 29,062 in 1896–97. It is only surprising that the passenger traffic has not been even more absorbed by the railway. Diminution of traffic along this canal is to the good from an irrigation point of view (see the Extract from Memorandum given in Chapter X, "Navigation,") and if the railway, which it must be remembered is also a "State" work, successfully competes with the canal without artificial hindrances being placed in the way of the water-borne traffic, so much the better. This subject will be found specially dealt with in Chapter No. X devoted to "Navigation."

RYVES' CANAL.—This large *Irrigation* Canal takes off from the end of the *Main Canal*, between the heads of the *Ellore* and *Masulipatam* Canals and supplies upwards of 45,000 acres of wet crop. Till 1891 there was at its immediate head a "Regulator" or Head-Sluice through which boats could not pass, but in that year this was removed and a new Regulator built one mile down the canal, leaving that length of it open for the use of boats. The reasons for this change are thus given in the Inspection Notes of the Chief Engineer for Irrigation in January 1890:

"Mr. Arundel, the Collector of the district, has suggested that the head of this canal for about a mile should be opened for boats to lie in and for the construction of wharves. This will entail the moving of the head-sluice or "regulator" from its present position to about a mile down, the widening of that portion of the canal by 15 feet to provide for the discharge required being carried with the reduced fall, and an increase in the size of the proposed bridge over the canal to provide for the extra width of the canal and for two tow-paths; the Superintending Engineer is getting the necessary plans and estimates prepared. The work would be of no benefit to irrigation interests and irrigation funds should not be called on to contribute towards it or to provide for the annual cost of clearing the extra silt that will be deposited in the reach, a cost which will be considerable as the clearances will have to be boated away because the new "Buckinghampetta" extends along the back of the canal banks on both sides. The convenience to the public, especially that of Bezváda, which will result if the proposals are carried out, will be great, and the value of the town lots in the new petta which lie close to the canal, along which wharves will doubtless be eventually constructed, will be greatly increased."

When this mile of the canal was thrown open, a Bridge was built across it to join the two new parts of the town, and a drawing of this will be found in Volume II, Plan 33.

The cost (Rs. 37,700) of the works connected with this alteration of the Ryves' Canal head were not charged to "Irrigation" but to "Provincial" and "Canal and Ferry Funds" (see P.M.G. No. 1432 W., dated 26th May 1891).

For 12 miles 5 furlongs from the new Regulator the canal runs with a bottom width of 90 feet and a depth of 7 feet and a uniform fall of 7″ a mile, to the Komatigunta weir over which the water is dropped 4′ 10″. It then runs for 9⅛ miles, giving off numerous branches, to where it joins the Pulléru.

There are two "Under-tunnels" under this canal to pass the drainage of the strip of country between it, the Masulipatam Canal, and the upper portion of the Pulléru, to the Uppulúr and Chendrayakodu drains.

THE MASULIPATAM CANAL is the third of the large canals which branch off from the end of the *Main Canal.* It runs South-East for almost 50 miles to where it joins tide water near Masulipatam. It is divided into five reaches by Locks (first class) and Lock-weirs, situated at 12 miles 45 chains, 24 miles 50 chains, 37 miles 15 chains, 43 miles 8 chains and 49 miles 20 chains (Delta Mileage), the last Lock being, of course, tidal.

The canal runs through some of the richest lands of the delta to the only considerable port of the district and is therefore of great importance both as regards its irrigation and its navigation.

In its first reach, at 4 miles 43 chains (Delta Mileage) is the head of the *Bank Canal* where a *Lock* (second class) and *Head-Sluice* (see Plans 15 and 28 of Volume II) have been built, and at the end of this reach just above Kankipad Lock are the two *Head-Sluices* ("Old" and "New") for supply of the "Pulléru," the first few miles of the natural course of which were, as already explained in Chapter I, incorporated in this canal. From this first reach also near its end is taken off, to the right, the large distributary known as the "*West-side Channel.*" The reach starts with a bottom width of 80 feet (depth 8 feet) which, after the *Bank Canal* off-take, is reduced to 67 feet (depth 7 feet 6 inches). So large a quantity of water is sent off from this first reach and so comparatively small an area has to be irrigated from the canal lower down, that beyond Kankipad Lock the canal is no longer of the imposing dimensions of its upper reach, but is reduced to a uniform width of 25 feet and depth of 5 feet.

In the third reach where the canal is approached within a distance of half mile by the Pulléru (at about 16 miles from its head at Kankipad Lock) is a cut between the two, known as the "*Pamarru Junction Canal,*"

in which there is a lock rendered necessary for navigation by the different and varying levels of the Masulipatam Canal and the Pulléru.

The PULLÉRU, as explained in Chapter I, was a large natural drainage course much used for irrigation before the Anicut was constructed. Part of the course of the Pulléru was incorporated in the Masulipatam Canal and at the end of that part where the canal leaves it, at Kankipad, it now receives most of its supply of water from the canal through two large sluices. It ends at 39 miles 29 chains (D.M.) where it bifurcates into the *Polráz* and *Bantumilli* Canals. Nearly 7 miles above their heads the "Pamarru Junction Canal" above mentioned, joins the Pulléru, and at 7 miles farther up, the "Ryves' Canal" tails into it.

The POLRAZ CANAL from the end of the *Pulléru* runs north-east for 26 miles to where it joins the Upputéru not far below its exit from the Collair Lake. The last few miles of this canal traverse the "Kaldindi plain," which but a few years ago was a barren tract of brackish soil, dotted here and there with patches of prickly-pear and coarse herbage on which grazed large herds of antelope; it is now in the irrigation season a wide expanse of flourishing rice crops. The canal is navigable throughout and has three locks (second class)—one at its head, another at 16⅝ miles along its course, and the third into the Upputéru, along which boats can pass to and from any of the three locks ("Yelúrpad," "Bhimavaram," "Mogultur") by which the Gódávari system of Navigable canals is also brought into communication with that tidal river.

No drainage has to cross this canal; that to the north of it running to the Collair Lake, and that to the south of it, between it and the Bantumilli Canal, falling into the Upputéru.

The BANTUMILLI CANAL is the southern of the two canals which branch off from the end of the Pulléru. It runs nearly due east for 26 miles to the Upputéru which it joins by the Lakshmipúram Lock nearly opposite where the navigation of the Gódávari Bhimavaram Canal comes into that river, at about half way between the ends of the Gódávari Akid and Narasapur Canals. Besides its tidal lock the Bantumilli Canal has a lock at its head and another 5½ miles further along its course. The lower part of the canal, like that of the Polráz, runs through salt plains and swamps which but a few years ago were quite uncultivated, but are now covered with crops.

The Lakshmipúram Lock was built in 1892 and 1893; its foundations in tidal mud gave much trouble; a plan of it will be found in Volume II, No. 18.

The BANK CANAL, as already stated, has its head on the *Masulipatam Canal* at 4 miles 43 chains (D.M.). About 13 miles of this canal were excavated, and it was intended that it should be continued along the bank of the river as far as the Pulligadde branch, and eventually taken *over* that flood-channel of the river into the Divi Island by an aqueduct, in the same way that the Gódávari Central Delta Gunnaram Canal was carried into the Polaram Island (*see* "Engineering Works of the Gódávari Delta," Chapter VI). The experience of higher floods than previously known have shown that the levels are such that this method of crossing the Pulligadde is not practicable and that if the canal water is ever taken into Divi Island, it must be by an inverted syphon tunnel, or pipes, *under* the river bed. For the present even the excavated portion of the canal is unused, and there is no present intention of opening it, the Superintending Engineer being of opinion that it "is decidedly inadvisable to bring it into use till the river margin has grown considerably" (Extract from Letter N., dated 8th September 1898, of Chief Engineer for Irrigation).

The following list gives in a tabulated form some of the information about the canals above dealt with, and in Volume II will be found condensed sections of them :—

LIST OF CANALS *classed under Main-Head* (2) *Main Canals and Branches— Eastern Section of the Delta.*

Distance of Head of Canal from Head of Delta.		Names of Canals.	Lengths of Canals.		Remarks.	Areas irrigated in 1897-98.	
						First crop.	Second crop.
MLS.	CHS.		MLS.	CHS.		ACRES.	ACRES.
...	...	MAIN	...	51	.....	...	...
...	45	ELLORE	39	60	Head on Main Canal.	48,166	32
...	51	RYVES'	22	60	Head on Main Canal (only 1 mile navigable).	45,467	11
...	51	MASULIPATAM ...	49	7	Head on Main Canal.	42,667	5
4	43	BANK	...	...	Head on Masulipatam Canal (construction in abeyance).	...	...
12	45	PULLÉRU ...	26	64	Head on Masulipatam Canal; only 7 miles 30 chains, including Pamarru Junction, navigable.	116,783	15
39	29	POLRÁZ	26	40	Head on Pulléru.	26,465	96
39	29	BANTUMILLI ...	26	15	Do. do. ...	21,524	264
		TOTAL ...	191	57	Only 150 miles 43 chains navigable.	301,072	423

DRAINAGE OF THE EASTERN DELTA.—The drainage of this section of the delta (exclusive of Divi Island which does not as yet come within the scope of the irrigation works) may be considered as divided into four main portions, viz.:—

1. Between the Ellore Canal, the Masulipatam Canal Head, the Pulléru, and the Polráz, Canals.

2. Between the Polráz and Bantumilli Canals.

3. Between the Bantumilli Canal, the lower portion of the Masulipatam Canal, and the Sea.

4. Between the Pulléru and the River.

Portion No. 1 is served by—

(*a*) The BUDAMÉRU, the natural river which, as already stated, crosses the Ellore Canal by various works between 7 and 11 miles (D.M.) and falls into the Collair Lake at its south-west corner. The Budaméru has been considerably improved in its lower portions which receive several affluents between the Canal and the Lake. The drainage of the small piece of country between the heads of the "Ryves'" and "Masulipatam" Canals is brought to the Budaméru by the "Uppulúr" Under-tunnel under the Ryves' Canal, at 11 miles 17 chains (D.M.).

(*b*) The "CHENDRAYAKODU".—This was originally one of the branches which carried water to various tanks from the Pulléru when that natural drainage was used for irrigation purposes, as explained in Chapter I. When the "Completion Project" was prepared, the Chendrayakodu ended in the Tamersa tank, but the arrangements then provided for, and since carried out, at a cost of Rs. 75,872, devoted the Chendrayakodu exclusively to drainage purposes and carried it on to the Collair Lake. The drainage of the land between the Masulipatam and Ryves' Canal is brought to this drain by an Under-tunnel under the latter canal.

(*c*) The "OLD POLRÁZ-KODU".—This was another branch of the Pulléru; it has been extensively improved at a cost of Rs. 86,474, and carries to the Collair the surplus waters of the tract between the Chendrayakodu affluents and the Polráz Canal.

Portion No. 2 is of comparatively small area and its surplus waters are carried to the Upputéru by—

(*a*) The LINGALA DRAIN along the right side of the Polráz Canal,

(*b*) The PEDDA-KOMILERU, and

(*c*) The PEDDALANKA; and some minor drains.

The drainage of Portion No. 3 finds its way to the GOKAVARAM and other tidal creeks by many drainage channels, the chief of which is the

LAZZABANDA DRAIN, on the improvement of which Rs. 1,13,964 have been spent.

Of Portion No. 4 the chief drain is the KANNIKALA-MADUGU, in the lower portion of its course known as the "DAYAPUKALWA," which starting from between the Bank Canal Head and the Masulipatam Canal, winds about till it falls into the tidal creeks in connection with the Pulligadda branch of the river and the Masulipatam bay. Its chief affluents are the BHIMANADI and AGAKODU; into the latter flows the INAMPÚDI DRAIN, which brings under the Masulipatam Canal, at 28 miles 25 chains, the drainage of the land lying between that canal and the Pulléru above the Pamarru Junction Canal.

River embankment.

The River is embanked through this section of the Delta to the Puligadda branch, and the Divi Island is embanked for another 13 miles along the main river, and for 10 miles along the branch. Above the Delta the embankment on the left side of the River extends to Ibrahampatam, about 8 miles from Bezwada.

WESTERN DELTA.

The MAIN CANAL into which water is passed through the Head-Sluices already described under "*Head-works*," runs nearly due south for 13 miles. It is an imposing stream carrying at times nearly 4,000 cubic feet of water per second, upwards of five times the ordinary summer discharge of the Thames at Staines. Its bottom width is 230 feet for 7¾ miles to the head of the *Bank Canal*, and thence onwards 170 feet. For almost the whole of its length, except where straight cuts have been made, the Main Canal has followed the course of the old Tungabhadra, the natural drainage stream into which, in old pre-anicut days, a cut was made from the river for irrigation purposes (*see* Chapter I). At 7½ furlongs from the head the canal is crossed by the East Coast Railway skew girder bridge of four spans of 70 feet, on screw-piles.

The direct irrigation from the Main Canal is small, the ultimate expected being 10,000 acres.

The BANK CANAL takes off from the *Main Canal* at 7 miles 58 chains, with a second-class Lock and a Head-Sluice. The canal is 46 miles long and for almost all that distance runs near the river, the flood bank of which has been formed to a great extent by the spoil from the canal excavation. The canal is divided into four reaches by the following Locks (second class) and their weirs: (1) Kollúr 28 miles 16 chains (D.M.), (2) Vellatúr, 33 miles 54 chains, (3) Mortota, 45 miles 43 chains;

below the last of these the canal continues navigable for about 8 miles and then sends on a distributary, known as the Razu Channel, for another 5 miles along the back of the river bank. The navigation along this canal is small, but its irrigation is considerable, amounting to 56,234 acres in 1897–98, the "ultimate expected" being no less than 95,000 acres, comprising all the country between the canal and the Répalle drains.

This canal, like all others in the Gódávari and Kistna Deltas which run close to the rivers, is a source of great trouble on account of the dangers to which it is subjected by the 'sets,' and encroachments of the river.*

The temptation to take canals close along the edges of the rivers has been irresistible, because from such a position it is easy to command the considerable strip of exceptionally rich land which always slopes away from the margins of deltaic rivers to the first inland drainage, and also because part of the earth from the excavation of the canals can be used in making the river embankments along them. The cost of such canals, therefore, at first appears small, but in the long run they are generally exceptionally costly, because of the extensive and expensive protection which has to be resorted to in places to prevent their being washed away by river encroachments, and because of the costly diversions, through very valuable lands, which have to be made when such protection proves of no avail. The danger from river encroachment on a '*Bank*' Canal is not infrequently increased by percolation and leakage from itself; these hasten on the caving in of the river margin by washing out at the face of its scarp the thin layers of nearly pure sand, so generally found interspersed with the firmer deposits for some distance back from the edges of deltaic rivers.

The principal diversions which of late years have had to be made on this canal, on account of encroachments of the river, are, that near Vallabhapuram, about 3,600 feet long, which cost some Rs. 6,000, and that near Penumudi, nearly 3 miles long, which cost nearly a quarter of a lakh of rupees.

The COMMAMÚR CANAL takes off from the end of the *Main Canal* at 12 miles and runs south-west for 58¼ miles to Peddaganjam where it joins the "Buckingham" (East-Coast) Canal, at *its* 196 miles from Madras.

The Commamúr Canal is divided into five reaches by the following Locks (first class) and Weirs:—

* *See* 'The Engineering Works of the Gódávari Delta,' Chapter VIII.

(1) Commamúr, at head of Canal.
(2) Jaggerlamudi, at 20 miles 73 chains (Delta mileage).
(3) Kolimerla, ,, 31 ,, 54 ,, ,,
(4) Nallamada, ,, 43 ,, 36 ,, ,,
(5) Santaravúr, ,, 59 ,, 50 ,, ,,
(6) Pedda Ganjám, ,, 70 ,, 21 ,, This is the terminal lock by which Navigation passes to and from the "Buckingham Canal."

As the Commamúr Canal runs along the outskirts of the deltaic lands, it has little irrigation on its right side, but on its left, east, side it supplies a large area lying between it and the *Tungabhadra* and *Rompéru* drains—an area which in 1897–98 amounted to 91,162 acres and is expected to eventually rise to 130,000 acres.

For about 8 miles from its head, as far as the crossing of the Guntúr Nalla, the canal occupies the course of the old Tungabhadra, the upper portion of which was, as already stated, taken into the Main Canal. From that point, 20 miles 15 chains, D.M. the canal runs right athwart the watershed of some 1,386 square miles, and for a considerable part of its length at such a level that there is great difficulty in getting the drainage across it. The works constructed for the purpose are given in the subjoined statement (page 141), on which is noted what lengths of bank have been lowered or entirely removed to allow water to pass freely into and out of the canal.

The masonry works given in this statement are sufficient to pass the heaviest ordinary falls of rain, but occasionally cyclonic downpours gorge the streams and cover the surface of the country with water; this before the canal existed used to find its way quietly to the sea, or rather to the Rompéru swamp. The conditions, however, became very different when the canal with continuous embankments, much of them due to "spoil" from excavation, was carried as a bar across the country, causing the excessive flood waters to head up till they broke in destructive torrents across the canal, filling it with silt in places and at others tearing great chasms through it, stopping irrigation and navigation for weeks at a time. After many years of such trouble and trying to fight the floods on the old lines, Colonel (now General) Mullins, R.E., Chief Engineer for Irrigation, adopted the system of so adjusting the levels of the various reaches of the canal as to bring the water surface as near ground level as possible, providing flush inlet and outlet walls of great length and removing as much of the right bank as practicable, thus allowing the water which used to flow over the surface of the land to still do so, and to cross the canal with little increase of velocity. The system has proved most successful, and the canal is now seldom blocked, or navigation stopped, for many hours at a time.

WORKS FOR PASSING DRAINAGE *across the Commamúr Canal, from* 20 *miles* 15 *chains to end.*

Point at which drainage crosses the canal (Delta Mileage).		Area of drainage basin, square miles.	Description of works.	Aqueducts and under-tunnels.		Inlets.	Outlets, weirs and walls.		Remarks.
				Area of water-way, square feet.	Head available, feet.	Length (feet).	Length (feet).	Depth of discharge over crest.	
1	2	3	4	5	6	7	8	9	10
MS.	CH.							FEET.	
20	15	100	Guntúr Nalla new under-tunnel.	183·0	3·00	...	...	...	
20	19		Guntúr Nalla old under-tunnel.	121·0	3·00	...	36·00	3·20	
31	42	125	Kollimerla aqueduct ...	278	2·08	...	...	...	
31	65		Kollimerla inlet and outlet.	...	...	870	870	2·0	
33	61		Pondrapad surplus weir.	...	...	...	28·0	2·70	
33	68		Old inlet	...	...	60	...	...	
36	22	251	Nakkavagu outlet... ...	...	...	...	2,800	2·0	Another aqueduct has been proposed here.
40	9	428	Appapuram outlet ...	...	...	...	1,800	2·50	Besides the masonry works here shown, the right bank has been removed from 36th to 45½ miles (except for short lengths near masonry works) allowing flood waters to freely enter the canal.
40	39		Nallamada old outlets ...	...	...	...	2,150	2·0	
40	77		Old Nallamada surplus sluices.	...	...	..	150	6·67	
41	3		New Nallamada surplus sluices.	...	...	...	90	4·67	
41	12		Nallamada new outlet ...	...	...	...	1,800	2·06	
45	19	200	Murkondapad outlet ...	...	...	...	2,700	1·00	
45	62		Sakikalva outlet	...	...	...	880	2·00	
45	77		Do. aqueduct ...	265·2	0·44	...	...	...	From 46 ms. 13 ch. to 46 ms. 40 ch., no right bank.
47	...		Inlet	...	...	60	...	...	From 46 ms. 43 ch. to 49 ms. 10 ch., no right bank.
49	4		Kunkalamarru outlet ...	...	...	...	500	2·00	
49	14		Do. inlet ...	...	...	160	...	...	
49	14		Parchurvagu surplus sluices.	...	..	...	96	4·6	From 49 ms. 62 ch. to 49 ms. 70 ch., no right bank.
50	27	50	Karenchedu outlet ...	...	...	...	1,002	2·00	From 49 ms. 70 ch. to 50 ms. 20 ch., right bank, 1 foot high.
51	45		Do. aqueduct ...	132·6	3·00	...	...	...	
54	70	15	Swerna old outlet ...	...	...	...	200	1·00	From 54 ms. 27 ch. to 54. ms. 72 ch., right bank, 1 foot high.
55	53		Do. outlet and inlet.	...	...	600	600	2·00	
55	65		Do. aqueduct	88·4	·67	...	...	...	
58	21	78	Santaravúr old outlet ...	...	...	...	95	2·00	
58	63		Alléru surplus sluices ...	...	...	...	96	6·22	
59	26		Santaravúr outlet ...	...	...	...	806	2·00	
59	26		Do. inlet	...	...	67	...	...	
62	28	29	Appéru inlet	...	...	450	...	...	
62	40		Do. inlet and outlet.	...	...	185	185	2·00	
62	47		Do. do.	...	...	600	600	2·00	
66	77	90	Firangidibba outlet and inlet.	...	...	2,000	2,000	2·00	From 66 ms. to 67 ms. 15 ch., right bank, 1 foot high.
68	49	20	Uppukondur aqueduct ...	76·0	2·00	...	...	...	

The Commamúr Canal, like the Ellore Canal, forms one of the links in the chain of canals which provides inland water communication between Madras and Cocanada. The traffic along it is considerable, the numbers of lockages through its head and tail locks in 1896–97 having been—

	UP.	DOWN.
Commamúr Lock	4,135	4,191
Pedda Ganjám Lock	4,272	4,250

The greater part of the Singaréni coal which reaches Madras is carried there along the canal and the Buckingham Canal; the quantity was, in 1896–97, 33,325 tons.

The NIZAMPATAM Canal has its head at the extreme end of the Main canal and runs nearly due south for rather more than 28 miles to where it locks into the large tidal creek on which stands Nizampatam, at about 3 miles in a direct line from that town, but some 8 miles by the windings of the creek.

The canal runs along the slightly elevated ridge between the Repalle and Tungabhadra drains, and is therefore not troubled with cross drainage.

The irrigation from it (62,447 acres in 1897–98) between the two drains mentioned, is almost all supplied by two large distributaries, known as the 'east' and 'west' side channels, taking off from above the head lock, the former carrying approximately 460 and the latter 280 *cusecs*.

The navigation along this canal is not large; * it is provided for by the following locks (Second class), viz.:—

At the head, "Duggirala", with weir.
,, 22 miles (D.M.) "Kuchipúdi," } *without* weirs, scarcely
,, 31 miles 24 chains ,, "Intúr," } any water having to be
,, 36 ,, 59 ,, ,, "Nallavada," } passed on for irrigation.
,, 41 ,, 7 ,, ,, Tidal, with surplus weir.

The following list gives in a tabulated form some of the information about the canals above dealt with, and in Vol. II will be found "condensed sections" of them:—

* In 1896–97, Lockages *Up* 1,940; *down* 1,886.

LIST OF CANALS *classed under Main Head* "(2) *Main Canals and Branches*," WESTERN SECTION *of the Delta.*

Distance of Head of Canal from Head of Delta.		Names of Canals.	Lengths of Canals.		Remarks.	Areas irrigated in 1897-98.	
						Acres.	
Miles.	Chains.		Miles.	Chains.		1st crop.	2nd crop.
...	...	MAIN	13	...	.....	9,007	...
7	58	BANK	46	4	Head on Main Canal.	56,234	19
12	...	COMMAMÚR ...	58	20	Do. do.	91,162	3
13	...	NIZAMPATAM ...	28	7	Do. do.	62,447	6
		TOTAL ...	145	31	All navigable	218,850	28

DRAINAGE OF THE WESTERN DELTA.—The drainage of this section of the delta divides itself naturally into three main portions, viz. :—

(1) Between the Bank and Nizampatam canals.

(2) Between the Nizampatam canal and the Nallamada Drain, which crosses the Commamúr canal at 41 miles.

(3) All south and west of No. 2.

The first portion is served by—

(*a*) THE "RÉPALLE MAIN DRAIN", which starting in the angle between the Main and Bank canals runs for about 33 miles (including its upper feeder the Kuchipúdi drain) till it falls into the tidal creek near Nizampatam, receiving many affluents on its way. Rs. 2,55,013 have been spent on this drain to end of 1897-98, a large portion of it on "straight cuts", and further improvements are contemplated.

(*b*) THE BHATTIPROLE DRAIN.—This begins from near 20 miles (D.M.) of the Bank canal and after a course of upwards of 38 miles falls into a tidal creek near Adavaladivi. It has only one affluent of any size, the "*Jagajeru*".

No improvements have been carried out.

(*c*) THE PEDDAPALLI DRAIN, which runs for about 4 miles near the east side of the Nizampatam Canal, and falls into the tidal creek just below the terminal lock. This drain has been much improved at a cost, to date, of Rs. 15,513.

The second portion is served by the TUNGHABHADRA, the chief affluents of which are (*a*) the *Tenali drain* which serves the country between the Nizampatam Canal and the Tunghabhadra itself, (*b*) the *Kolimerla*, and (*c*) the *Nallamada*; the two last besides serving the lands on the right side of the Commamúr Canal between 31 and 41 miles (D.M.), carry the upland drainage of some 800 square miles which there crosses the canal.

It has already been explained how the upper portion of the old Tunghabhadra was incorporated in the *Main* and *Commamúr* Canals, and the drain may be said to now commence where the Guntúr Nulla crosses the Commamúr Canal in the 21st mile (D.M.), bringing down the drainage of 100 square miles of uplands. From there the Tunghabhadra has a course of about 29 miles to the tidal creek west of Nizampatam, into which it discharges the surplus waters of some 1,140 square miles, including the upland drainages above mentioned.

For this drain and its affluents, Rs. 6,15,191 were provided in the "Project" (see Statement in Chapter VI), of which Rs. 3,65,672 have been actually spent, chiefly, as regards the main drain itself, on "straight-cuts" which have not proved entirely satisfactory.

The Tunghabhadra has still a dam across it (at about 12 miles along its course) to raise its water for irrigation, a relic of the vicious old system referred to in Chapters I and VIII, but this will be soon superseded and the drain left to its proper duties.

The main drainage line of the *third portion* is the ROMPÉRU. As explained in Chapter I, this is really a broad swamp lying at the back of the sea-coast sand ridge from near Bápatla to the Chinna-Ganjám tidal creek, a distance of about 26 miles. Into this comes the upland drainage of some 480 square miles brought down by the *Sakikalwa*, *Pachúrvagu*, *Swerna*, *Alléru*, *Appéru*, *Emiléru*, and other minor streams which cross the Commamúr Canal by various works.

Rs. 1,30,333 have been spent on this drain, chiefly in making a new cut to take to the Bápatla creek some of the drainage which used to fall into the Rompéru near its northern end, and find its way along the swamp for nearly its whole length to the Chinna-Ganjám creek.

The River is embanked through this section of the delta for 52½ miles to Adivipalem, and an embankment is carried for a mile *above* the anicut to the Undavilli Hill.

CHAPTER VIII.

VARIOUS INFORMATION AS TO MATERIALS, DESIGN, ETC., OF WORKS.

Earth-work—Canals and Channels.

In the Kistna as in the Gódávari anicut system, desire for cheapness and rapidity of execution led at first to the use of old native channels and natural water-courses for taking anicut water to various parts of the delta. Now, nothing can be more certain than the inadvisability of attempting in a Delta country to use the natural drainages for other than their legitimate duty, and the adoption for the purposes of distribution of old channels faulty in alignment, gradient, section, and every particular, though at first apparently an economical course has, in the long run, proved anything but satisfactory. On this subject Colonel Baird Smith, R.E., who was sent in 1853 by the Government of India to visit the works, made * the following remarks:—

"The coincidence with pre-existing lines common to both the Ellore and Masulipatam channels probably originates in economical considerations. I admit the force of these . . . . But the contempt for directness of course, and economy of slope, which characterize such anicut works, is generally so marked as to make the ultimate economy of adhering to them very questionable indeed . . . . I take the opportunity of recording my opinion to be against the use of tortuous natural, or old artificial, lines, even when the saving of expense thereby may be very clear unless that saving materially exceeds the various sources of loss, not merely to Government, but to the irrigating community, having their origin in a system which practically throws the water into holes from whence, to do its maximum of work, it must be presently got out again. By carrying compact channels along the highest levels, and in the most direct courses compatible with local necessities, economy of repairs, of water, of labor by the agriculturist in the distribution by detail over his fields, and of land occupied, is combined with extension to its utmost of the area of irrigation; and such manifest advantages should never be abandoned on considerations of economy of money, which, however specious at first sight, will, unless great caution be used, turn out in the end to be utterly hollow and unsubstantial."

* See his "Irrigation in the Madras Province."

Canals and Distributaries are now, and have for a long time past been, laid out on scientific principles, and care is taken not to use the natural drainage courses for other than their proper purposes. In designing channels the formula used up to about 1879, was that known as '*Du Buat's*,' but since then the more accurate formula and coefficients of *Bazin* have been adopted, viz., $V = c.\sqrt{r.s.}$ in which

V = velocity in feet per second.

r. = Hydraulic 'radius,' or 'hydraulic mean depth,' in feet.

s. = Fall in unity, of surface.

C = A variable coefficient, which for earthern channels, is arrived at from the formula.

$$C = \frac{1}{\sqrt{0{\cdot}00008534\left(\frac{r + 4{\cdot}1}{r}\right)}}$$

The *Side slopes* generally adopted for earthwork in the Delta are 1½ (*base*) to 1 (*height*).

Masonry—and Masonry Works.

Brickwork has been little used in the Delta works except for arches; almost all the works have been constructed of *Concrete* and *Rubble Masonry* with, in the more important works, *Ashlar* facings, quoins, and copings.

Concrete.—Foundations are, as a rule, platforms of concrete of various thicknesses according to the nature of the soil and the weight of the superincumbent work. The concrete is generally composed of 3 parts, by measurement, of *stone*, broken to 2-inch gauge, and 1 part *mortar*, laid and rammed in layers of about 6 inches thick; the mortar is usually composed wherever the foundations are wet, and often also in the superstructure, of 1 part slaked lime, 2 parts of river sand and from ½ to 1 part of finely ground brick dust, known in India as '*surki*'; the addition of the '*surki*,' makes the mortar eminently hydraulic.

The Stone used is almost and entirely from the Bezwada and Sitanagarum quarries thus described in Vol. XVI, of 'Memoirs of the Geological Survey of India.' "This gneiss is a rather fine-grained quartzo-micaceous felspathic schist . . . . It weathers considerably at the surface and becomes there of a powdery texture, or else coats itself with a close highly polished surface like serpentine in appearance."

Locks.—There are in the Kistna Delta, as in the Gódávari, two standard sizes of Locks, viz., 'First' and 'Second' class. The

chamber of the former is 150′ × 29′, that of the latter 105′ × 15′. The following are the canals considered 'First class' and therefore provided with the larger sized Locks.

Eastern Delta *.— Main, Ellore, and Masulipatam Canals.

Western Delta *.— Main and Commamur Canals.

Including the 'Head Locks' there are in the whole system 13 Locks of the first class and 17 of the second class—plans of two first class and five second class Locks will be found in Vol. II.

Weirs.—There are 15 Lock-Weirs, and several Surplus-Weirs to relieve the canals of excess water. These works have, as a rule, been designed with a length capable of discharging the maximum required, with a depth of from 2½ to 3 feet passing over the crest, on which are wooden shutters of that height, lifted or lowered at will by screw-gearing. Nine feet has been found a convenient length for such shutters.

The form of Weir adopted has wisely been that with a vertical overfall. In the earlier works of the kind, the fall was on to a horizontal floor of large stone, but in subsequent works a 'water-cushion' has always been provided. The system of forming the cushion floors of Weirs simply of concrete, which has proved so successful in the Gódávari Delta (see 'Weirs,' Chapter IX of the "Gódávari Delta Engineering History"), has not been generally adopted in the Kistna, nor has so much attention been devoted to the form of the cushion walls.

The superiority of a vertical overfall for such Weirs has been shown by the little trouble the Gódávari and Kistna Canal-Weirs have given compared with that which resulted on the Ganges Canal from the adoption there of the 'Ogee' form, with reference to which Mr. Buckley, in his excellent book '*Irrigation Works in India*,' says: "These 'Ogee' falls have given endless trouble. The velocity increased of course as the water ran down the 'Ogee' and the friction did as much damage as the shock would have caused, and the velocity was so great that a standing wave was created below the fall, and the washing of the banks was considerable."

Plans of two Lock-Weirs and one Surplus-Weir will be found in Volume II.

Aqueducts.—There is not in the Kistna system any aqueduct of a size comparable with the Gunnaram aqueduct over the Vainatéyam branch of the Gódávari (see Chapter VI, "Gódávari Delta Engineering

* The Head Locks are only 16 feet wide.

History"), but there are many over minor streams and channels, and plans of four of these will be found in Volume II.

Irrigation Sluices.—Of sluices at the heads of Irrigation Distributaries there are nearly 400 in the Kistna Delta System. All the modern ones are fitted with shutters worked by screw-gearing by which careful regulation is secured, and in most of the more recent sluices the system has been adopted of widening out from behind the shutters to reduce the velocity of the water as it issues into the channel and so lessen the wear and tear on banks and bed.

Bridges.—The provision of Bridges over Canals and Channels is small. Over the larger canals there are only 26 Bridges, besides those provided at most of the Locks. This has arisen from the fact that when the works were undertaken, there was scarcely a made-road in the Delta, and the people were accustomed to wade through the streams and water-courses which crossed their pathways, or when the water was too deep for wading, to use 'dug-outs,' or 'rafts' supported on hollowed-out palmyra trunks, locally known as '*Sangadies*;'* of such '*Sangadies*' for crossing the Canals there are many, a few of them provided by Government, but most belonging to villagers and worked on Government permit. At the more important crossings of large Canals and drains Government maintains 143 *ferry-boats*, locally known as '*balla-kats*'† which can carry carts and cattle.

The following are the rules for *Headway, &c.*, for Bridges over the Navigable Canals:—

"*First-Class Lines of Navigation.*

"*First*—If there be more than one arch, the arches to be not less than 30 feet span, or 25 feet exclusive of a 5 feet tow-path. If there be but one arch, 40 feet to be minimum span.

"*Second*—The clear headway under the arch or arches should give a rectangle 12 feet wide and not less than 11 feet above full supply or ordinary flood level.

"*Third*—The waterway of canal should not be contracted so as to produce a velocity in excess of 1·5 feet a second."

"*Second-Class Lines of Navigation.*

"*First*—If there be more than one arch, the arches to be not less than 27½ feet span, or 23 feet exclusive of a 4½ feet tow-path. For a single arch bridge, 30 feet to be the minimum span.

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* Telugu *San* = together, *katte* = tie or fasten.

† Do. *Balla* = a plank, *katte* = tie or fasten.

"*Second*—The clear headway under the arch or arches should give a rectangle 10 feet wide and not less than 9½ feet high above full supply or ordinary flood level.

"*Third*—The waterway of canal should not be contracted so as to produce a velocity of more than 1·5 feet a second."

As for the smaller Irrigation Channels, they are rarely provided with bridges or boats; they have to be waded across. This, however, it must be remembered, is no great inconvenience in a warm climate where shoes and stockings are not worn, and the usual lower single garment seldom extends below the knee, and is easily lifted.

CHAPTER IX.

IRRIGATION.

Irrigation, the primary object of the Anicut and Canals.

Irrigation is the primary object of the Kistna Anicut and Delta Works, the Navigation which has been combined with it being merely an adjunct, though by no means an unimportant one. Year by year the *Irrigation* covers with unfailing crops nearly 800 square miles of country, two-thirds of which but for it would be unproductive waste with only a few patches here and there of cultivation at the mercy of uncertain rains. The District is thus not only saved from the famines which used to ravage it, but is also enabled to send large quantities of food-grains to less favoured regions.

Anticipated and actual areas of irrigation.

The first attempt to estimate the probable area of irrigation and the amount of direct money returns from the proposed works will be found in Captain Lake's report of 3rd July 1847 and its appendices printed in Chapter II.

The anticipated areas there given are—

	ACRES.
in the Guntúr District (now "Western Delta") ..	482,961
in the Masulipatam District (now "Eastern Delta")	564,824
Total ..	1,047,785

and the annual direct returns at Rs. 46,19,148.

The Committee, whose report has been given on pages 30 to 48, did not, however, endorse these extravagant anticipations, but gave the area likely to be irrigated as only—

	ACRES.
in the Guntúr District	*125,038
in the Masulipatam District	118,818
Total ..	243,856

* Taking the area of "waste land in Repally" to be irrigated, at 13,000 acres.

and the probable direct annual returns, to be arrived at in 4 years, as Rs. 7,32,059.*

The Committee, however, was evidently loath to quite give up the brilliant prospect which had been placed before it, and remarked in paragraph 50 of its report that the anicut "will command in Guntoor about half a million of acres, and the same in Masulipatam (of Government and other lands) exclusive of Deevy, and the supply of water of this tract will be most abundant during the season of cultivation of paddy, and very considerable even in the lowest state of the river, so that there is every reason to believe that the whole will eventually be cultivated."

The more moderate anticipation of the Committee itself as to the area that would be irrigated was realized, not indeed in the 4 years, but in 20 from the completion of the anicut (see "Statement showing areas irrigated, Appendix III").

When, in 1881, the "Completion Project" was submitted to the Secretary of State (see Chapter VI) the irrigation had risen to nearly 300,000 acres and the forecast then made of the ultimate areas was—

	ACRES.
for the Eastern Delta	270,000
for the Western Delta	200,000
Total ..	470,000

and in a revised forecast of 1885 for 20 years, the "*final ultimate*," to be reached in 1902–3, is given as 475,000 acres.

† In 1891-92.

Eastern division ...	274,424
Western division ...	206,304
Total ...	480,728

When the "Project" works were put in hand their effect soon became apparent and the irrigation rapidly advanced till in 10 years† it exceeded the 'ultimate' anticipated in each division of the Delta and has now, after considerable variations, reached the large area of 519,922 acres.

Increase of irrigated area.

It will thus be seen that since the so-called "Completion" Works were undertaken there has been an increase in irrigation of some 70 per cent., and the question naturally suggests itself, will the increase continue to any considerable extent? That the suitable area still available would admit of this is undoubted, and the answer, therefore, depends

* See paragraphs 8 to 18 and Appendices A and B of the Committee's Report.

on the sufficiency of water. The total quantity of water brought down the river in every year, or even that in every irrigation season, is certainly much in excess of what would suffice for every acre commanded, but it must be remembered, that now by far the greater part of the water necessarily passes in floods over the anicut and flows uselessly to the sea, whilst not infrequently towards the end of the irrigation season the river falls below the level required to give a full supply, under existing arrangements, even to the area already reached; *e.g.*, in his letter, No. 593, 12th September 1898, the Superintending Engineer, 2nd Circle, says that in *November* 1896: "The water was for 16 days at or below the anicut crest and the Eastern and Western Deltas were put on turns for water-supply, which means that the whole available supply in the river was not sufficient for the crops. Fortunately heavy local rains occurred and saved the situation." The total area of irrigation in that year (1896–97) was 482,633 acres.

It would obviously be unwise to encourage during periods of superabundance of water the cultivation of a larger area of wet crops than could be brought to maturity by the scantier supply available later on.

This difficulty and that of supplying any appreciable area of second crop would of course be met by the provision of reservoirs on the Kistna and its tributaries to impound a portion of the large excess of water which is at times available, and enable it to be used for supplementing the natural flow of the river when deficient, and it is to be hoped that some day this may be found possible. It is highly unlikely that suitable sites for such reservoirs are to be obtained on the Kistna or its tributaries where they lie wholly in the Bombay Presidency, but on the Kistna and the Tungabhadra where they skirt the Madras Presidency and the Nizam's Dominions, and on the main feeders of the latter river which come from Mysore territory, reservoirs have from time to time been suggested, though, except in one case, not with the object of improving the supply of the Kistna Delta, but for independent systems of irrigation or for the purposes of the Kurnool-Cuddapah Canal.

Sites for reservoirs investigated by the Madras Irrigation and Canal Company.

With the latter object the Madras Irrigation and Canal Company in the sixties investigated several sites, on the Hagari (or Vedavatti), the Tunga and the Bhadra. The site which was considered most promising on the first of these three rivers was near Holalagundi, but this need no longer receive consideration because the Madras

Government has, in 1894,* permitted the Mysore State to undertake *without restrictions* the construction of an immense storage reservoir higher up the river, at the "Marikanave," which will in most years impound, for use in Mysore, all the water coming down the Hagari.

Of the various sites examined on the Tunga and the Bhadra only one was considered really promising and this was on the Bhadra near Lakavalli; for it contours were run, surveys made and approximate estimates prepared; the estimated † capacity of the reservoir being 33,075 millions of cubic feet and its cost about 50 lakhs. As the site lies wholly in Mysore territory, it is doubtful, even if the construction of the reservoir were considered advisable, if it would be possible to obtain powers to carry out the work merely for advantage of British interests. On the Tungabhadra the construction of a large reservoir by damming the river near Hoscotta has been frequently advocated; this site was, to some extent, investigated by the Madras Irrigation and Canal Company chiefly with the object of irrigating land in the Bellary and Kurnool districts. It would cover a large area of valuable land and many villages in the Nizam's Dominions as well as on the British side of the river, which would add greatly to its cost and give rise to political difficulties.

Sir Arthur Cotton's proposal for a reservoir on the Kistna.

On the Kistna itself a scheme was five and twenty years ago put forward by Sir Arthur Cotton for forming a reservoir to provide a supply of water to the Kistna Canals during the "dry season" for irrigation and so "that water transit may be secured to the whole district throughout the year." He proposed (see his Memo., dated 14th February 1873, with P.M.G., No. 2099, dated 23rd August 1873) that at the narrow gorge where the river enters on the open plains of the Kistna district the precipitous sides should be blown down by ten mines, each containing 100,000 lb. of gunpowder thus "forming a dam, suppose 100 yards high, by a solid barrier of rock in large masses for a length perhaps of a quarter of a mile." He did not enter into any details as regards the works which would be necessary to let the required quantities of water out of the reservoir, and as the Madras Government remarked when dealing with the proposal, the "outlets would have to be

* See P.M.G., No. 75 I., dated 26th January 1894. Two years previously the construction of the reservoir had been objected to except under certain restrictions to safeguard British interests (see Note by Chief Engineer for Irrigation, No. 58 I., dated 17th March 1892, with P.M.G., No. 331 I., dated 31st March 1892).

† See P.M.G., No. 1500, dated 7th June 1873.

constructed at great cost before the dam itself and their entire destruction might be involved in its sudden precipitation on them by the agency proposed." The Government of India, in its letter No. 656 I., dated 20th September 1873 (see P.M.G., No. 886, dated 30th March 1874), suggested that the "project might not be lost sight of," but nothing further on the subject can be traced except a reply to the Government of India's letter, in which it is stated that the Government of Madras does not see "sufficient reason for an investigation of Sir Arthur Cotton's rough project."

Duty of water.

The "Duty"* of the water available has also, of course, a most important bearing on the area which can be successfully irrigated, and this has received attention. When the Kistna works were originally undertaken, and for many years afterwards, it was assumed that 1 cubic foot of water per second during the period of cultivation would be required for each 66 acres of rice, but it gradually became apparent that a much higher duty might be obtained in the deltas, and when in 1874 and 1876 the Kistna Delta "Completion Projects" were dealt with, the duty was assumed at 74 acres, whilst in 1882 a duty of 81 acres was adopted for the Gódávari Western Delta.

Mr. Chatterton's investigations as to "Duty" of water in the deltas.

On this subject Mr. Chatterton, Professor of Engineering, Civil Engineering College, Madras, who had been temporarily attached to the Public Works staff of the Kistna district, made some interesting investigations in 1891–93; they will be found in his "Note" circulated with Irrigation Branch "Circular Memorandum" No. 32, dated 28th July 1894. He concludes thus—

"The conclusion which I have come to at the end of this inquiry, the investigations connected with which have extended over the greater part of two irrigation seasons, is that the duty of water may be taken as 90 acres per cubic foot per second and that all canals and distributaries should be arranged to work at that duty, that during the transplanting time and occasionally at other times, such as, when the river is low and a succession of small freshes rising only one or two feet on the anicut pass down it, it is convenient to supply a somewhat larger quantity of water than usual and this can best be done by increasing the flow in the canals, and that at times of short supply one cubic foot per second to every 100 acres will enable a good crop to be grown *if care* † *be taken to prevent the waste of water.*

* The "Duty" of water is the area which a given quantity of it will efficiently irrigate. It is usual to take 1 cubic foot per second as the unit.

† Italics not in original.

"It will probably be possible to obtain a minimum supply of 8,000 cubic feet per second from the Kistna till the end of November in each year as soon as the raising of the crest is completed, and the adoption of the conclusions just stated will make the ultimate area of the irrigation of the Kistna Delta about 800,000 * acres, an increase of over 300,000 acres on the original project area."

This led to the adoption as the "probable ultimate" of the areas given in the following statement, to which have been added the actuals of 1897-98 :—

	Probable ultimate areas.	Actual areas of 1897-98.
Eastern Section.	ACRES.	ACRES.
Ellore Canal	65,000	48,166
Masulipatam Canal	58,000	42,667
Ryves' Canal	55,000	45,467
Pulléru ,, ...	152,000	116,783
Polraz ,, ...	27,000	26,465
Bantumilli Canal	43,000	21,524
Total ..	400,000	301,072
Western Section.		
Main Canal	10,000	9,007
Bank ,, ...	95,000	56,234
Nizampatam Canal	65,000	62,447
Commamur ,, ...	130,000	91,162
Total ..	300,000	218,850
Grand Total ..	700,000	519,922

Prevention of waste of water.

The prevention of waste of water which Mr. Chatterton truly refers to as a necessity if the above sanguine anticipations are to be realized without reservoirs, is a most difficult matter to deal with, for every cultivator is, night and day, doing his utmost to send as much water as possible over his fields so that the silt which it bears may be deposited on his lands; indeed the enforcement of anything like *strict economy* is now impracticable, because Government has no control over the

* But see extract from Superintending Engineer's letter of 12th September 1898 given above (page 152), showing that even after the raising was done there was difficulty in supplying little more than half that area.

management of the smaller village and field channels. That much has been done in the direction of economy by improved sluices and distribution arrangements for the larger channels, is shown by the increase in the duty of water which has already taken place.

Rice, the chief crop, grown in the Kistna Delta.

In the above remarks the cultivation of rice is taken as governing the consideration of the case. This is because nine-tenths of the lands which take anicut water grow that crop. Unlike most of the crops under the canals of the North-Western Provinces and the Punjâb, which want only periodical waterings of comparatively short duration, rice requires almost continuous flooding from the time it is planted out till it is almost ready for the sickle. The length of that period varies from $3\frac{1}{2}$ to 6 months according to the description of the rice grown, the better kinds requiring the longer time to come to maturity.

The area on which two wet crops a year are grown is very small in the Kistna Delta, only 451 acres in 1897–98, or less than $\frac{1}{300}$th of that in the Gódávari Delta; this is due to the small quantity of water available in the Kistna during November, December and January, already noticed, the supplies received in that river from the north-east monsoon rains being much less than in the case of the Gódávari. Storage reservoirs would doubtless largely increase the area of two-crop wet lands.

The irrigation rules and rates now in force are given below; the rates are now 25 per cent. higher than before 1895:—

Rules for levying Water-rate in the Kistna and Gódávari Deltas.

RULE I.

The water-rates charged for irrigation in the Gódávari and Kistna Deltas are as follow:—

(1) For a single *wet* crop, Rs. 5 an acre.

(2) For a second *wet* crop on irrigated land, Rs. 5 an acre, provided that the cultivator may compound for irrigation for two crops for a term of years not less than five, for Rs. 8–2–0 an acre.

N.B.—A second crop is a crop grown on land on which a first crop has been grown in the same fasli.

(3) For a second *dry* crop on irrigated land, Rs. 2–8–0 an acre, if the crop is watered only occasionally, and Rs. 3–12–0 an acre, if it is irrigated systematically at regular intervals, except where the land-holder has compounded under clause 2.

(4) For sugar-cane, betel, plantains, turmeric and other garden produce, remaining on the ground for the time of two crops, Rs. 10 an acre,

provided that the cultivator may compound for a term of years not less than five, for Rs. 8-2-0 an acre.

Note.—Cocoanut and other trees forming tope plantations will be charged the same rates as the garden crops above referred to, if they take water for a number of months in the year sufficient for raising two rice crops. If not, they will be charged the rate for a single wet crop specified in clause (1) of these rules.

(5) For a dry crop grown on land for which irrigation has never been supplied, or, having been once supplied, has been since discontinued under Rule III, Rs. 2-8-0 an acre, whether the crop be a first or a second crop provided that the crop is watered only occasionally: if it is systematically irrigated at regular intervals the charge will be Rs. 3-12-0. These rates shall be paid according to the Kistbandi of the district.

(6) When the water used for irrigation cannot be obtained without raising it by baling or mechanical contrivances, a deduction of one-fourth of the water-rate will be made.

(7) When the Collector considers the supply of water to be precarious, the charge for a single wet crop will be Rs. 2-8-0 an acre.

Rule II.

(1) Cultivators will be allowed to take or to refuse irrigation for *wet* crops every year, on condition that a formal application, specifying the number and extent of the fields for which irrigation is sought or declined, be made to the head of the village, and, after registry by the Karnam, be sent to the Tahsildar up to the following dates:—

Applications for irrigation to be supplied—

(*a*) For a first crop, 31st March.

(*b*) For a second crop, 30th November.

Applications for irrigation to be discontinued, 31st March.

(2) When water is required for *dry* crops under Rule I, clause (5), the application may be made at any time.

(3) When water is not available for all applicants, applications will ordinarily be admitted in the following order:—

(*a*) To applicants for water for two crops, or one of sugarcane, &c.

(*b*) To those who have received water longest, preference being given to those whose lands lie nearest the head of the channels.

(4) In the case of all applications for irrigation to be supplied, water being available, and of all applications for irrigation to be discontinued, the Tahsildar will admit the application, endorse it to that effect, and give it back to the Karnam for delivery to the applicant.

(5) Printed forms of these applications will be kept in stock by the Karnam.

(6) A register of applications, showing whether they have been admitted or rejected, will be kept both by the Tahsildar and the Karnam.

(7) The Tahsildar will send extracts from his register to the Executive Engineer of the division concerned every week. The Karnam's register will be kept open to inspection by the villagers.

RULE III.

When land has once been irrigated as *wet* land, it will be described as such in the accounts, and will be supplied with water, and remain liable to the water-rate (water being available) until a formal application for the irrigation to be discontinued has been made and admitted in the manner prescribed in Rule II.

RULE IV.

Application for water for *dry* crops grown on *dry* land, *i.e.*, land for which irrigation has never been supplied, or having been once supplied, has been since discontinued under Rule III, may be made at any time to the Karnam, who will send one copy to the Delta Gumastah or Overseer, and one to the Tahsildar.

RULE V.

When water is taken for land not previously irrigated or of which the irrigation has been relinquished, or when it is taken for raising a second crop, wet or dry, on a registered single crop wet land, before a formal application for water has been made by the ryot concerned and accepted by the Tahsildar as prescribed in Rules II and IV, or after an application has been refused, a water-rate equal to twice the rate chargeable according to Rule I will be exacted. Double water-rate will also be charged if water be taken from a sluice or channel or other source of supply other than that which is provided or approved by the responsible officer of the Public Works Department. The Collector may, for sufficient cause, remit or reduce the penal portion of the water-rate.

RULE VI.

No water-rate will be levied for a single crop on lands in Inams and Zemindaries which have been determined by the Collector under the orders of the Board of Revenue to be entitled to irrigation from before the time the anicut was built as "mamool wet" lands.

RULE VII.

Water will be granted free of charge on application to the D.P.W. officers, through the Collector, for flooding lands made barren by 'Soudoo,'* whenever

* A salt efflorescence, known in the North-Western Provinces as "reh."—G.T.W.

a sufficient supply of water is available, for a period not exceeding two years, provided that, if a crop or crops are raised on the land during this period, half the usual water-rate will be charged.

Rule VIII.

Anything in the foregoing rules notwithstanding, Government reserve to themselves the full right, with or without reason given, to discontinue either temporarily or permanently the supply of water for irrigation.

Note 1. No water-rate should be charged on lands assessed as wet under tanks simply because the land is irrigated by anicut water.

2. A cultivator (tenant) may be called upon to pay for water which he has obtained on his own application against the will of the landlord, and, if he fails to pay the water-rate, his property, real and personal, may be sold. In such a case, the tenant's real property will mean the defaulter's right, title and interest in any land in his holding if such possesses any value. The sale of such real property will be free of encumbrances, but will leave unaffected the landlord's right on the land, whatever it may be. A tenant's right in such cases should not be bought in on behalf of Government. When the tenant does not possess sufficient property, it will be discretionary with the Collector either to require prepayment of the water-rate or refuse the application altogether.

3. When water is given on the application of the landlord, the landlord or his authorized agent should alone be allowed to tender relinquishment.

The aggregate length of irrigation distributaries in the Kistna Delta System is approximately 1,600 miles.

The average rainfall in the delta is * —

	INCHES.
January to March	0·91
April and May	1·98
June to September	21·72
October to December	12·03
Total ..	36·64

* See Benson's "Statistical Atlas".

CHAPTER X.

NAVIGATION.

Combination of Navigation with Irrigation.

THE battle as to the advisability of combining Navigation with Irrigation on the larger delta canals was still being fought over the Gódávari works when those for the Kistna were decided on; it is certain that the Engineers who had to deal with the latter shared Sir Arthur Cotton's views on the subject, but nothing very definite about it appears in the papers which preceded the commencement of the works, except that in the estimate submitted by the Committee and sanctioned by the Court of Directors (see Chapter II) a head lock was provided from the river into the *Main Canal* of each of the two divisions of the delta. By the time, however, that the estimates for the various principal canals were prepared in detail, the battle had been won, and the provisions for making them navigable were accepted without demur.

Navigation arrangements in the Kistna.

The navigation arrangements, like those for irrigation, were at first dealt with piece-meal and not as a comprehensive whole, but the final result has been that all the chief canals have been provided with the necessary locks and other works for making them efficient lines of communication. The following list gives in a condensed form the information on this subject:—

Statement of the NAVIGABLE CANALS, *Kistna Delta System.*

[Navigable Tidal Creeks in connection with the artificial canals are not included in this statement.]

Name of Canal.	Class.	Length navigable.		Number of locks.	Remarks.
		MILES.	CHS.		
EASTERN DELTA.					
Main	1st ...	...	51	1	Head Lock from river 150' × 16'.
Ryves' (Head of)	1st ...	1	...	...	
Ellore	1st ...	39	60	...	There is a lock at junction with Ellore Canal, *Gódávari District*, which belongs to that system.
Masulipatam	1st ...	49	7	5	
Bank	2nd ...	...	...	1	No portion yet navigable, but lock at head built.
Pamarru Junction (between Masulipatam Canal and Pulléru).	2nd ...	...	40	1	Length of lock 106', breadth 16'.
Pulléru	2nd ...	6	70	...	From Junction Canal to Polras and Bantumilli Canals.
Polraz	2nd ...	26	40	3	
Bantumilli	2nd ...	26	15	3	
Totals, Eastern Delta ...	...	150	43	14	

Name of Canal.	Class.	Length navigable.		Number of locks.	Remarks.
WESTERN DELTA.					
Main	1st ...	13	...	1	Head lock from river; length 150′×16′.
Bank	2nd ...	46	4	4	
Commamúr	1st ...	58	20	6	
Nizampatam	2nd ...	28	7	5	
Totals, Western Delta ...	...	145	31	16	
Totals, Kistna System ...	...	295	74	30	

It will be thus seen that in the Kistna Delta there are nearly 300 miles of canals which besides carrying water for irrigation are excellent lines of communication; they also form part of a system of inland navigation upwards of 1,000 miles in length, for they connect with the 500 miles of Gódávari Canals, and with the Buckingham Canal which runs for 196 miles to Madras, and for a further 65 miles south of it.

Effect of Navigation on development of the district.

There cannot be the slightest doubt that the provision of means for easy transit not only about the district itself, but also to other districts and to the ports of Masulipatam and Cocanada, had a great effect on the rate at which irrigation developed and the general prosperity of the district increased.

In this way * the cost of the works specially required for Navigation has been repaid over and over again, quite irrespective of the direct returns from boat licenses, tolls and so on. This fact, however, has been obscured by the practice of attempting to show the financial results from *Navigation* separately from those due to *Irrigation*; the following are extracts from a 'Note' on the subject by the then Chief Engineer for Irrigation, in 1890:—

" . . . No attempt should be made at separation of receipts and charges between Irrigation and Navigation, or at all events there should be no consideration of them separately; the *total* receipts under both heads should be compared with the *total* charges.

" 2. When in the same canal or system of canals Irrigation and Navigation are combined, the works for the two purposes are so interwoven, as it were, that it is impossible to arrive with any accuracy at the share of original cost due to each; and it is still more impossible to separate the cost as regards 'Maintenance and Repairs.' It is, for

* See " Engineering Works of the Gódávari Delta," Chapter XI.

example, impossible to tell with even approximate accuracy how much of the necessary silt clearance, or bank-repairing, is due to Irrigation, how much to Navigation.

"3. The attempt at separation as now carried out is not only useless but mischievous, for it has resulted in the misconception that the making of the Gódávari and Kistna canals navigable has not paid, whilst the truth is that it has been to Government an excellent investment.

"4. It must be remembered that Government is in this matter on an entirely different footing from private owners of canals; the latter get only the *direct* returns, the absolute payments for use of the canals; whilst the former in addition to the direct returns, receives indirect benefits and returns which cannot be tabulated, but which largely outnumber and exceed in importance, and even in money value, those which *are* brought to book. The increased comfort and prosperity of the people resulting from cheap communications cannot be shown in money columns, nor is it possible to credit to Navigation the portion of the enhanced revenue under excise, salt, stamps, and so on, really due to it.

"5. For example, after the construction of the combined Irrigation and Navigation works in the Gódávari Delta the imports and exports of the District increased rapidly, they doubled in a little over ten years; in twenty years they had increased four-fold, and in thirty-five years upwards of ten-fold; so with the general revenue; the district which for many years had not paid the cost of its administration soon rose to the second place amongst the great revenue-yielding districts of the Presidency, whilst the population of the delta has about doubled itself. It is certain that these splendid results compared with which the direct navigation collections from licenses and tolls are insignificant, would not have been achieved so rapidly, and it is probable they would never have been reached at all, had it not been that the delta is intersected by navigable canals which make it easy to export the produce due to irrigation, and which bring salt and the various commodities required by a well-to-do people almost to their very doors."

But, though the combination of the two duties of Irrigation and Navigation has been most successful in the canals of the Deltas, it is not entirely without drawbacks even there, especially on the high-level canals, and it is but right that those drawbacks should receive some notice. With this object the following extract is given from a 'Memorandum' written * in 1888 in support of a proposal for a railway between

* By Mr. G. T. Walch, then Superintending Engineer, 1st Circle.

the Kistna and Gódávari rivers, a proposal which has since developed into the 'East Coast Railway':—

"CANALS for the combined purposes of irrigation and navigation, with special reference to such canals in the Gódávari district, and the necessity for providing other means of traffic between the Kistna and the Gódávari.

"It may be accepted as an axiom in canal engineering that the requirements of irrigation and navigation are conflicting, *e.g.*, for *irrigation* large quantities of water, and consequently of silt, have to be taken into a canal, and therefore the slope of the surface must be considerable; for *navigation*, the less water taken into the canal, the better, and its surface should have no slope; for *irrigation* there are times when the canal should be kept low, so that large quantities of surplus water may not have to be passed into the drainages when they are already filled by rain-water; for *navigation* the canal should always be kept up to its full level; for *irrigation*, even when the river or other source of supply is low, it is often necessary to go on letting as much water as possible *out of* the canal to supply crops, thereby reducing the level and the depth in the canal, especially at its end; for *navigation* at such times the water should be kept *in* the canal, to maintain as nearly as possible its full depth.

"2. The canals of the Gódávari (and Kistna) delta are primarily for *irrigation;* they have been made also navigable to supplement their usefulness, and never has there been a more successful combination. Its very success, however, now threatens, especially on the through lines, to cause the secondary object of the canals to overtop and seriously interfere with the primary one.

"3. The clashing of the irrigation and navigation requirements mentioned in para. 1 is well exemplified on the Ellore canal, which is the through line of communication between the Kistna and the Gódávari river. On that canal considerable silting, inevitable when large quantities of water have to be passed through a canal from a silt-bearing river, frequently impedes traffic, whilst the necessity for keeping sufficient water for heavily laden boats leads at times to more water being taken into the canals and surplussed out, and at other times to less water being given out of the canal to its distributaries, than suits the irrigation; and it is a fact that much tempting and perfectly possible extension of irrigation from near the end of the canal has to be foregone, because it would still further add to the already great difficulty a times of keeping the navigation going."

Extent to which the Navigation in the Kistna system is made use of.

The extent to which the navigable canals of the Kistna system are used, may be judged from the following statement :—

TRAFFIC STATEMENT, KISTNA DELTA CANALS.

Sources of Navigation revenue.	Collections in 1896-97.	Nature of cargo.	Traffic, 1892-93.			Traffic, 1896-97.			Value of goods.		Remarks.
			Up.	Down.	Total.	Up.	Down.	Total.	1892-93.	1896-97.	
1	2	3	4	5	6	7	8	9	10	11	12
		BOAT TRAFFIC.	TONS.	TONS.	TONS.	TONS.	TONS.	TONS.	Rs.	Rs.	
		1. Cotton, raw and manufactured ..	1,136	4,205	5,400	843	546	1,394	27,27,428	10,07,153	Decrease due to the cotton from the Kistna district to Cocanada now going chiefly by railway.
		2. Woollen goods, raw and manufactured.	5	13	18	3	23	26	29,857	39,250	
		3. Dyes and tans ...	64	274	338	381	508	889	1,01,400	2,66,700	
		4. Paddy and rice ...	49,761	41,115	90,876	12,825	19,442	32,267	29,62,828	11,30,280	
		5. Other food-grains...	8,012	6,042	14,054	4,744	7,230	11,974	7,02,621	5,98,900	
		6. Hides and skins ...	89	79	168	59	29	88	1,34,786	56,000	
		7. Liquors	195	196	391	58	109	167	1,62,440	66,800	
		8. Metals	4,505	1,902	6,407	2,067	1,333	3,399	12,81,580	6,79,877	In 1892-93 rails, &c., brought by canal for East Coast Railway and Kistna Bridge. Much of the oil and oil-seed now goes to Cocanada by rail.
License Fees and Tollage of—		9. Oils	2,945	2,061	5,029	1,166	1,050	2,216	7,54,474	2,57,070	
Boats ...	25,517	10. Oil-seeds ...	515	16,237	16,752	597	8,627	9,224	8,37,604	4,61,200	
Rafts ...	1,313	11. Provisions ...	6,734	4,028	10,762	5,273	4,517	9,790	10,73,779	9,58,210	
Miscellaneous.	2,564	12. Salt	15,138	1,825	16,963	13,025	1,415	14,440	13,47,000	11,55,200	
Ground rents.	2,316	13. Spices	5	1	6	11	1	12	6,400	12,200	
		14. Sugar	3,589	497	4,086	1,060	494	1,554	2,78,420	1,17,680	
		15. Tobacco	205	1,252	1,457	299	1,766	2,065	4,21,875	6,19,300	
		16. Building materials.	4,913	31,031	35,943	5,996	42,432	46,428	1,07,785	1,45,392	
		17. Miscellaneous goods.	3,724	3,725	7,449	5,240	5,322	10,562	10,76,619	13,78,892	
		18. Timber	3,538	1,214	4,752	2,913	3,055	5,968	3,80,261	4,77,440	
		19. Firewood	2,996	134	3,132	5,455	1,501	6,956	18,792	1,39,996	
		20. Bamboos	2,729	826	3,555	6,246	2,774	9,020	71,063	1,83,000	
		21. Coal and coke ...	8,924	13,480	22,404	1,362	22,175	23,537	2,68,843	2,82,444	The coal is chiefly that from Singareni going to Madras by the Commamur and Buckingham Canals.
		22. Treasure	...	...	...	...	27	27	21,57,734	24,35,676	Treasure is simply the movement of Government specie between treasuries.
		Total, Boat Traffic ...	119,772	130,160	249,932	69,628	124,375	194,003	1,63,63,663	1,24,67,870	

TRAFFIC STATEMENT, KISTNA DELTA CANALS—*continued.*

Sources of Navigation revenue.	Collections in 1896-97.	Nature of cargo.	Traffic, 1892-93.			Traffic, 1896-97.			Value of goods.		Remarks.
			Up.	Down.	Total.	Up.	Down.	Total.	1892-93.	1896-97.	
1	2	3	4	5	6	7	8	9	10	11	12
		RAFT TRAFFIC.	TONS.	TONS.	TONS.	TONS.	TONS.	TONS.	Rs.	Rs.	
		23. Timber in logs ...	3,556	1,586	5,142	860	1,633	2,493	3,85,812	1,86,955	In 1892-93 much timber brought in rafts for the East Coast Railway and Kistna Bridge construction.
		24. Squared timber ...	1,173	630	1,803	535	205	740	1,44,207	30,720	
		25. Sleepers, broad gauge	...	...	...	...	...	...	1,920	...	
		26. Sleepers, metre gauge	12	...	12	...	...	...	...	...	
		27. Poles...	1	13	14	...	...	...	547	...	
		28. Bamboos	1,911	1,724	3,635	1,056	2,061	3,117	72,715	67,080	
		Total, Raft Traffic ...	6,653	3,953	10,606	2,451	3,899	6,350	6,05,201	2,84,755	
		Grand Total, Boat and Raft Traffic	126,425	134,113	260,538	72,079	128,274	200,353	1,74,98,863	1,27,52,625	
		Numbers of Passengers.	...	...	No. 138,257	...	...	No. 97,143	...	...	The falling off is due to competition of the Railway, along the Ellore Canal, with the passenger boats plying thereon. The number of passengers on that canal fell from 75,754 in 1891-92 to 65,925 in 1892-93 and to 29,062 in 1896-97.

NOTE.—The "tonnages" and values in this statement are merely approximations, as the quantities and descriptions of goods are simply from information given by boatmen, who rarely have any "manifests."

Licenses fees and tolls for use of canals.

No license fees or tolls seem to have been enforced on the Kistna Canals before 1863, but after that, charges were made which varied from time to time, till in 1882 the question of the navigation charges and rules for the Gódávari, Kistna and East Coast Canals was gone into by a committee, whose proposals are to be found in P.M.G., No. 562 W., dated 20th February 1883. The rates proposed by it were considerably modified by the Chief Engineer for Irrigation (Colonel J. O. Hasted, R.E.), and his modifications sanctioned by Government are given in the following statement together with those which were superseded:—

——	Present (1882) rates per ton of 50 cubic feet.	Rates proposed by Chief Engineer for Irrigation and sanctioned by Government.	Remarks.
ANNUAL LICENSES.	ANNUAL LICENSES.	PER TON OF 50 * CUBIC FEET PER ANNUM.	* 15 per cent. deducted from gross measurement for net tonnage.
Cargo Boats.	Rs.		
Gódávari	2½	Rs. 2½ to clear all the canals.	
Kistna	1¾		
Buckingham Canal ...	2 per section, † 10 for whole canal.		† The Buckingham Canal was divided into six sections.
Passenger Boats, 1st Class.			
Gódávari	4½		
Kistna	4¾		
Buckingham Canal ...	2 per section, 4 for whole canal.	Rs. 5 „	
Passenger Boats, 2nd Class.			
Gódávari	3½	Rs. 3 „	
Kistna	3¼		
Buckingham Canal ...	2 per section, 4 for whole canal.		
Steamers.			
Gódávari	5	Rs. 5 „ ‡	‡ One-third deducted from gross measurement for net tonnage.
Kistna	5		
Buckingham Canal ...	As cargo on passenger boats.		
TOLLS.	TOLLS.		
Rafts, Timber.			
Gódávari	4 annas per 100 square feet *each canal.*	8 annas per 100 square feet for *each system* for one month.	
Kistna	Do.		
Buckingham Canal ...	1 anna per square yard.		

—	Present (1882) rates per ton of 50 cubic feet.	Rates proposed by Chief Engineer for Irrigation and sanctioned by Government.	Remarks.
Rafts, Bamboo.			
Gódávari	2 annas per 100 square feet.	4 annas per 100 square feet for *each system* for one month.	
Kistna	Do.		
Buckingham Canal ...	1 anna per square yard.		
Vessels.			
Gódávari	4 annas per ton *each canal.*	8 annas per ton for six weeks over all canals in any direction.	
Kistna	Do.		
Buckingham Canal ...	4 annas per ton *each section of canal.*		
Steamers.			
Gódávari	Same as vessels.	1 rupee per ton for six weeks over all canals in any direction.	
Kistna	...		
Buckingham Canal ...	...		

The main features of the new arrangement were the reduction in the number of toll stations, which had been found to harass traffic, and the discontinuance of separate licenses for each system, in favour of a 'compound rate' covering all the systems. As bearing on these subjects, the following extracts from the Memorandum of the Chief Engineer for Irrigation are given :—

"8. . . . The Committee consider that tolls cannot be entirely abolished, but that to allow of the occasional use of the canals without taking out a license, toll stations must be maintained at the head locks of each section of the deltas, all tidal locks, at Ellore near the junction of the Gódáveri and Kistna Canals, and four places on the Buckingham Canal, for the public convenience, thus reducing the number of toll stations from 47 to 20. To these proposals I agree on the understanding that the toll stations are maintained for the public convenience only, that no obstructions such as now exist in the shape of a chain drawn across the canal shall be allowed, and that the toll-taker has no authority to stop any boat or call for the production of its license unless there is some apparent infringement of the rules. A subordinate in the position of a Lock Superintendent or toll-keeper should never be allowed the powers of an Inspecting Officer. The toll-keepers should be

restricted to issuing toll tickets when called upon to do so. It is better to risk some loss than to harass the traffic." . . . .

"10. The Committee give the rates at which they propose to fix license fees and tolls, and here they follow the system at present in force to some extent. They propose a separate license fee for each system, and a compound rate for all these systems, but they do not propose to retain the present plan of charging a separate fee for each section of the Buckingham Canal. Passenger boats of both classes are dealt with in the same way as cargo boats, also steamers. I am prepared here to go a great deal further than the Committee. What I desire to see is one demand to clear all the canals. I would remove all obstacles in the way of Navigation that I possibly could, believing that the interest of Government will be best served by improving the communications, stimulating consumption, and consequently extending production."

"11. . . . I do not look for an immediate return, but I do expect that the opening of the canal to traffic in this way will eventually prove remunerative to Government, and I allow that it will be practicable to raise these rates at some future time."

The rates thus sanctioned in 1883 remained in force for upwards of 15 years, but have now (1898) been increased as explained below.

Early in 1893 that portion of the "East Coast (State) Railway" which runs along the "Ellore" Canal of the Gódávari and Kistna systems was opened between the two rivers, and later in the year completed to Cocanada; it is in order that some idea may be formed of the effect of the railway on the canal traffic that, in the statement on pages 164-5, has been shown what that traffic was in 1892-93 (*i.e.*, 1st April 1892 to 31st March 1893), as well as in 1896-97.

Railway *v.* Canals.

The railway between Bezwada and Cocanada had not long been opened when its officers began to complain that it could not successfully compete with the water carriage, without a considerable enhancement of the charges for use of the canals, or at all events of the line between Bezwada and Cocanada, consisting of the Kistna-Ellore Canal and the Gódávari, Ellore and Cocanada Canals. Many ways were urged of effecting this, the most favoured being an almost prohibitory toll at the Gódávari river locks. The matter was in 1896 referred to a committee who recommended a reversion to the arrangement in force before 1883 (see statement on page 166) by which the "Gódávari," "Kistna" and "East Coast" Canals were treated as separate and independent systems of navigation, with the fees to be paid for their use very largely enhanced, in most cases quadrupled,

from those in force since 1883, and a preliminary notice to this effect was published. This would have been handicapping the canals with a vengeance, and not only the canals with which the railway is in direct rivalry, but also those which serve parts of the country which the railway does not reach and which are positively "feeders" to it; the result would have been that the best interests of the public and the Government would have been sacrificed with the object that a portion of the traffic which perferred to use the *State* canals might be *forced* on to the *State* railway, so that the latter might be thus artificially made to show better returns.

Fortunately before the Government was finally committed to this course, further consideration was given to the subject and wiser counsels prevailed. After some time the matter was ably dealt with by the Chief Engineer for Irrigation, Mr. W. Hughes, in a "Note" which will be found with P.M.G., No. 319 I., dated 18th April 1898. In this, he points out that in all the "most advanced countries" of Europe, "the tendency is to treat canals as roads, freeing them from all charges except remuneration for services actually rendered, and looking for a return in the general increase of the prosperity of the country which the canals serve. They are considered rather as complements than rivals to railways, each kind of transport being specially suitable for certain kinds of traffic. In no progressive country is any direct profit on (canal) navigation sought," by the State; and that it is "felt to be a national misfortune" that "in England the Railway Companies were allowed to get control of many of the canals."

He deprecates the attempt "to adopt the same system here," and he combats the idea "that the railway cannot get a fair amount of traffic owing to the through traffic on the canals, unless the latter be so taxed as to prevent boats carrying for less than 4½ pies per ton per mile." As regards this he says:

"The railway traffic between Bezwada and Cocanada in 1896 was 72,000 tons, which is nearly the amount by which the canal traffic fell off. The railway was at the time charging 2¼ pies per ton per mile, but was handicapped by the breakage of bulk and delay and exposure of goods at the Gódávari crossing. Nevertheless practically all the salt, cotton, and oil-seeds, which constituted the more valuable part of the canal traffic went to the railway, and there seems no reason to doubt that the railway can largely increase its rates and still keep the valuable traffic when the Gódávari bridge is completed or other arrangements made to take loaded waggons across the river. The experience of other countries all goes to show that since the great improvements of recent times in permanent way and rolling-stock, railways running in competition with canals get nearly all the more

valuable traffic, leaving the canals to carry goods of much bulk or little value, trade in which is affected by a very slight difference in freight."

He then recommends the scale of licenses for use of the canals which is shown in the following table, in which are also shown the rates in force since 1883 and those recommended by the committee above referred to:—

Nature of vessel.	Rates in force since 1883.		Proposed in draft notification.		Proposed by the Chief Engineer for Irrigation and approved by Government.	
	Annual.	Six weeks.	Annual.	Six weeks.	General license, annual.	Six weeks.
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
Steamers, per ton—						
1 line	5 0 0	1 0 0	10 0 0	2 0 0	15 0 0	3 0 0
2 lines			15 0 0	2 0 0		
3 lines			20 0 0	3 0 0		
Cargo boats—						
1 line	2 8 0	0 8 0	2 8 0	1 0 0	...	...
2 lines			6 0 0	1 0 0	...	...
3 lines			10 0 0	1 8 0	...	...
Open cargo boats... ...	...	...	...	...	3 0 0	0 10 0
Passenger boats, 1st class—						
1 line	5 0 0	0 8 0	5 0 0	1 4 0	6 0 0	1 4 0
2 lines			9 0 0	1 8 0		
3 lines			14 0 0	2 0 0		
Passenger boats, 2nd class—						
1 line	3 0 0	0 8 0	3 0 0	1 0 0	...	...
2 lines			7 0 0	1 0 0	...	...
3 lines			12 0 0	1 8 0	...	...
Decked cargo boats and passenger boats, 2nd class	...	...	...	...	4 0 0	0 13 0
Rafts of timber 100 square feet—		(1 month.)				
1 line	...	0 8 0	...	1 8 0	...	1 0 0
2 lines	...	0 8 0				
3 lines	...	0 8 0				
Rafts of bamboos—						
1 line	...	0 4 0	...	1 0 0	...	0 8 0
2 lines	...	0 4 0				
3 lines	...	0 4 0				

With reference to his proposed enhancements of navigation charges the Chief Engineer for Irrigation remarks:

"This is a tariff for revenue to satisfy the objection of the Government of India that the navigation is being worked at a loss. The amount of additional revenue required to cover the present deficit and the further falling off which will occur when the Madras-Bezwada line is opened is of course purely conjectural. The rates entered are such as it is thought traffic will bear without sensible injury. The rates for annual licenses are increased 20 to 33 per cent. and for six-weeks licenses 20 to 150 per cent., the reason for the great variation in the latter case being that in the 1883 tariff a uniform rate of 8 annas was imposed in lieu of two tolls irrespective of the class of vessels. The six-weeks rates now proposed are roughly one-fifth of the annual rates. The rates for steamers are trebled. The canals are generally not deep enough for steam traffic, and steamers unless very small

and worked at a low speed do much injury to the banks. It is decidedly a bad time to increase rates at all, but the increase cannot be avoided if the receipts and charges are to be made to balance." *

Government accepted the recommendations made, and the new scale of fees came into force in May 1898.

Navigation Maintenance charges.

The annual Maintenance charges against Navigation are to a considerable extent purely arbitrary, and to show the way in which they are assessed, the following statement of those charges for the Kistna system in 1897–98 is appended:—

Description.	Total charges for 1897–98.	Debitable to			
		Navigation.		Irrigation.	
		Rate.	Amount.	Rate.	Amount.
	Rs.		Rs.		Rs.
1. Lock establishment ...	6,167	Whole ...	6,167	...	...
2. Locks and lock-weirs repairs	18,278	Do. ...	18,278	...	...
3. Navigation buildings ...	1,804	Do. ...	1,804	...	...
4. Towpath maintenance ...	18,765	Do. ...	18,765	...	...
5. Miscellaneous (including charges not appertaining to the above items) ...	9,934	Do. ...	9,934	...	...
6. Share of canal maintenance	96,792	One-third.	32,264	Two-thirds.	64,528
Total ...	1,51,740	...	87,212	...	64,528

Navigation rules.

There are complete Rules dealing with 'Licenses,' 'Tolls,' 'Wharfage fees,' and general 'Regulations' for navigation; but it seems unnecessary to give them here, for they are lengthy and are from time to time published.

Towage on Canals.

The following remarks on the Towage on the Canals, which are as applicable to the Kistna Canals as to those of the Gódávari, are taken from the "Engineering History of the Gódávari Delta":—

Manual labour as the motive power for boats is extensively used, but the waterway of most of the canals is so broad that sailing is largely resorted to. The passenger, or 'Rahadri,' boats have two large lateen sails, the peaks of which rise high above the banks, whilst barges or 'Dhonies' are generally square-rigged and often carry 'Main,' 'Top,' and 'Top-gallant' sails, and sometimes even 'Royals.'

* See also remarks on page 161.

Of course the introduction of steam power for the transportation of freight along the canals has often been considered, and it has to some extent been tried, but without success. It cannot compete with manual labour, unless that becomes far less plentiful and cheap than it now is, and unless the canals along the chief lines of communication be maintained *along their whole lengths and at all points* to a depth greater than is now the case. As bearing on this interesting subject, the following information is given about it, in connection with one of the most important artificial inland waterways of the world, the Erie Canal in the New York State, running from Lake Erie at Buffalo, to the Hudson River at Albany, a distance of 363 miles. Up to nineteen * years ago, all attempts to introduce financially successful steam navigation on that Canal had failed, and this though it had to compete only with the haulage by animal power there used, which is many times more expensive than that by manual labour in the Gódávari District. In the last few years, however, continuous attention to the subject has resulted in such improvements to the steam-tugs and the general towing arrangements connected with them, that their use on the Canal is gradually extending. To secure this result, however, it has been found necessary to lengthen the Locks considerably and to maintain the depth of water in the Canal at not less than 7 feet; a low rate of speed has also had to be adopted, under 3 miles † an hour on the average.

That steam, or perhaps electricity, will eventually supersede the towing coolie on the Gódávari and Kistna Canals is most probable, but this will not be for many a long day yet.

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* See page 81 of "Navigable Rivers and Canals of the United States and Canada."—WALCH.

† Report of State Engineer, State of New York, for 1891.

CHAPTER XI.

RESULTS OF THE KISTNA DELTA WORKS.

THE financial and other results of the Kistna Delta System of Irrigation and Navigation have already been noticed in various parts of this History, but it will probably prove convenient to have the information about the more important of them grouped in one chapter.

I.—DIRECT MONEY RETURNS.

	Rs.	Rs.
Total CAPITAL Expenditure, including "Indirect charges", from 1852 to end of 1897-98—*see* Appendix No. II.	..	**1,31,91,665**
TOTAL RECEIPTS from the Works to end of 1897-98	4,52,39,350	..
But of this, *assumed* as due to the irrigation existing before the works of the system were commenced ..	33,59,135	
Balance credited to the Works ..	..	4,18,80,215
TOTAL EXPENDITURE AND CHARGES ON REVENUE ACCOUNT ("*Minor Extensions and Improvements*," *Maintenance, Interest Charges—see* Statement, Chapter VI) to end of 1897-98 ..	..	2,31,85,707
BALANCE—CLEAR SURPLUS of Receipts over "Revenue" Expenditure and Charges to end of 1897-98	..	**1,86,94,508**

or nearly half as much again as the whole Capital expended; and this it must be remembered is after having provided interest on the money spent; for such interest has been, and is still being, charged at 4 per cent. year by year against the Works, though it might have been extinguished long ago by a sinking fund raised from the surplus profits.

The *net Annual Revenue* of the system *after* paying interest at 4 per cent. gives 9·5 per cent. on the Capital outlay, or 13·17 per cent. were

interest charges not made; this is shown in the following statement for 1897-98:—

Capital Outlay, Direct and Indirect, to end of 1897-98.	Revenue Receipts in 1897-98.*	Working Expenses, 1897-98 (including collection charges).	Net Revenue due to the system in 1897-98.	Percentage of Net Revenue on Capital Outlay in 1897-98.	Interest on Capital charged 1897-98.	Surplus Revenue after deducting interest.	Percentage of Surplus Revenue on Capital Outlay after deducting interest.
Rs.	Rs.	Rs.	Rs.		Rs.	Rs.	
1,31,91,665	24,79,695	7,41,419	17,38,276	13·17	4,86,248	12,52,028	9·5

* Exclusive of Rs. 66,100 assumed as due to "Old irrigation."

When the "Completion estimates" were sanctioned by the Secretary of State, it was anticipated † that the net revenue, excluding interest charges, would be only Rs. 9,41,132, and the percentage on expenditure only 6·77 per cent.

II.—Growth of Revenue of the District.

The following statement gives the income from various sources of Revenue of the Kistna District at intervals of ten years since the year in which the anicut was begun:—

Sources of Revenue.	In 1850-51.	In 1860-61.	In 1870-71.	In 1880-81.	In 1890-91.	In 1897-98.	Remarks.
1	2	3	4	5	6	7	
Land Revenue and Water-tax	Rs. 21,59,672	Rs. 27,67,389	Rs. 35,91,758	Rs. 41,71,685	Rs. 49,94,895	Rs. ‡54,67,478	The water-tax increased in 1895-96 by about 25 per cent.
Income tax—Assessed taxes	...	24,538	1,14,117	29,284	80,107	1,46,532	
Stamps	21,526	36,776	1,37,793	2,08,151	2,97,029	4,52,468	
Abkári	78,068	1,04,530	1,74,897	2,30,660	8,11,814	3,40,198	
Opium	...	...	...	7,158	46,727	51,564	
Sea Customs	6,982	6,232	9,835	74,601	65,650	16,378	
Salt	6,93,090	6,70,517	14,09,977	10,28,390	§ 16,52,686	‖ 6,17,665	For decrease see note below.
Moturpha (tax on Manufacturing and Trading community)	72,740	49,023	...	...	...	...	
Totals ...	30,32,078	36,59,005	54,38,377	57,49,929	79,48,908	75,92,283	

From this it will be seen that the total revenue raised by Government from the District has, in less than 50 years, risen from 30¼ lakhs

† See Chapter VI, page 107.

‡ In this the whole of the Rs. 24,79,695 of the statement under I is included.

§ This is the Revenue of the Masulipatam Salt Sub-Division which in 1890-91 comprised the whole of the Gódávari District and the greater portion of the Kistna District.

‖ This is the Revenue of the *present* Masulipatam Salt Sub-Division which consists of the greater portion of the Kistna District only.

to nearly 76 lakhs, and besides this, large sums are now collected as "Local" and "Municipal" taxes which did not exist in former days, but are now raised without hardship, owing to the greatly increased prosperity of the people. The whole of the increase of the Revenue is not of course solely due to the Delta Works, but most certainly far more is due to them than merely that with which they are credited (Rs. 24,79,695 in 1897–98) for *all* the sources of Revenue, and not merely the Land and Water-tax, are largely affected by the increase in population and general prosperity resulting from the Anicut and its attendant Irrigation and Navigation Works.

Amongst all the districts of the Madras Presidency, the KISTNA stands *second* as regards its "Land Revenue and Water-tax," and *third* as regards its total Revenue from all sources, coming next after the two other extensively irrigated districts of Tanjore and Gódávari.

III.—POPULATION.

The population of the district has, in 25 years, increased by about 43 per cent. as shown in the following statement. The effect of irrigation on the density of population is very marked:—

Population of the Kistna District, Census of 1866–67, 1871, 1881 *and* 1891.

Taluks.	Census, 1866–67.	Census, 1871.	Census, 1881.	Census, 1891.	Area in square miles.	Population per square mile.
1	2	3	4	5	6	7
Irrigated by Anicut water more or less.						
Bandar or Masulipatam	146,522	163,447	175,482	198,384	740	268
Bapatla	129,528	139,878	151,736	181,940	679	268
Bezwada	73,373	84,201	82,895	106,477	422	252
Nuzvid	105,438	107,760	125,165	153,628	789	194
Gudivada	80,171	89,900	99,233	118,310	595	* 198
Repalli or Tenali ...	155,092	168,577	184,340	222,757	644	345
Guntur	113,963	124,505	136,083	166,817	500	333
Not irrigated at all by Anicut water.						
Nandigama	98,637	107,255	107,288	126,701	677	187
Narasarowpet ...	102,136	121,080	128,791	156,377	712	219
Palnad	106,395	120,519	125,799	142,011	1,042	136
Sattenapalli ...	84,000	102,203	110,290	138,617	714	194
Vinukonda	52,574	64,284	66,977	82,445	646	127
Vissannapet ...	48,823	55,399	54,401	61,118	338	180
Total ...	1,296,652	1,449,008	1,548,480	1,855,582	8,498	...

* Includes a considerable area of the Colair Lake.

IV.—Cultivation.

The area of irrigated land in the Delta has since the construction of the Anicut increased from some 40,000 acres of precarious cultivation, to upwards of half a million of acres of wet crops grown annually with almost absolute certainty, whilst large areas of "dry" crops, "garden cultivation," and so on, which do not ostensibly "take" water and therefore do not pay water-tax, are greatly benefited by the Canals and Channels.

V.—Communications.

Before the Anicut was begun the deltaic portions of the district were almost entirely without internal means of communication worthy of the name, and such traffic as there was, had to be carried on chiefly by means of coolies and pack-cattle; now, the Delta is intersected by nearly 300 miles of excellent navigable Canals furnishing the cheapest of all means of inland carriage, and there are some 350 miles of well-made roads for wheeled traffic, constructed and maintained from Local Funds, which the great prosperity of the district has made it possible to collect within itself.

VI.—General.

This History has shown how important are the results of the Kistna Delta Irrigation and Navigation Works. They have raised the district from poverty and deterioration to prosperity and progress; they have converted hundreds of square miles of its barren lands into fruitful fields, and secured it against the famines which used to ravage it, so that besides growing sufficient food-grains for its own inhabitants it provides a surplus for less favoured regions; and this has been accomplished with the happiest financial results, for the direct returns alone have far more than repaid to the State all the capital expended on the works, and they yield a yearly surplus revenue, after paying all expenses, of upwards of 17 lakhs of rupees.

The Kistna Irrigation and Navigation System is therefore a conspicuous success even if regarded by itself; but it does not stand alone; it is, as it were, the complement of the adjoining still greater Gódávari Delta System, the combined area of irrigation of the two systems being upwards of one and-a-quarter million acres, intersected by numerous navigable Canals, and forming a thriving province of exceptional fertility.

APPENDIX No. I.

List of Officers employed in connection with the Kistna Delta Works since 1859. (*Registers before* 1859 *imperfect.*)

[NOTE.—This list was prepared in the Office of the Chief Engineer, P.W.D., but is not quite complete.]

Names.	From	To
* CHIEF ENGINEERS FOR IRRIGATION.		
Lieut.-Colonel J. H. BELL, Chief Engineer, P.W.D.	April 1859 ...	May 1860.
Lieut.-Colonel W. H. HORSLEY, Chief Engineer, P.W.D.	May 1860 ...	June 1862.
Colonel W. J. BIRDWOOD, Chief Engineer, P.W.D.	June 1862 ...	September 1863.
Colonel C. A. ORR, Chief Engineer, P.W.D. ...	September 1863.	April 1871.
Lieut.-Colonel J. C. ANDERSON	November 1867.	March 1869.
Major J. MULLINS (Acting)	March 1869 ...	August 1869.
Lieut.-Colonel J. C. ANDERSON	August 1869 ...	October 1870.
Major J. MULLINS	November 1870.	March 1871.
Captain F. G. RYVES (Acting)	March 1871 ...	July 1871.
Captain R. F. OAKES (Acting)	September 1871.	November 1872.
Lieut.-Colonel J. MULLINS	November 1872.	May 1875.
Major J. O. HASTED	May 1875 ...	August 1875.
Lieut.-Colonel J. MULLINS	August 1875 ...	October 1878.
Lieut.-Colonel J. O. HASTED (Acting)	October 1878 ...	January 1879.
Colonel J. MULLINS	April 1879 ...	April 1881.
Lieut.-Colonel J. O. HASTED (Acting)	April 1881 ...	July 1881.
Colonel J. MULLINS	July 1881 ...	March 1882.
Colonel J. O. HASTED	March 1882 ...	September 1886.
Lieut.-Colonel J. PENNYCUICK (Acting) ...	September 1886.	March 1887.
Colonel H. R. MEAD	March 1887 ...	October 1888.
G. T. WALCH	October 1888 ...	October 1892.
Lieut.-Colonel R. R. E. DRAKE-BROCKMAN ...	October 1892 ...	October 1896.
W. HUGHES	October 1896 ...	July 1898.
J. C. LARMINIE (Acting)	July 1898 ...	October 1898.
W. HUGHES	October 1898 ...	.....

* The post of Chief Engineer for Irrigation appears to have been created in 1867.

APPENDIX No. I—*cont.*

List of Officers employed in connection with the Kistna Delta Works since 1859—cont.

Names.	From	To
SUPERINTENDING ENGINEERS.		
Major W. H. HORSLEY, Dy. Chief Engineer, North Circle.	May 1859 ...	May 1860.
Lieut.-Colonel S. O. E. LUDLOW, Dy. Chief Engineer, North Circle.	December 1860.	February 1861.
Lieut.-Colonel J. C. ANDERSON	May 1863 ...	April 1865.
Lieut.-Colonel G. V. WINSCOM	April 1865 ...	November 1868.
Colonel F. J. MOBERLY	November 1868.	May 1872.
Major J. O. HASTED	January 1873 ...	May 1875.
G. T. WALCH, Superintendent of Works, Gódávari-Kistna.	March 1880 ...	August 1880.
J. W. RUNDALL	August 1880 ...	July 1885.
Lieut.-Colonel J. L. L. MORANT	July 1885 ...	April 1886.
Major S. C. CLARKE	June 1886 ...	August 1886.
G. D. WYBROW	August 1886 ...	August 1887.
J. W. RUNDALL	August 1887 ...	December 1887.
J. HANNAN	December 1887.	July 1892.
J. W. MARTIN	July 1892 ...	April 1893.
A. A. G. MALET (Acting)	April 1893 ...	July 1893.
J. W. MARTIN	July 1893 ...	April 1894.
Major W. L. C. BADDELEY	April 1894 ...	November 1897.
W. C. DEMORGAN (Acting)	15th Nov. 1897.	27th Nov. 1897.
J. E. PAUL (Acting)	28th Nov. 1897.	7th Jan. 1898.
J. HANNAN	January 1898 ...	Up to date.
W. C. LEWIS (Acting)	30 July 1898 ...	8 October 1898.

APPENDIX No. I—*cont.*

List of Officers employed in connection with the Kistna Delta Works since 1859—cont.

Names.	From	To	Nature of charge.
EXECUTIVE ENGINEERS.			
Captain O. W. S. CHAMBERS.	November 1857.	October 1859 ...	Kistna Division.
Lieutenant J. VIRTUE ...	October 1859 ...	March 1860 ...	Do.
Captain F. G. RYVES ...	March 1860 ...	January 1861 ...	Do.
Major J. C. ANDERSON ...	March 1861 ...	April 1863 ...	Do.
G. S. SAGE	July 1863 ...	September 1864.	Fifth Range.
Captain G. V. WINSCOM ...	September 1864.	March 1865 ...	Do.
Captain J. N. HUNTER ...	November 1865.	Not known ...	Seventh Range.
Captain S. J. SMITH ...	May 1865 ...	January 1868 ...	Sixth Range.
Lieutenant H. M. VIBART ...	December 1866.	July 1868 ...	Kistna Division.
J. L. MACALPINE	April 1868 ...	March 1870 ...	Seventh Range.
R. CAREW	April 1868 ...	November 1868.	First Range.
Lieutenant A. R. EDGCOME...	July 1868 ...	February 1870.	Sixth Range.
Captain H. SMALLEY ...	January 1870 ...	January 1873 ...	Seventh Range.
Lieutenant H. M. VIBART ...	February 1871...	July 1872 ...	Western Delta.
Lieutenant D. MCNEIL CAMPBELL.	April 1874 ...	January 1876 ...	Not known.
R. W. NORRIS	February 1875...	June 1879 ...	Western Delta.
C. J. PETERS	April 1875 ...	October 1880 ...	Eastern Delta.
G. D. WYDROW	June 1879 ...	May 1883 ...	Western Delta.
J. D. GRANT	August 1880 ...	July 1886 ...	Eastern Delta.
J. HANNAN	December 1882.	March 1885 ...	Gudivada Division.
W. C. DEMORGAN	May 1885 ...	April 1886 ...	Do.
C. H. B. BURLTON	August 1886 ...	October 1887 ...	Eastern Delta.
J. TRAILL	September 1887.	May 1888 ...	Do.
N. B. TODD	September 1887.	November 1891.	Western Delta and Gudivada Division.
D. M. HAYES	May 1888 ...	December 1888.	Eastern Delta.
Major L. LANGLEY	January 1889 ...	April 1890 ...	Do.

APPENDIX No. I—*cont.*

List of Officers employed in connection with the Kistna Delta Works since 1859—cont.

Names.	From	To	Nature of charge.
EXECUTIVE ENGINEERS—*cont.*			
J. E. PAUL	September 1889.	February 1891.	Western Delta.
W. JOPP	February 1890.	April 1893 ...	Eastern Delta.
A. A. G. MALET ...	March 1891 ...	April 1893 ...	Western Delta.
	July 1893 ...	September 1896.	Do.
C. J. USSHER ...	April 1890 ...	February 1891...	Eastern Delta.
	November 1891.	February 1893 ...	Western and Gudivada Divisions.
C. F. SMITH	April 1893 ...	July 1896 ...	Eastern Delta.
J. TRAILL	October 1893 ...	February 1894...	Gudivada Division.
Captain W. M. ELLIS ...	December 1894.	February 1896 ...	Northern Delta.
	December 1893.	Up to date ...	Do.
H. J. KEELING	February 1896.	December 1896.	Do.
W. C. LEWIS	September 1896.	July 1898 ...	Western Delta.
J. S. WILSON	February 1897.	Up to date ...	Eastern Delta.
R. A. SRINIVASA AIYANGAR.	July 1898 ...	October 1898 ...	Western Delta.

APPENDIX No. I—*cont.*

List of Officers employed in connection with the Kistna Delta Works—cont.

Names.	From	To
ASSISTANT ENGINEERS.		
Captain D. G. POLLARD	December 1857..	January 1861.
Lieutenant J. BEATLY	January 1857 ...	January 1860.
Lieutenant J. MAGNAY	December 1857.	May 1860.
W. B. LEGGATT	December 1859.	April 1860.
Lieutenant J. O. HASTED	July 1861 ...	April 1865.
F. N. HAWKINS	October 1861 ...	July 1863.
Lieutenant A. R. EDGCOME	February 1863.	Not known.
	January 1868 ...	July 1868.
Lieutenant H. M. VIBART	June 1863 ...	December 1866.
Lieutenant A. C. SMITH	September 1864.	March 1870.
Lieutenant W. H. COAKER	April 1866 ...	October 1867.
R. W. NORRIS	November 1867.	February 1875.
C. J. PETERS	December 1867.	April 1875.
Lieutenant D. MACNEIL CAMPBELL	June 1869 ...	April 1874.
Lieutenant C. C. RAWSON	April 1872 ...	November 1876.
Lieutenant C. B. WILKINSON	April 1873 ...	October 1874.
W. B. DEWINTON	December 1874.	January 1876.
C. M. SMITH	January 1876 ...	January 1884.
Lieutenant O. V. BODDY	October 1876 ...	January 1879.
	January 1881 ...	November 1881.
G. B. LAMBERT	November 1877.	April 1882.
A. H. GARRETT	June 1879 ...	December 1881.
S. D. PEARS	November 1880.	March 1885.
C. J. USSHER	June 1880 ...	October 1883.
	January 1890 ...	April 1890.
A. M. FOORD	February 1881...	October 1883.

APPENDIX No. I—*cont.*

List of Officers employed in connection with the Kistna Delta Works—cont.

Names.	From	To
ASSISTANT ENGINEERS—*cont.*		
J. J. WHITELEY	November 1881.	July 1884.
	February 1885...	May 1885.
A. T. MACKENZIE	November 1881.	January 1883.
	September 1883.	August 1886.
A. R. BOYLE	March 1882 ...	October 1883.
G. P. CARLESS	June 1883 ...	December 1883.
P. R. ALLEN	October 1883 ...	December 1886.
J. INGLIS	December 1883.	May 1886.
W. S. HAY	December 1883.	March 1884.
C. A. SMITH	March 1884 ...	June 1886.
H. A. MOSS	October 1886 ...	January 1890.
A. C. LAUGSTON	December 1886.	February 1889.
C. W. WOOD	September 1886.	April 1890.
G. F. HANDCOCK	August 1888 ...	March 1889.
C. H. D. MARJORIBANKS	October 1886 ...	May 1888.
C. MILDRED	December 1888.	June 1890.
S. GOPALAKRISHNA AIYAR	February 1889.	April 1894.
S. B. MURRAY	January 1891 ...	April 1893.
T. W. S. SMYTH	January 1891 ...	August 1895.
R. SRINIVASA AIYANGAR	February 1891.	October 1891.
	February 1892.	August 1893.
R. N. H. REID	December 1891.	June 1896.
A. H. MORIN	January 1893 ...	December 1896.
S. A. SUBRAHMANYA AIYAR	February 1894.	March 1896.
L. D. VENKATARAMA AIYAR	January 1894 ...	April 1897.
T. SUBRAMANYA AIYAR	October 1893 ...	April 1894.
G. R. VENKATARAMA AIYAR	August 1895 ...	Up to date.

APPENDIX No. I—*cont.*

List of Officers employed in connection with the Kistna Delta Works—cont.

Names.	From	To
ASSISTANT ENGINEERS—*cont.*		
M. R. KHAREGAT	December 1895.	May 1897.
	December 1897.	Up to date.
L. L. WICKHAM	September 1896.	February 1897.
R. KALYANARAMA AIYAR	March 1896 ...	April 1897.
J. B. LUTMAN	December 1896.	September 1897.
C. T. MULLINGS	December 1896.	July 1897.
R. A. SRINIVASA AIYANGAR	August 1896 ...	Up to date.
S. A. JAGADISA AIYAR	July 1896 ...	November 1896.
	June 1898 ...	Up to date.
R. W. FORMBY	January 1898 ...	Do.
A. W. CAMPBELL	November 1897.	Do.
S. G. ROMILLY	February 1898 ..	Do.

APPENDIX No. II.

Statement showing the Expenditure incurred on CAPITAL Account of the Kistna Delta System to end of 1897-98.

Years.	Direct Charges.					Indirect Charges.			Total Direct and Indirect Charges.	Remarks.
	Works.	Establishment.	Tools and Plant.	*Less* receipts on Capital Account.	*Net* Total.	Capitalized abatement of Land Revenue.	Leave and Pension Allowances.	Total.		
1	2	3	4	5	6	7	8	9	10	11
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	
1852-53	2,66,095	62,231	13,632	...	3,41,958	2,217	13,224	15,441	3,57,399	
1853-54	2,66,095	62,230	13,632	...	3,41,957	15,369	13,224	28,593	3,70,550	
1854-55	2,66,095	62,230	13,632	...	3,41,957	1,842	13,224	15,066	3,57,023	
1855-56	2,66,094	62,230	13,632	...	3,41,956	12,856	13,224	26,080	3,68,036	
1856-57	2,91,793	68,241	13,998	...	3,74,032	13,746	14,501	28,247	4,02,279	
1857-58	96,907	22,664	11,215	...	1,30,786	19,270	4,816	24,086	1,54,872	Orders restricting expenditure on account of the Mutiny issued in June 1857, but in January 1858 permission given to go on with the Masulipatam Canal as of Military importance.
1858-59	65,599	15,341	10,769	...	91,709	5,443	3,260	8,703	1,00,412	
1859-60	84,489	19,759	11,038	...	1,15,286	3,508	4,198	7,706	1,22,992	
1860-61	1,19,926	28,045	11,543	...	1,59,514	11,331	5,960	17,291	1,76,805	
1861-62	1,31,577	30,771	11,710	...	1,74,058	8,526	6,539	15,065	1,89,123	

APPENDIX No. II—*cont.*

Statement showing the Expenditure incurred on CAPITAL Account of the Kistna Delta System to end of 1897–98—cont.

Years.	Direct Charges.					Indirect Charges.			Total Direct and Indirect Charges.	Remarks.
	Works.	Establishment.	Tools and Plant.	*Less* receipts on Capital Account.	*Net* Total.	Capitalized abatement of Land Revenue.	Leave and Pension Allowances.	Total.		
1	2	3	4	5	6	7	8	9	10	11
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	
1862–63	2,25,042	52,628	13,045	...	2,90,715	4,699	11,184	15,883	3,06,598	
1863–64	2,07,441	48,513	12,794	...	2,68,748	5,345	10,309	15,654	2,84,402	
1864–65	1,58,473	37,061	12,094	...	2,07,628	5,079	7,876	12,955	2,20,583	
1865–66	1,00,226	23,439	11,264	...	1,34,929	15,986	4,981	20,967	1,55,896	
1866–67	94,862	22,185	11,185	...	1,28,232	9,942	4,714	14,656	1,42,888	
1867–68	2,25,993	52,852	3,226	...	2,82,071	3,333	11,231	14,564	2,96,635	
1868–69	2,09,455	48,985	2,990	...	2,61,430	3,240	10,409	13,649	2,75,079	
1869–70	1,38,033	32,281	1,970	...	1,72,284	13,267	6,860	20,127	1,92,411	
1870–71	96,003	22,452	1,370	...	1,19,825	26,159	4,771	30,930	1,50,755	
1871–72	1,05,235	24,612	1,501	...	1,31,348	6,320	5,230	11,550	1,42,898	
1872–73	91,184	21,328	1,301	...	1,13,813	7,579	4,532	12,111	1,25,924	
1873–74	1,11,208	26,008	1,587	751	1,38,052	7,751	5,527	13,278	1,51,330	
1874–75	1,16,606	27,270	1,665	477	1,45,064	...	5,795	5,795	1,50,859	
1875–76	68,106	32,773	18,842	...	1,19,721	4,016	6,964	10,980	1,30,701	
1876–77	33,328	17,502	5,957	...	56,787	5,173	3,719	8,892	65,679	Expenditure restricted on account of financial pressure.
1877–78	26,944	15,558	16,298	90	58,710	1,775	3,306	5,081	63,791	
1878–79	15,000	16,834	1,491	...	33,325	236	3,577	3,813	37,138	

APPENDIX No. II—*cont.*

Statement showing the Expenditure incurred on CAPITAL Account of the Kistna Delta System to end of 1897-98—cont.

Years.	Direct Charges.					Indirect Charges.			Total Direct and Indirect Charges.	Remarks.
	Works.	Establishment.	Tools and Plant.	*Less* receipts on Capital Account.	*Net* Total.	Capitalized abatement of Land Revenue.	Leave and Pension Allowances.	Total.		
1	2	3	4	5	6	7	8	9	10	11
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	
1879-80	1,51,749	63,373	15,064	63	2,30,123	1,409	13,467	14,876	2,44,999	
1880-81	1,10,647	30,042	57,260	37	1,97,912	...	6,384	6,384	2,04,296	
1881-82	90,046	24,849	2,069	2,228	1,14,736	256	5,280	5,536	1,20,272	
1882-83	1,52,805	33,562	15,669	1,088	2,00,948	7,146	4,755	11,901	2,12,849	The "Completion Project" sanctioned by the Secretary of State, 9th Feb. 1882.
1883-84	3,13,761	67,839	17,184	1,494	3,97,290	...	9,497	9,497	4,06,787	
1884-85	3,46,729	75,675	42,785	103	4,65,086	6,538	10,594	17,132	4,82,218	
1885-86	2,63,854	56,722	42,018	177	3,62,417	21,186	7,941	29,127	3,91,544	
1886-87	2,82,838	62,016	11,718	13	3,56,559	..	8,682	8,682	3,65,241	
1887-88	3,32,117	74,441	6,498	...	4,13,056	64,638	10,422	75,060	4,88,116	
1888-89	4,16,981	93,851	18,646	983	5,28,495	20,930	13,139	34,069	5,62,564	
1889-90	4,04,189	90,788	350	86	4,95,241	16,947	12,710	29,657	5,24,898	
1890-91	3,64,673	77,820	28,756	270	4,70,979	31,800	10,895	42,695	5,13,674	
1891-92	3,37,328	73,078	18,371	— 125	4,28,902	17,643	10,231	27,874	4,56,776	
1892-93	2,46,657	53,674	13,724	7,461	3,06,594	13,703	7,515	21,218	3,27,812	
1893-94	3,05,292	68,847	7,706	...	3,81,845	9,319	9,639	18,958	4,00,803	
1894-95	3,21,698	71,488	14,589	...	4,07,775	11,414	10,008	21,422	4,29,197	

APPENDIX No. II—*cont.*

Statement showing the Expenditure incurred on CAPITAL Account of the Kistna Delta System to end of 1897-98—cont.

Years.	Direct Charges.					Indirect Charges.			Total Direct and Indirect Charges.	Remarks.
	Works.	Establishment.	Tools and Plant.	*Less* receipts on Capital Account.	*Net* Total.	Capitalized abatement of Land Revenue.	Leave and Pension Allowances.	Total.		
1	2	3	4	5	6	7	8	9	10	11
	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	
1895-96	4,35,583	95,231	12,357	204	5,42,967	...	13,332	13,332	5,56,299	
1896-97	4,51,411	91,821	*41,650	...	5,84,882	5,107	12,855	17,962	6,02,844	
1897-98	2,84,721	53,118	51,149	...	3,88,988	10,993	7,437	18,430	4,07,418	
Total ...	94,90,888	22,14,258	6,60,944	15,400	1,23,50,690	4,53,037	3,87,938	8,40,975	1,31,91,665	

* The chief items of this were: Part payment for stern-wheel steamer, Rs. 7,671; punts and "scouring dams," Rs. 20,592; iron ferry boats, Rs. 4,347; tramway plant from Rushikulya, Rs. 6,387.

Column 2, *Works.*—The expenditure from 1852-53 to 1866-67 was taken from statement printed in G.O., No. 193, dated 21st January 1869. In this statement the expenditure from 1852 to 1855-56 having been shown in the aggregate, the total outlay was divided equally between those years. In so doing charges amounting to Rs. 64,336 and Rs. 30,147 on account of establishment and tools and plant were eliminated from works outlay in which they were erroneously included.

Column 3, *Establishment.*—The charges from 1852-53 to 1873-74 appear to have been calculated by distributing the total cost of establishment in proportion to the outlay on works under each head. The charges from 1874-75 to 1881-82 were calculated at 25 per cent. on the grant for or expenditure on works, whichever was greater, *plus* the proportionate share of the cost of the Chief Engineer for Irrigation and his establishment, and the cost of special Survey establishment. The charges from 1882-83 to 1896-97 were calculated at 23 per cent. on the outlay on works, exclusive of land compensation.

Column 4, *Tools and Plant.*—The charges for each year from 1852-53 to 1877-78 appear to have been calculated by distributing the total cost of tools and plant in proportion to the outlay on works under each head, *plus* the special charges incurred on boats, machinery, &c., supplied directly for use on the Delta works. The charges from 1878-79 to 1881-82 comprise not only the actual charges, but also 2½ per cent. on the grant for or outlay on works, whichever was greater, on account of general tools and plant. The charges for 1882-83 comprised actuals as well as 1½ per cent. on account of general tools and plant. From 1883-84 to 1896-97, the debits indicate only the actual charges of special tools and plant.

Column 7, *Capitalized Abatement of Land Revenue.*—The charges in this column represent sums which at 4 per cent. will yield a revenue equal to the abatement of land revenue.

Column 8, *Leave and Pension Allowances.*—These charges were calculated up to 1881-82 at 25 per cent. on the amount of salaries taken at 85 per cent. of the establishment charges, and from 1882-83 at 14 per cent. on the gross establishment charges.

APPENDIX No. III.

Statement showing the area irrigated under the Kistna Delta system from 1855–56 *to* 1897–98.

Years.	Kistna delta system.			Remarks.
	Eastern section.	Western section	Total.	
	ACRES.	ACRES.	ACRES.	
1855–56 ...	...	...	18,967	Anicut finished in 1855.
1856–57 ...	...	...	75,758	
1857–58 ...	...	...	85,177	
1858–59 ...	...	...	107,099	
1859–60 ...	...	...	123,514	
1860–61 ...	...	...	117,344	
1861–62 ...	...	...	139,650	
1862–63 ...	...	...	154,377	
1863–64 ...	...	...	221,634	
1864–65 ...	...	...	211,964	Information by sections is not available.
1865–66 ...	...	...	214,638	
1866–67 ...	...	...	188,133	
1867–68 ...	...	...	200,874	
1868–69 ...	...	...	194,415	
1869–70 ...	...	...	199,775	
1870–71 ...	...	...	204,982	
1871–72 ...	...	...	211,102	
1872–73 ...	...	...	228,532	
1873–74 ...	...	...	233,842	
1874–75 ...	...	...	255,118	
1875–76 ...	...	...	264,256	
1876–77 ..	165,681	100,379	266,060	
1877–78 ...	169,662	110,666	280,328	
1878–79 ...	160,740	115,455	276,195	
1879–80 ...	194,048	109,315	303,363	
1880–81 ...	170,980	120,811	291,791	
1881–82 ...	169,923	117,151	287,074	
1882–83 ...	151,206	110,031	261,237	
1883–84 ...	172,435	125,791	298,226	
1884–85 ...	178,827	130,652	309,479	
1885–86 ...	192,282	137,931	330,213	
1886–87 ...	189,269	148,150	337,419	
1887–88 ...	219,482	168,023	387,505	
1888–89 ...	241,413	174,792	416,205	
1889–90 ...	247,141	186,834	433,975	
1890–91 ...	261,709	201,362	463,071	
1891–92 ...	274,424	206,304	480,728	
1892–93 ...	269,265	202,136	471,401	
1893–94 ...	293,384	219,194	512,578	
1894–95 ...	299,250	220,726	519,976	
1895–96 ...	271,311	210,064	481,375	
1896–97 ...	295,537	187,096	482,633	Include 'Second Crop.'
1897–98 ...	301,495	218,878	520,373	

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