M.R.O. 1—77,000—8-4-37.

(1) Number of pages 118

(2) Date of repair 23-5-62

(3) Initials of the Reference

MADRAS RECORD OFFICE.

Government of Madras.

Public Works DEPARTMENT.

G.O. No. 324 Press / Mis.

427-429

Dated 28-2- 1962

Not to be folded or roughly handled

Proceedings of the Madras Government, Public Works Department, 28th February 1862.

Read the following papers.

No. 437. From Lieutenant-Colonel J. OUCHTERLONY, Acting Deputy Chief Engineer, Northern Circle, to Lieutenant-Colonel W. H. HORSLEY, Chief Engineer and Secretary to Government, Public Works Department, dated Chepauk, 3rd February 1862, No. 8:—

SIR,

With reference to Order of Government, No. 83, under date 21st January 1862, I have the honor to submit for their consideration, the accompanying letter from Captain Haig, District Engineer of the Upper Godavery, of this day's date.

From Captain F. T. HAIG, District Engineer Upper Godavery, to Lieutenant-Colonel J. OUCHTERLONY, Acting Deputy Chief Engineer, Northern Circle, dated Madras, 3rd February 1862.

SIR,

1. With reference to O. G. No. 83, of 21st January, I have the honor to submit my views upon the several points laid down for my consideration in His Excellency the Governor's Minute of that date.

2. These points are—

First. The relative advantages and disadvantages, without reference to cost of execution, of the two following methods of rendering the Godavery navigable from the Coast upwards to Berar during those months of the year when the diminished volume of the stream affords a depth more or less insufficient for navigation:—

(1.) What may be called the Dam and Slack-water system, and

(2.) The Reservoir system.

The removal of all impediments in the shape of rocks and rapids in the river bed is assumed as necessary in either case, and the suitability of the works originally proposed and now under execution for this purpose is admitted. In fact the feasibility of the original scheme, estimated to cost 30 lacs, and which had reference chiefly to the monsoon navigation of the river being granted, the Government is desirous to know which of the above methods, between which alone our choice seems to lie, it will be best to adopt with a view to extend the period of navigation so as to embrace the whole year.

The second point is the probable cost of each of the two systems proposed.

Lastly, the question is raised whether it would not be advisable, in the first instance at least, to construct the Locks and Canals at the three Barriers of much smaller dimensions than was at first proposed, making them of a size sufficient for the passage of cargo boats only, the operations of steamers being confined to towing in the navigable reaches between the Barriers.

3. With regard to the first point. Apart from the question of expense, the consideration which must decide between the claims of the two proposed systems of improvement, is the comparative facilities which each will afford for cheap, regular, and uninterrupted communication.

I proceed therefore to an investigation of this point. The object in view is to secure a continuous navigable channel, with a fixed minimum depth of water, clear of all obstructions; and with such dimensions and slope as may afford the best possible navigation which the nature of the stream will admit of.

4. The two methods proposed for attaining this object, are—

(1.) To construct a series of Dams or Anicuts along the whole length of the river, so placed that the pool or slack-water formed by each shall extend to the one next above it. These Anicuts would be furnished with Locks for the passage of boats and steamers, the lower sills of which would in every case be laid at a certain fixed depth below the crown of the Anicut next below, that depth being the minimum which it is desired to maintain in the navigable channel.

(2.) To regulate the course of the stream, and confine it within certain limits at those points where it has a tendency to wander, by means of low wing dams and training walls, and to pour in from reservoirs constructed on the head waters of the river, a stream sufficient to afford the requisite depth for navigation.

5. It will be necessary, in the first place, to determine what this minimum depth is to be. I will take it at 5 feet, as I consider that will be quite sufficient for all purposes.

Dam and Slack-water system.

6. With regard to the first of the two proposed methods, the first point for consideration is the height to be given to the Anicuts.

This would probably vary from 15 to 20 feet above the general level of the bed, according to the height to which the floods rise in each particular part of the river. It is manifestly desirable to have as few Anicuts as possible, in order to diminish to the utmost the detention of boats in passing them. The greater the average height the less the number required.

The less the average height, the greater the number, the greater the difficulties of lockage (owing to the great rise of the floods) the more frequent the detentions, and the more numerous the points at which injuries to the works may take place, to the obstruction, if not actual interruption of the navigation.

7. The general velocity of the stream in full flood being 6 miles an hour, Anicuts obstructing about a third of the flood section, or 15 to 20 feet in height, would be about as high as a due regard to the cost and security of the structures would render it advisable to adopt. Great accuracy not being required, or in fact in the present state of our knowledge of the localities, attainable in the present paper, I shall assume the above as the average heights for the Anicuts in all the calculations which follow.

8. Between Púrshetaputnam at the entrance of the hills, and the Devanapilly the lower terminus of the Canal at the first Barrier, the fall to be overcome in the river bed is 48 feet. That between the first and second Barriers 69 feet. Between the 2nd and 3rd 82 feet. Between the 3rd and Hingen Ghát 105 feet. Total fall in open parts of the river between Púrshetaputnam and Hingen Ghát 304 feet.

9. The average height of the bed at each place is probably about 4 feet above the lowest summer level of the water. Allowing, then, that each Anicut shall raise the water to a height of 5 feet on the sill of the Lock in the Anicut next above, or in other words that its crown shall be 4 feet above the sill of Lock, leaving 1 foot for the slope in the surface of the water, we find that the number of Anicuts required would be—

In the 1st of the above-named reaches 3 of 20 feet high
2nd..... .... 7 of 15 feet
3rd..... .... 8 of 15 feet
4th..... .... 9 of 15 feet

10. In this calculation, I have made a deduction of about 35 feet from the total height to be overcome, being that portion of it which the Anicuts at the three Barriers will probably surmount. No doubt these heights would be varied more or less to suit the varying fall of the bed, and possibly in the 2nd and 3rd reaches it might be found that the number of Anicuts might be reduced by increasing the height of one or two of them. It would also be a question for consideration whether it would not be worth while to give an additional height of 3 feet to each by means of movable shutters, but I think it doubtful whether such would be the case. At any rate for our present purpose we may reckon that three Anicuts of 20 feet, and twenty-four of 15 feet in height in addition to the three at the Barriers would be required.

11. The next point to be considered is the arrangement of the Locks in the Anicuts. This is a very difficult part of the scheme. The great height to which the floods rise, from 40 to 80 feet, presents great difficulties and objections to Locks placed in the river bed. On the one hand if the floods are to be excluded from the Lock, the gates must be made of immense height, *viz.*, 32 to 66 feet, which is objectionable, and on the other if we make the Locks submersible, we are met by the more serious difficulty of the deposit of silt within and around them.

12. Without entering into any discussion of different modes of overcoming this difficulty, I may just state that I am sure it is by no means insurmountable, and that the plan I would propose (from such consideration of the question as I have been able to give to it) is to place two

or more Locks side by side in the Anicut, their sills being laid at different levels from that of the lowest Lock intended for the summer's navigation to about 25 feet below the highest flood level.

13. The arrangement is shown in outline in Fig.

The lower Lock would be the one in use for about nine months of the year, *viz.*, during the time when the river is not more than 10 feet deep on the Anicut. When the rise of the flood exceeds this level, the gates of this Lock would be fastened open by means of a pair of skeleton gates, with movable planking placed in front of the upper gate, and the flood allowed to sweep through it while the other two Locks are in use. One of the latter, the lowest of the two, would in its turn be submerged as the river rose, but as it would only be so for a few days, it might not be necessary to provide for fastening its gates open, as the quantity of silt deposited in that time in its chamber, raised as the latter would be so many feet above the bed would probably be trifling. When the flood had risen above the walls of this Lock, the third would come into use. It seems to me however very doubtful whether, for the few days that the river would overtop the second Lock, it would be worth while to provide for the ascending navigation. A detention of a few days to up-going steamers in that state of the river, when the current would render their progress so slow, would not be of much consequence. It is questionable therefore whether there would be any necessity for a third Lock.

14. In this way I should hope to keep the lowest Lock with the channel immediately above and below it free from silt. There would be a deposit in front and rear of the other two, but this would be of no consequence as it would not interfere with the navigation, and might be removed every year during the summer.

15. The outer Lock of the three would have a wall carried 200 or 300 yards up-stream from the extremity of its outer wall, and another down-stream for a shorter distance, to guide steamers in and out during the freshes. Similar guard walls of shorter length would probably also be required for the two inner Locks.

16. Under-sluices, or what might probably answer the purpose as well, a shoot of capacious dimensions made in the Anicut, with its top 6 feet below the crown of the latter, would be required to maintain a proper scour along the navigable channel to and from the Locks. The shoot would enable descending steamers to pass the Anicut without the Locks during a good part of the flood season, and would be closed by shutters, by some such arrangement as that of the French Barrage Mobile on the subsidence of the freshes.

17. I may here remark that the upward passage over the Anicut would never be practicable for any but fast passenger steamers and for them only at the top of the flood. Anicuts even 10 feet only in height would occasion an overfall of six inches at that time, and a current of nearly 7½ miles an hour. Hence Locks are indispensable for the upper navigation.

18. Having thus disposed of the Anicuts and their appurtenances, the next question is whether any and what kind of works would be required in the pools between for the maintenance of a navigable channel of the required depth. This is the most difficult question of the whole, and one on which a great amount of obscurity still rests. It is one on which the experience of other countries will not afford much light, for though it is certain that many rivers have been treated successfully in the manner now under consideration, it is at the same time true that their physical characteristics were very different from those of the Godavery, which from the velocity and enormous weight of the floods which it rolls to the sea, as well as from the immense masses of sand which are swept by its tributaries into its channel, acts upon its bed in a way which so far as I am aware no other river improved as now proposed affords an example of.

19. The question however I would repeat is not whether the Dam and Slack-water system could be worked out on the Godavery or not; I have no doubt it might be, were the requisite funds available. But the question is whether a considerable amount of stone-work might not be required in the pools between the Anicuts, for the regulation of the currents and fixation of the deep Channel. Ordinarily such work is unnecessary, but on the Godavery with its shifting bottom, I am convinced that it would be required.

20. We cannot proceed further in the consideration of this part of our subject without a distinct understanding of what the actual state of things in the Godavery is, what the nature of its banks, of its bed, and of its shoals.

21. In the first place, the Godavery differs from the Ganges in two very important particulars. Its banks are but little liable to erosion, and subject to little change. The changes which take place on the Ganges in the course of a few weeks or months would be on this river the work of a century, or rather it would be more correct to say that the country along its banks presents incontestable proof that no material alteration has taken place in the position of its Channel for ages. In the second place, the material of which its bed is composed, is a large coarse-grained sand totally unlike the fine powdery sand of the Ganges, and therefore requiring a very much more powerful current to displace it.

22. Two important consequences result from these conditions, the first is that the position of the shoals is for the most part fixed and invariable from year to year, the second that the length of each shoal undergoes but little extension during the months that intervene between the time of its deposition and the next flood season.

23. The exceptions to the first of these rules, and even they are but slight in degree, are met with in the part of the river between the Dowlaishwaram Anicut and the hills, and that between the 1st and 2nd Barriers. In these places the banks being either of a more yielding material or unprotected as in other parts of the river by protruding groins of rock, have in the course of years been cut away to such a degree that the river channel is widened to much beyond its natural dimensions. The consequence has been the raising of the bed, and the formation of high sand banks and of islands out of the loose silt deposited by the river. These banks and islands change their shape from year to year, and with them change the position and shape of the deep channel of the river. Here consequently the shoals shift their position also, though within narrow limits.

24. It is proper to remark that the aggregate length of these two parts of the river amounts to only 60 miles out of the 500, which it is proposed to render navigable.

25. It is most important to bear these two points distinctly in mind in consideration of the question before us, the fixed positions of the shoals, and the solid, permanent and unyielding character of the banks, from whence results permanence in the position and dimensions of the river channel itself.

26. The next point to be cleared up is what causes the shoals, and where are they generally met with. Shoals are formed wherever, whether from the peculiar shape of the river or from obstructions caused by rocks in the bed, the position of the deep channel during the flood season varies very much from that which it takes during the low water months. The river generally takes a gently winding course, so that the deep channel except when the river is very full, follows one bank or the other. All such parts of it are free from shoals, excepting where rocks occur to interrupt the uniform flow and scour of the stream and to obstruct its channel by the deposits which they encourage. But where the deep channel passes from one side of the river to the other, as it must do occasionally, there a shoal is sure to be met with, as the direction which the stream takes at these points during the floods differs very much from, and usually crosses at a considerable angle, that which it follows, on their subsidence. The few exceptions to this rule are where the turn in the river is very abrupt or its channel very confined.

27. The only other places where shoals are formed are in those parts of the river already mentioned, where the bed has been widened to very much beyond its usual dimensions, where the slackened current favors deposits, and the stream at low stages of water instead of being confined within a well-defined channel spreads irregularly over a wide and shallow bed.

28. We are thus thoroughly acquainted with the nature of the shoals and with the causes which lead to their formation. The present question is the effect which damming the river into a series of pools may be expected to produce in its bed at those points where these obstructions are now met with, whether they would entirely disappear, or whether further works in the shape of groins and training walls would be required to remove them. My own opinion is that these works *would* be required, and that without them no permanence either of the depth or of the

direction desired in the navigable channel could be relied on. The experience at the Dowlaishwaram Anicut shows that the deposits of sand in the pools above Anicuts in a river of this class are very irregular, and that while an under-sluice may secure the existence of a deep channel immediately above it, yet that this effect is but local, and is not to be always depended upon to a much greater distance above than that to which the groins or training walls extend which confine the stream flowing to it.

29. I should further expect to find the effect of such walls for confining or directing the stream much less when placed in the pool above an Anicut than when in an open river, inasmuch as the time during which the stream would have sufficient velocity to scour its channel effectually would be so much less in the one case than in the other. For it must be remembered that the use of the under-sluices would be very much more limited than in the case of Anicuts erected only for irrigation purposes or to feed a canal or canals led off from them. In such cases it matters not what amount of silt may be swept into the river channel *below* the sluice, provided that above it is kept clear, and the sluice may be set in operation at any time of the year without objection. But in the case proposed its use would be confined to only certain times during five months of the year; at all other times its peculiar effect could only be produced at the risk of obstructing the channel below it by the deposits swept down from that above. It follows that the deep channel in the pools must be formed almost entirely by the scour due only to the surface slope of the stream, which being much less than that of the river in its natural state, the scour will be proportionably less effective, and will require a correspondingly increased amount of assistance. Without therefore attempting to estimate to what extent such assistance in the shape of groynes and walls would be necessary, I think there can be little doubt that a considerable outlay would have to be incurred on its account.

Reservoir System.

30. I proceed to consider the second method of improvement proposed, *viz.*, that by means of reservoirs and regulating walls in the river bed.

The works that would be required in this case would be—

(1.) Reservoirs constructed about the heads of the valleys of the principle affluents, sufficient to store the quantity of water required to produce a stream of the volume and depth desired, and

(2.) Regulating walls in the river bed, formed either of stone or brushwood and piles, or a combination of both, for restraining and directing the flow of the stream.

The removal of isolated rocks in different parts of the bed and groynes here and there for securing the river banks against the attacks of the stream, might be added, but do not call for particular notice here, being works of no difficulty and which would be required under either system of improvement.

31. As we are now dealing with this question without reference to *expense*, I need only remark that there could be no difficulty in finding suitable sites for reservoirs capable of holding all the water that might be required about the heads of the valleys of the Wurdah and Wyne Gunga, which alone drain an area of 50,000 square miles. Within an area of only about 1,500 square miles in the Western Ghâts, Mr. Frazer, Civil Engineer, some years ago surveyed and examined the sites for thirty-three reservoirs, ten of which were capable of holding together 12,60,000,000 cubic yards of water. There can therefore be no question that with the immense area we have in which to select sites in the two rivers mentioned, to say nothing of the valley of the Godavery proper, which is of equal extent, we should find no difficulty in storing any *quantity* of water. The *cost* of doing so is a separate question. And as all will admit that the river is now navigable when there is a certain body of water in it, no one will be disposed to deny that it will be so at all times if we keep up the discharge to that amount by artificial means. We need therefore enter no further at present into this part of the subject for the purpose of comparing this mode of improvement with the former.

32. The work to be done in the river bed, after it had been thoroughly cleared of all rocks in the line of the deep channel, would consist of a number of detached walls of stone, by means of which a permanent and fixed position would be given to the channel at those points where by nature it is shifting, and by which also the stream would be confined within narrower limits at the few places where it now spreads over too wide a surface.

33. The success which has attended this method of regulating the deep channel if a river has varied with the character of the rivers on which it has been tried, the degree of skill with which it has been applied, and the amount of improvement sought to be obtained by its means, as compared with what it is really capable of affording unsupplemented by an increased supply of water artificially provided.

In America, the only large river on which it has been tried is the Ohio, but the attempts made there have been so few, so desultory, and so ill-sustained, that it is not surprising that they have had little success.

In France it has produced excellent effect on the Saone, where the river is now navigable for steamers drawing three feet water with a discharge under 300,000 cubic yards per hour. It is now being applied to the Rhone also. On the Loire it has only been tried fairly at two places, at one of which it has succeeded well, and at the other has greatly benefited the navigation, though the attempt in this case has been made to compel the channel contrary to nature to follow the *convex* bank in a bend of the river, *viz.*, at Orleans, where the town lies on that side. On the Danube, as far as it has been carried out, the system has answered well, though the stream has a much greater velocity than the Godavery.

34. On the other hand it is certain that the system has yielded but poor results in some cases, but this has, I believe, always been either where such utter violence was done to nature in the planning of the works that certain failure might have been anticipated, or where too much was attempted by their means. It is evident that to attempt to confine the low water stream of a river within two continuous walls in a channel much smaller than its natural one, and merely to direct and regulate its course here and there as proposed for the Godavery, are two very different things, and that the difficulty of the undertaking in the one case is but a fraction of what it is in the other. It is the latter mode which I propose to use in the Godavery, confining the stream only at those places where it is apt to spread over too wide a surface, and increasing its flow from artificial lakes to the extent required to give the desired depth for navigation.

35. The general fall in the open parts of the river being less that 1¼ foot per mile the average current, with the depth which it is proposed to maintain,* would be 1¾ miles per hour.

* 5 feet.

36. We may now compare the two methods of improvement. In the one case we have a series of pools, with little or no current in them during more than half the year, connected by Locks; in the other a continuous navigable channel with an average current of 1¾ miles per hour in the summer months, and considerably more in the freshes.

37. The first plan has the advantage of affording greater facilities to the up-traffic by reducing the current in the pools, and this is I believe its sole claim to superiority, while it has the disadvantage of immensely increasing the risks of delay and interruption of the navigation by interposing at every few miles an Anicut and Locks which must always be more or less liable to injury or accident. The diminished current would of course facilitate the progress of up-going Steamers, but would proportionably retard that of those going down, and as the up-traffic may be expected to be both smaller in amount and of higher value than that down, and consequently better able to bear a higher charge for carriage, the natural arrangement by which the force of gravity acts in the direction of the heaviest tonnage is decidedly the best so long as that force does not oppose any very serious obstacle to the ascent of the stream. This certainly would not be the case on the Godavery, as an adverse current of 1¾ miles per hour is perfectly compatible with very cheap navigation. Moreover, the advantage gained by the diminution of the current would be to a certain extent counter-balanced by the loss of time in passing the Locks, as well as

by the liability to occasional detention either from accidents deranging the working of the Locks, or from the accumulation of silt in their neighbourhood, a source of delay which it would be impossible wholly to obviate.

It should be remembered too that the passage of the Locks would be an obstruction to the down trade also during the greater part of the year.

With every possible precaution, Locks in a line of great traffic must always be more or less liable to accidents. Even in Canals where boats can be led in and out of the Locks with so much more precision than in an open river, accidents occasionally happen. A better arrangement of the Locks than I have proposed may very possibly be devised, but if not, it should be borne in mind that the lowest Lock in each Anicut which would be the one in use during three-fourths of the year, would have an extra liability to injury, during the time of its submersion in the freshes.

38. I am of opinion therefore that these defects, which are inseparable from the Dam and slackwater system of improvement, more than counter-balance any advantages it may afford, and that the preference should be given to the reservoir system, which, while it would afford an open and unobstructed channel at all times of the year, would afford a steady current in the direction of the heaviest traffic, and that not too great for the ascending navigation. I forbear here to notice the incidental advantages of the use of the water for irrigation after its work in the river bed is done, and the possibility of restraining the floods by means of the reservoirs, as well as the advantage in point of expense which this system would afford, as I think the reasons above adduced are sufficient to decide the question in its favor.

Comparative expense of the two systems.

39. We have next to compare the two systems in point of expense. The materials are wanting for anything beyond a rough approximation to the cost of the works required in either case. On the one hand the price of labor is rising so rapidly all over the country that it is difficult to foresee what increase on present rates should be allowed in estimating for works which will take many years to complete, and on the other we are uncertain even as to the sufficiency of our present rates on the Godavery, as the whole of the labor has to be imported from considerable distances, and the wages offered during the year that has elapsed since the works were commenced, have attracted much fewer numbers than we require. The cost of storing water on a large scale is also variable, and much more careful and detailed measurements and observation of the discharges of the river will be necessary before we can be in a position to form reliable estimates of the quantity of water required to maintain given depths in the navigable channel.

40. With regard then, first, to the probable cost of a series of Anicuts with Locks and other subsidiary works, in estimating the probable number of Anicuts that would be required, I have (paragraph 7) assumed average heights of 15 and 20 feet. As the number of those of 20 feet is only three I propose to substitute for them four of 15 feet to simplify the calculation of the total cost. I find from the Map of the river,* that the aggregate length of the Anicuts required will be close on 20 miles. This gives an average length for each of 1,260 yards.

* Herewith forwarded.

The question then is the cost of an Anicut of this length and 15 feet in height, obstructing nearly one-third of the flood section in a river with a flood velocity of 6 miles per hour, and furnished with locks of the kind already proposed. I am inclined to think that the under-sluice might be dispensed with, and that an opening in the Anicut next the Locks, with its crest depressed 6 feet below that of the Anicut, would answer the same purpose, while it would cost less money, and would serve as a shoot to pass downward bound Steamers in the freshes.

41. With regard to the cost of the Anicut we have two very reliable guides in the Dowlaishwaram and Bezwadah works. The first of these has cost, as nearly as I can ascertain, about 200 Rupees per running yard in length of Anicut without under-sluices or locks. It is 14½ feet in height, obstructing three-sevenths of the flood waterway in a stream with a velocity of 3½ miles an hour.

The second or Kistna Anicut has cost about 350 Rupees per yard run of Anicut without sluices or locks.

It is 14 feet in height, obstructing one half the waterway of a river with a flood velocity (where the Anicut is built) of about 7 miles per hour. The Anicut now under consideration for the upper river is to block up one-third of the flood waterway of a stream running 6 miles per hour, and its height to be 15 feet.

42. If we take the trial to which the Godavery Anicut is exposed as 1, that of the Kistna would be $5\frac{1}{2}$, and that of the proposed Anicut $2\frac{1}{4}$, the extreme flood velocities over each being respectively 6 miles, 14 miles, and 9 miles per hour. Supposing the rates for work to be the same in all three cases, the probable cost of the proposed Anicut would be about the mean between the other two, but taking into consideration the fact that the prices paid at the Kistna were about 30 per cent. higher than those paid at the Godavery, the cost *at the Kistna rates* would be about 310 Rupees per yard run. We are however, now giving 50 per cent. higher wages than were given at the Kistna, and by the time the series of Anicuts on the Godavery (20 miles in length) had been completed, it is hard to say to what extent wages would have risen. It is also to be considered that there were remarkable facilities at Bezwadah for constructing the work there, such as we shall scarcely meet with at more than one or two out of the twenty-eight points on the Godavery. Taking these things into consideration, I do not think we can reckon on the Anicuts on this river costing less than 500 Rupees per running yard, and accordingly I have taken this rate in the Estimate which follows. This covers all expenses, superintendence, plant, and contingencies included.

43. In the next place I allow for a rise of flood of 50 feet above the lowest summer level, and for only two Locks, placed one beside the other in the manner already described, the gates of the first to be raised to a height of 14 feet above the Anicut, those of the second to a little above the flood line.

Skeleton gates are also provided for.

I allow 200 feet by 30 feet for the dimensions of the lock-chamber, for reasons to be stated hereafter.

Under these conditions, the quantity of rubble masonry in the Locks would not be less than 23,000 cubic yards. Their cost I estimate as follows :—

	RS.
23,000 cubic yards masonry @ 6 Rupees.....	1,38,000
Guard Walls 12,500 cubic yards @ 6 Rupees.....	75,000
Well Foundations.....	10,000
Cut stone 2,000 cubic yards @ 10 Rupees.....	20,000
Gates.....	16,000
Total of Locks.....	2,59,000
Add for 1,260 yards in length of Anicut at 500 Rupees per yard.....	6,30,000
Wing walls, 5,000 cubic yards at 6 Rupees.....	30,000
Total for one Anicut.....	9,19,000

This amount includes every charge.

44. The next item to be estimated for is the stone-work in the bed for regulating the stream.

The extent that might be required of this is very doubtful, but we may perhaps take it at one-third of what would be necessary under the reservoir system, which, as will hereafter be seen, amounts to $31\frac{1}{3}$ lacs, a third of which is 10 lacs.

45. Water would have to be stored to provide for the lockage, evaporation and absorption. That required on the first account would be insignificant in quantity, but that for evaporation and absorption would be considerable. I allow for an annual consumption on this account equal to a depth of 4 feet on a width of 500 yards and a length of [illegible] miles equal to 300 million cubic yards, which at 500 cubic yards per Rupee would cost 6 lacs.

46. The expense of removing all detached rocks from the navigable channel and of groyne for the protection of the river banks I estimate roughly at 3 lacs.

47. To sum up then the total probable cost of the dam and slack-water system, we have—

28 Annicuts with Locks at 9 lacs each.....	252 lacs.
Stone-work for regulating stream.....	10
Clearing channel and groynes for protecting banks.....	3
Storing water.....	6
Total...	271 lacs.

Cost of Reservoir System.

48. The cost of the reservoir system would be as follows :—

First. Training walls in the river-bed.

The total length of the open parts of the river between and above the three Barriers is 330 miles. Of this 100 miles above the 3rd Barrier is of such width that the stream which I would propose to throw in would fill the river channel from bank to bank, so that scarcely any stone-work in the bed would be required.

Of the remaining 230 miles, 60 are deep pools where there is at all times a sufficient depth.

The other 170 miles would require, as well as I can judge from observation of the part of the river below Badrachellum, 100 miles at most of training wall.

49. I would propose to make these walls 2 yards in height with a width of $1\frac{1}{2}$ yards at top and slopes of $1\frac{1}{2}$ to 1. Their contents would be 15,840 cubic yards per mile. The cost I think may be safely taken at Rupees 2 per cubic yard inclusive of all charges, or 31,680 Rupees per mile, or for 100 miles, $31\frac{1}{2}$ lacs.

50. With regard to the quantity of water which it would be necessary to store, I would remark that the calculations made in my Report of May 1856, of the discharge required to maintain given depth in the shoals give results wholly inapplicable to the problem under the conditions in which we are now considering it. In that Report I assumed—

First. That the channel was to be unconfined and the water allowed to spread over the natural surface of the bed, and

Second. That the profile of the river bed at the shoals continued the same whether the stream passing over it were 300,000 cubic yards per hour or 1,500,000, which is manifestly an error. The average fall of the bed at these shoals when the river is at its lowest, is about 3 feet per mile, but this only happens because the stream has either not been sufficiently concentrated to plane down the bed to slopes approximating to the average declivity of the whole river, or because its volume diminishes too rapidly for it to produce this effect.

The shoals are all humps in the bed which, if the stream is suffered to spread over at will, it has not the power to remove, but which, if it be concentrated and sustained in volume, it cuts down soon after the subsidence of the freshes. This might have been supposed beforehand, but it has been fully confirmed by the effect of a groin constructed last year at Rudramcota, by which a shoal which was then the worst on the whole river has in great part disappeared.

In my present estimate therefore I assume a width of channel of 300 yards, and a fall not exceeding $1\frac{1}{2}$ feet per mile, such a channel would require a stream of about $1\frac{1}{2}$ million cubic yards per hour to afford a depth of 5 feet for navigation.

51. The following Table shows the quantity of water which it would be necessary to throw into the river to keep up the discharge to this amount.

Months.	Average hourly discharge of river in cubic yards in the driest years, below the last affluent.	Difference between amounts in preceding column and a discharge of 1,500,000 cubic yards per hour.	Daily.	Monthly.
			Deficit which would have to be supplied from reservoirs to keep up a constant discharge of 1,500,000 cubic yards per hour.	
			Cubic yards.	Cubic yards.
December...	2,250,000			
January...	1,075,000	425,000	10,200,000	316,200,000
February.....	550,000	950,000	22,800,000	638,400,000
March..... ...	375,000	1,125,000	27,000,000	837,000,000
April.....	275,000	1,225,000	29,400,000	882,000,000
May.....	225,000	1,275,000	30,600,000	948,600,000
First half of June.	200,000	1,300,000	31,200,000	468,000,000
Total quantity to be provided in Reservoirs...				4,089,200,000

Between the 1st Barrier and the mouth of the Pranbeeta it might be necessary to contract the navigable channel to rather smaller dimensions than those allowed for it below the Sebbery, to compensate for the diminished flow of the stream in that part of the river, the discharges here given in column one being those below the confluence of the Sebbery.

52. The question now is the cost of storing such a quantity of water. The only thing that seems tolerably certain upon this point is that the cost would not *exceed* 1 Rupee per 500 cubic yards, and that it might be very far below that amount, as much as one-half or one-fourth, as sites have been found where 1,000 to 3,000 cubic yards might be obtained per Rupee. The presumption is that the cost of storing water on the principal affluents of the Godavery would be small, both because of the gentle declivity of their valleys, and the immense area in which to select sites. Any estimate now formed before the examination of a single site or even the search for one, must be mere guess work, but we may confidently reckon on 1 Rupee per 500 cubic yards as the very extreme cost, with full expectation of accomplishing our object for one-half that amount. At this rate the above quantity would cost 80 lacs. If however we wish to compare the cost of this mode of improvement with that of Dams and slackwater, this extreme figure should not be taken, but rather one more within the limits of probability. Perhaps 60 lacs might be assumed for this purpose.

53. It is important however to point out here, how erroneously the cost of the improvement is increased by making the river navigable for twelve instead of ten months. The above Table shows that the quantity of water to be artificially provided for the last two months of the hot season would be 1,916 millions cubic yards, or almost one-half that required for the whole year. In other words the extension of the time of navigation for this short period doubles the expense of the most costly part of the works.

It is quite probable that it will eventually be worth while to pay 20 or 30 lacs more to make the communication perennial, but nothing seems to me more certain than that this is a consideration which may be wholly set aside at present as of no importance whatever, and that a ten months navigation for boats drawing four feet of water will meet all the wants of that part of India for at least a generation to come.

54. The value of the water for irrigation has also to be taken in account. Probably three-fourths, if not the whole of the quantity which it is proposed, as above, to throw into the river, would be required for the Delta lands alone, especially if the Anicut proposed by Sir A. Cotton, be constructed at the outlet of the hills, by which probably another 200,000 acres would be irrigated. Already, though only a part of the land under the Dowlaishwaram Anicut has been brought under irrigation, the deficiency of the summer supply of water is beginning to be seriously felt, and has been in one year at least a cause of actual loss of revenue. Without therefore taking into consideration the requirements of the upper country, portions of which at the three Barriers will no doubt be eventually watered by extensions of the navigation Canals at those points, it appears that the greater part, if not the whole cost of the scheme now under consideration for the improvement of the river, might be charged to the irrigation, as it is certain that the water so applied would be abundantly remunerative.

55. I can only briefly glance at the incidental but most important benefit which attaches to this system of affording a means of restraining the violence of the floods. We are not yet in a position to discuss this part of the subject, but the materials are gradually accumulating for an accurate investigation of it. In France the problem of checking the devastations caused by the floods of the Loire by this method was in 1859 being carefully worked out by one of the most eminent of the Corps des ponts et Chaussées, and will no doubt furnish valuable results. A similar investigation was, I believe, being conducted in the valley of the Rhone. In this country it would be interesting to know the actual amount of damage done by a single flood. I suppose that of the Godavery in the present year has cost the Government 50,000 Rupees in the Delta alone, while no estimate can be formed of the value of the property destroyed along the whole length of the river.

However, half a lac is the interest on 10 lacs, and as there was a more destructive flood only eleven years ago when the remissions of revenue in consequence in Rajahmundry were heavy, probably 30 lacs would be the principal represented by the loss to Government from this cause during the brief period of ten or twelve years.

56. I will offer but one consideration on this part of the subject. The Godavery in the Delta when in full flood has a width of about 2½ miles, and a surface velocity of 4½ miles per hour. The last two feet if its rise is not maintained for more than forty-eight hours, and it is during this time that all the damage is done. To prevent the river rising, this last two feet we should have to draw off from it for forty-eight hours at the rate of 11,616,000 cubic yards per hour, or 557½ millions of cubic yards altogether. To what extent may the retention of 4,000 millions cubic yards in reservoirs be expected to contribute towards such a result?

57. There is one more consideration worthy the attention of those who may still doubt the possibility of making an Indian river navigable during the low water months by any method or at any expense, and that is the safe because progressive character of the method we have been investigating.

It is easy to ascertain what quantity of water over and above that which the river supplies in the hot months we require for irrigation, and having done so and constructed the necessary reservoirs, we can then pour this quantity into the river, and ascertain by actual observation the effect it produces on the navigation as it passes on its way to the land it is intended to fertilize or reclaim. If the result is unsatisfactory we shall have lost nothing. If, on the contrary, our expectations have been realized, we shall have our improved navigation for nothing and may proceed with confidence in the same course to whatever extent the exigencies of the trade and the requirements of the country may demand. There need be no fear of our embarking in an unlimited expenditure upon works of doubtful utility. Our work will pay as it proceeds, and its efficiency be practically tested at every step.

58. We may now compare the cost of the two systems, which is as follows: —

Dam and Slackwater.		Reservoirs.
Anicuts.....	252 lacs.	
Training Wall...	10 „	31½
Clearing Channel and protecting banks...	3 „	3
Storing water...	6	60
Total.....	271 lacs.	94½

But if, as we may fairly do, we charge the whole cost of the water in one case, and half of it in the other, to irrigation, the respective costs would be 265 and 64½ lacs.

If to these amounts we add 40 lacs for the works at the Barriers, allowing for a probable increase of one-third above the rates in the original estimate, we find the whole cost of rendering the river navigable to be

		Lacs.
1.	By Dam and Slackwater for 12 months.....	305.
2.	By Reservoirs for do.	104.
3.	By do. for 10 months.	89.

Of course this is merely an approximation, but it should be borne in mind that while the cost in the first case would not be less than that stated, there is a fair probability of its being considerably so in the other two.

59. On a review of all that has been said for and against the two systems proposed, I think there can be no question of the superiority of that of reservoirs, and I would accordingly recommend it for adoption. It is very possible that it might be modified in some of its details as applied to the Godavery. The Anicut at the entrance of the Rajahmundry hills has some strong recommendations, and on examination of that project by means of levels and surveys might be undertaken whenever there are men available for the purpose. On the Wurdah also it might be found that Anicuts might be constructed with advantage as the fall of that river is slight, and its width narrow. All these are details which a careful instrumental examination of the localities will alone decide, and they need not occupy our attention at present. The first thing to be done is to open the monsoon navigation by means of the works at the three Barriers, the next to clear and regulate the Channel in the open parts of the river, and the next to increase the flow of the stream to the extent required in the first instance for irrigation in the Delta and afterwards for the navigation in whatever degree the latter may be found to require.

These improvements may be carried out successively or simultaneously according to the amount which the Government may see fit to allot annually to the purpose.

60. Any discussion of the value of the communication so improved would be foreign to the object of the present paper, and indeed unnecessary, as the Government is, I believe, fully satisfied on this head.

61. It only remains to consider the question of the size that should be given to the Locks at the Barriers and that of making the Canals at these points practicable for cargo boats only.

With regard to the former, I think that the width of opening between the gates which I originally recommended, 45 feet, might very well be reduced to 30 feet, and that Steamers of equal power might still be used by employing stern instead of side-wheelers. There are some important advantages belonging to the former class of vessels, which the experience of the North American rivers, where they have been many years in use, and are to be found literally by hundreds of all sizes up to 600 and 800 tons, fully establishes. Owing to the full lines with which they are built at the stern, where the width is but little less than amidships, they carry an equal load on a less draught of water with the side wheelers, an important consideration in a navigation of limitted depth. They have also another peculiarity which has been fully proved, that in the ascent of a rapid current they make better way than side wheelers of equal power.

In the case of the Godavery their adaption to Canal navigation would be an especial recommendation, for at the three Barriers there will not be less than 55 miles of Canal, and in the event of the construction of an additional Anicut in Rajahmundry, another 60 miles from thence to the Port.

The latter however would be only a boat Canal in the first instance, but might eventually be adapted to the use of Steamers.

62. A Steamer with side wheels requires a broad Channel to work in safely, and is at all times liable to injury wherever it is compelled to pass through narrow passages—such as Locks and Canals of limited width—a liability which of course increases with the increase of traffic.

A stern wheeler on the contrary may pass with safety through any passage a few inches wider than her own clear width amidships. The wheel is removed from all chance of damage from collision with another Steamer in a Canal, or with the wall of a Lock, or with the bank of a river in rounding to in a current at a landing place. The action of the wave produced by the passage of a Steamer on the Canal banks would also be less in the case of a stern than of a side-wheeler.

63. There are no practical objections to such Steamers. They have long been used, as I had said on the American rivers. And on the upper Ohio and smaller tributaries of the Mississippi are more in vogue than any other class of boats. They are not generally built for speed, being used chiefly as cargo boats, but have mostly a speed of 9 to 11 miles an hour. There is no reason however why they should not be built for a much higher speed than this.

64. I am the more inclined to accede to the reduction in the size of the locks proposed by the Chief Engineer, from the fact that with such diminished widths greater lifts would be practicable than those* originally proposed—a consideration which the importance of excluding the flood water as much as possible from the locks, to prevent silting, strongly recommends.

* *Ten feet.*

65. I would propose therefore 30 feet by 200 feet in the clear for the dimensions of the lock chambers.

66. The Government wish me to revise my estimates for the works at the 1st Barrier, by diminishing the Section of the canal and the size of the locks to that which would be sufficient to pass the largest cargo boats which are likely to be employed on the river. I am of course prepared to do this if the Government should still think such an alteration of the original design desirable; but I am myself opposed to it for the following reasons.

67. The only thing that would be gained by such a course would be the saving it would effect in the time and first cost of construction; but I am disposed to think that such saving would be comparatively trifling, while it would involve an ultimate increase of expense in the cost of the works, and for a time, in the cost of transport by the river.

68. The canal runs parallel to the river and within 200 to 300 yards of the bank, which is intersected at short intervals by deep gullies formed by the drainages which empty themselves into the river at these points. My intention has been to make use of these openings for the purpose of removing the earth excavated from the canal out into the river on trucks, instead of raising it by hand in the usual manner—heights of 18 to 24 feet. I calculate on a considerable saving of expense by this method, which would be applicable to about half the total excavation of the canal, and my estimates were made accordingly. If however, we cut the canal in the first instance to only half (8 yards at bottom instead of 15) its full width, we must eventually complete it at a greater expense than would be necessary if the whole were done at once. This is not perhaps a very important consideration if the gain in the time of opening the communication were considerable; but the probability is that the saving would not amount to more than 2 or 3 years for the whole line, during which time we should have the tramroads now under construction as substitutes for the canals.

It is true that the cost of carriage by the former would be greater than by the latter; but on the other hand by making the canals and locks of their full size at once we shall be hastening the time when continuous navigation by Steamers will be practicable—when it will no longer be necessary to have them stationed in the reaches between the barriers, and when the additional expense which this arrangement involves will be done away with. I look upon this as a most important consideration—one with which the saving in expense in carriage by canal instead of tramway is of little consequence.

69. I think that if it were known that for many years to come Steamers could only ply in the navigable reaches between the barriers it would act as a great discouragement to private enterprize; for in order to do the same amount of work it would be necessary to have nearly double the number of Steamers in the one case as in the other. A disabled Steamer in one reach could not be re-placed by one from another under a year in most cases, so that there would either be the constant risk of complete interruption of the communication for that time, or additional Steamers must be stationed in each reach to provide against such a contingency. Were the trade on the river considerably developed, the extra expense which this would involve would not be so great; but a Company starting with four or five Steamers would, if continuous navigation were impracticable, have to provide eight to do the same business.

Extra Establishments would also be required at the three Barriers, and probably workshops for repairs; while there would be a frequent loss from detention of the Steamers in consequence of the inevitable unpunctuality in the times of arrival and departure at eight instead of only two termini.

All these inconveniences and sources of extra expense would of course attach to the working of the river with the tramways; but the sooner we can dispense with them the better; and the saving which would be effected for two or three years by Canal instead of tramway carriage, would not, in my opinion, by any means justify the postponement of the works required for the completion of the project according to the original design.

70. It is certainly the case that there has hitherto been the greatest difficulty in procuring labor for the works at the first Barrier, and that the supply during the past year has been lamentably inadequate to our wants and expectation; but on the other hand, we can scarcely judge from the result of the first year's operations only, in a country so inaccessible and so new to the inhabitants of the more populous districts surrounding it, what our future prospects in regard to the supply of labor are likely to be. Moreover, if the Government carry out their present intention of prosecuting the works at all the three Barriers simultaneously, a largely increased amount of labor would certainly be available.

The construction of the tramways at the two upper Barriers has already attracted from 1,500 to 2,000 people from the neighbouring districts, who would most probably not have come 100 or 150 miles further down river to the work at the 1st Barrier.

I know in fact that large numbers of those employed at the 2nd Barrier refused to come down to Dumagudiem, even when tempted with the offer of an additional Rupee per month. I believe therefore that were the permanent works commenced at these three points at once, very much larger numbers would be attracted than would be the case if the field of operations were limited to its present extent.

I would therefore respectfully suggest that the Government should reconsider this part of the proposed arrangements, and that the Canals and Locks should be at once constructed of the full size which it is intended to give them.

No. 438. MINUTE BY THE HONORABLE THE PRESIDENT.

1. I have read attentively the accompanying Report from Captain Haig, and I have since talked over with that Officer several points connected with the prosecution of the works on the Upper Godavery, and am now prepared to submit certain recommendations with regard to these for the consideration of the Government of India, and of the Secretary of State.

2. My first impression on reading these papers was that the Government was not in possession of information sufficient to justify the adoption of any of the plans proposed, and I was rather inclined to blame Captain Haig; but it appears that in 1856 the Government in adopting a portion of his scheme limited him strictly to the improvement of the monsoon navigation of the river, and postponed the consideration of the other portions of his scheme *sine die*.

3. The actual amount of information of which the Government is in possession appears to be—

(1.) An accurate survey of the river from Dowlaishwaram to Chandah.

(2.) A series of levels which have been verified and can be depended on from the same place to the third Barrier.

(3.) Plans in detail with accurate sections of the ground at the first and second Barriers.

(4.) Plans and estimates of the works to be executed at the first or Sinterala Barrier upon the supposition that the locks were to be 200 feet long by 45 feet wide.

(5.) Information sufficient for the construction of the Tram roads round the three Barriers, of which those round the first and second Barriers are rapidly progressing, and a good bandy track will be made round the third, though it is possible that the Tram road will not be completed this year.

4. With reference to any additional works, such as those required for the storage of water to complete the summer navigation and to give additional supplies for irrigation, the Dam or Anicut at the exit from the mountains, as alluded to by Colonel Sir A. Cotton, or any works required to complete the navigation from the head of the third Barrier to the point to which it may be considered advisable to carry the improvement of the river, say to Hingen Ghât, the information is of the most general description. Looking then to the work as one calculated to open up a large tract of country in the interior of India, and which, if properly carried out, might, in addition to the benefits conferred by the improvement of the navigation, afford an opportunity of irrigating a large extent of country, and of securing thereby a certain return for the capital expended, I should say that the Government in 1856 imposed too narrow a limit upon the work to be performed, and I now therefore propose to bring the whole question again under consideration. Before, however, I do this, I must allude briefly to some of the statements made by Captain Haig with reference to the comparative advantages of the two modes of rendering a river navigable, and specially to the estimate of the actual amount of Anicut work to be executed. In paragraph 9 he states that the average height of the bed of the river at each place, where it was intended to place an Anicut, is probably 4 feet *above* the lowest summer level of the water, that is, the average foundation or point from which the height of the Dam is to be calculated is 4 feet *above* the existing surface water, not 4 feet below it. The actual amount of lift is said to be 304 feet, and Captain Haig has provided for 420 feet height of Anicut to overcome this divided among 27 Anicuts, whereas he would only require 21 Anicuts with an average height of 10 feet; this would at once make a reduction of £600,000 on the monetary estimate. I merely however allude to this for the purpose of showing that no dependence can be placed on a rough comparison of the kind given by Captain Haig, and of affirming my conviction that the whole question requires the most careful examination.

5. The Godavery is a river draining a very large tract of country, it has its origin in the hills bordering the West Coast of the Peninsula, and is subject therefore to the action of the south-west monsoon. During the three months of half June, July, August and half September, it pours down a vast volume of water, the rise of the surface varying from 20 to 50 feet and upwards. During the dry season the discharge diminishes rapidly, till for a few weeks previous to the setting in of the south-west monsoon the quantity discharged does not exceed 200,000 cubic yards per hour. During the monsoon an enormous amount of silt is brought down, the coarser and heavier portions of which form sand banks and shoals in the bed of the river wherever an eddy is created by any interruption to the stream; the finer portions are carried down the river and are discharged into the sea, forming the projecting spit of land to the south of Coringa and blocking up the harbour, or rather anchorage, of Cocanada, which is gradually shoaling, the deep water being pushed to the northward by the continuous addition of silt to the land which has been formed to the south. This silt, however, passes into the irrigation channels, and is distributed over the Delta, acting thereby as a manure to the irrigated land.

6. Several years ago the Government, acting under the advice of Sir A. Cotton, decided to avail itself of the means afforded by the river of irrigating the Delta formed by the diverging branch of the river, and such of the land to the right and left of these branches as could be brought within the reach of the water raised by an Anicut at Dowlaishwaram. This work was accordingly commenced. The Anicut, a large portion of the distributing channels, the Locks for navigation, &c., have been completed, and the returns have yielded a very large interest upon the outlay.

7. That the application of water to the land yields an ample return for the money invested we *know*; that there will be traffic sufficient up and down the river to pay not only the cost of transport, but also the interest upon the capital expended in improving the navigation, we only *infer*; in fact we have no data upon which to form an estimate. It appears to me therefore that in carrying out the works for the improvement of the navigation we should have an eye to the various profitable uses to which the water may be turned, and should frame the scheme upon such a comprehensive plan as would enable the Government to form an idea of the benefits which the country is likely to derive from it; of the cost which such a scheme would entail, of the time it would require for its completion. When the whole is thus clearly placed before the Government it will be in a position to decide whether the advantages held out are such as would justify the outlay of any given sum of money and whether such money should not be borrowed upon the security of the Government, in order that the work should be prosecuted with the utmost activity, and not be left dependent upon the amount which might be spared from the annual revenue. Various other questions connected with the principle and details of the work would also have to be considered.

8. In order to this however the first thing to be done is to employ several parties to complete the survey of the river from the head of the third Barrier to Hingen Ghât.

Second—To survey and level the land to the right and left of the river below its debouche from the mountains, in order to ascertain the character of the land which will be brought under the action of the water; supposing the latter to be raised, say, 25 feet.

Third—To inspect the country to the northward and westward about the heads of the affluents of the Godavery, for the purpose of ascertaining the most favorable positions for storing up water to be passed down the stream in the dry season for irrigation purposes, and for that of maintaining a sufficient depth of water for navigation.

Fourth—To inspect the course of the river between its exit from the mountains and Hingen Ghât, for the purpose of determining the sites at which it would be desirable to construct Anicuts and Locks, should this mode of rendering the river navigable be considered preferable to that proposed by Captain Haig.

9. I may say here that I am by no means convinced by the reasoning of Captain Haig, that his plan is the most advantageous; by keeping up an average current of 1¾ miles an hour for the whole distance, a great obstacle to the up-traffic is created; should the average speed of a steamer be eight miles per hour, it would be reduced to six by the current in

going up the stream ; and such a current as this would require steamers of greater power, these would require larger Locks, &c. ; so that although I quite admit that the system of slack water navigation by means of Anicuts and Locks would be the most expensive of the two, yet I am certain that the ratio between the cost of the two systems will be much nearer equality than that given by Captain Haig.

When thus the Government has all the data before it, the question of the *mode* in which the work is to be completed can be *fully* discussed. In the meantime it may be asked—What is to be done at the points where Captain Haig has commenced work ?

It must be borne in mind that whatever plan it may be decided eventually to adopt, the mode proposed by Captain Haig of surmounting the three Barriers is the only one worth consideration ; his Anicuts, Locks, and Canals must form part of any scheme for the improvement of the navigation. The first thing which he must do will be to complete the rail roads round the Barriers. When he has thus secured the means of bringing down the Cotton of 1862 during the monsoon freshes, he can proceed with the Anicuts and the other works as rapidly as the means placed at his disposal will allow. The only question which is of any importance with relation to these is. What shall be the dimensions of the Locks ?

Under the circumstances stated by Captain Haig, I am disposed to recommend that he should be allowed to make these Locks of the dimensions now recommended, viz., 200 feet long and 30 feet wide. This will of course require a corresponding width to be given to the Canal ; but though it might be possible to carry on the traffic with smaller Locks, and though smaller may eventually be found to answer, yet with a view to the removal of all chance of failure in getting steamers across the Barriers at all times of the year, I should not hesitate to recommend that the additional expense should be incurred. The substance then of my recommendation is—

(1.) That Captain Haig should be empowered to carry out the works at the three Barriers on the scale mentioned above, that is that the Locks and Canals should be made capable of passing steamers 200 feet long and nearly 30 feet wide.

(2.) That he should be directed to revise his estimate for the works at the Sinterala Barrier, substituting Locks 30 feet in width for those shown on the plan, which are 45 feet wide.

(3.) That he should be directed to send in as soon as possible detailed plans and estimates for the works at the second and third Barriers.

(4.) That the survey of the river should be completed thoroughly, a special survey being made of the site where Anicuts may have to be constructed.

(5.) That a distinct party should be employed to survey the upper part of the affluent of the Godavery, with a view to the discovery of spots where water may be stored in large quantities.

(6.) That a separate party or parties should be detailed for the survey of the site of the Anicut at the exit of the river from the mountains, and for that of the land to the right and left of the river, which might be brought under the influence of the water raised by the Dam.

(7.) That instructions should also issue to Captain Haig, directing him to keep the cost of the execution of the work altogether separate from that of the preliminary surveys and levels, and also from that of the conveyance of goods : preparations had better be made at once for the possible traffic which may pass down the river. The cost of the steamers now lying between the Barriers, that of the boats constructed, or being constructed, should be debited to traffic, and this had better be done from the commencement of 1862.

8. Should the Government concur with the view I have taken, a reference should be made at once to the Governor General in Council for leave to employ such parties as I have alluded to, on the different surveys. The Chief Engineer should give an estimate of the cost of these, and should the sanction of the Government of India be obtained the work should be pushed forward with all possible speed, in order that in the course of the present year sufficient information may be obtained to enable the Government to come to a definite understanding upon the whole scheme.

10th February 1862.

W. T. DENISON.

No. 439. ORDER THEREON, 28th February 1862, No. 324.

1. The Governor in Council having attentively considered the Report drawn up by Captain Haig in reference to the Proceedings of Government, No. 83, dated 30th January 1862, is now prepared to submit certain recommendations with regard to the prosecution of the works in the Upper Godavery for the consideration of the Government of India and of the Right Honorable the Secretary of State for India.

2. The Government having in Extract Minutes Consultation, No. 961, dated 19th May 1857, directed " that the plans for improving the summer navigation should not now be taken up," but that Captain Haig's attention should be confined to the improvement of the monsoon navigation, the information in their possession at present which may be relied upon is limited to the latter part of the subject and is as follows :—

(1.) An accurate survey of the river from Dowlaishwaram to Chanda ;

(2.) A series of levels which have been verified and can be depended on from the same place to the third Barrier ;

(3.) Plans in detail with accurate sections of the ground at the first and second Barriers;

(4.) Plans and estimates of the works to be executed at the first or Sinterala Barrier upon the supposition that the Locks were to be 200 feet long and 45 feet wide ;

(5.) Information sufficient for the construction of the Tram Roads round the three Barriers, of which those round the first and second Barriers are rapidly progressing. A good bandy track will be made round the third, as it is possible that the Tram Road will not be completed this year.

3. As respects additional works required for the full development of the project, such as those for the storage of water to complete summer navigation, and for the extension of irrigation ; the Anicut at the exit from the mountains suggested by Colonel Sir A. Cotton and its subsidiary works ; and the works requisite to perfect the navigation from the head of the third Barrier to the point to which it may be considered advisable to carry the improvement of the river, say to Hingen Ghât, the information is of a more general description.

4. That the application of water to the land yields an ample return for the money invested is a fact well *known*, and one which has been abundantly proved by the very large returns already made by the Anicut and Delta works in the Godavery District ; that there will be traffic sufficient up and down the river to pay not only the cost of transit but also the interest upon the capital employed in improving the navigation can at present only be *inferred*, as the Government have no data upon which to form an estimate. The Honorable the Governor in Council, therefore, is of opinion that in carrying out the works for the improvement of the navigation, the various profitable uses to which the water may be turned should be kept in view ; that the scheme should be framed upon such a comprehensive plan as will enable Government to form a correct idea of the benefits which are likely to result from it to the country ; and that a reliable estimate should be prepared of the outlay which such a scheme would entail, and of the time it would require for its completion.

5. When the whole is thus clearly placed before the Government it will be in a position to decide whether the advantages held out are such as would justify the outlay of any given sum of money, and whether that money should not be borrowed on the security of the Government in order that the work may be prosecuted with vigor, and brought to completion in the shortest possible time.

6. To obtain the requisite information it is necessary—

(1.) To employ parties to complete the survey of the river from the head of the third Barrier to Hingen Ghât ;

(2.) To survey and level the country to the right and left of the river below its *debouche* from the mountains, in order to ascertain the character and extent of land which could be brought under cultivation supposing the Anicut to be raised 25 feet above summer level ;

(3.) To inspect the country to the northward and westward about the heads of the affluents of the Godavery for the purpose of ascertaining the most favorable positions for storing water to be passed down the river in the dry season for irrigation purposes, and at the same time to maintain a sufficient depth of water for navigation ;

(4.) To inspect the course of the river between its exit from the mountains and Hingen Ghát for the purpose of determining the sites at which it would be desirable to construct Anicuts and Locks, should this mode of rendering the river navigable be considered preferable to that proposed by Captain Haig.

7. As respects the works to be proceeded with in the meantime, it must be borne in mind that whatever plan it may be decided eventually to adopt, the mode proposed by Captain Haig of surmounting the three Barriers is the only one worth consideration, as Anicuts, Locks and Canals at these points must form part of any scheme for the improvement of the navigation. The first thing Captain Haig has to do is to complete the Tram Roads round the three Barriers. When he has thus secured the means of bringing down the Cotton of 1862 during the monsoon freshes he can proceed with the Anicuts and other works at all three Barriers as rapidly as the means placed at his disposal will allow. The only question which is of any importance in relation to these is the dimensions to be given to the Locks.

8. Under the circumstances stated by Captain Haig the Government are disposed to think that in order to avoid all chance of failure in getting Steamers above the Barriers at all times of the year, it will be better to make these Locks of the dimensions now recommended, viz., 200 feet long by 30 feet wide. This will of course necessitate a corresponding width being given to the Canals.

9. The following then is a summary of what Government recommend to be done for the improvement of the navigation and irrigation of the Godavery :—

(1.) That Captain Haig should be empowered to carry out the works at the three Barriers on the scale mentioned above, that is, that the Locks and Canals should be made capable of passing Steamers of nearly 200 feet long and 30 feet wide ;

(2.) That he should be directed to revise his estimate for the works at the Sinterala Barrier, substituting Locks 30 feet in width for those shown in his original plan, which are 45 feet wide ;

(3.) That he should be directed to send in as soon as possible detailed plans and estimates for the works at the second and third Barriers ;

(4.) That the survey of the river should be completed thoroughly, a special survey being made of the sites where Anicuts may have to be constructed ;

(5.) That a distinct party should be employed to survey the upper part of the affluents of the Godavery with a view to the discovery of spots where water may be stored in large quantities ;

(6.) That a separate party or parties should be detailed for the survey of the site of the Anicut at the exit of the river from the mountains, and for that of the land to the right and left of the river which might be brought under the influence of the water raised by the Anicut ;

(7.) That Captain Haig should be directed to keep the cost of the *execution* of the work altogether separate from that of preliminary surveys and levels, and also from that of the conveyance of goods. The cost of the Steamers now lying between the Barriers and that of the boats constructed or being constructed should be debited to traffic, and this had better be done from the commencement of the Calendar year 1862. It is desirable that preparations should be made at once for the possible traffic which may pass down the river during the next monsoon freshes.

10. Reference will be at once made to the Governor General in Council for leave to employ such parties as have been mentioned above in the different surveys, an estimate of their cost being furnished by the Deputy Chief Engineer, and should the sanction of the Government of India be obtained thereto, the work should be pushed forward with all possible speed in order that in the course of the present year sufficient information may be obtained to enable the Government to come to a definite understanding upon the whole scheme.

(Signed) W. H. HORSLEY, Lieut.-Colonel,
Secretary to Government.

Received by Capt. Galloway

His Excellency the Governor in his Minute on my Report of 3rd February observes that an error has been made in the Calculation of the number and cost of the Masonry required for the Dam of Clarkenden Scheme, that the number of the height of each bay taken at 15 feet above the average bed of the bed, the number would be $\frac{304}{15} = 21$, and not 27 as stated in my letter. The difference is no doubt, a Compositor's error in the Report alluded to, for figures in the calculation of the number required, a height of 15 feet above the mean bed of the bed is allowed for, and in the estimate of the cost an actual average height of the dam of 15 feet. In the former case the actual height of the work would be 15 + 4 = 19 feet, as the bed must be cut down and the foundations laid at the deep bed level.

If therefore the number of Masonry bays be reckoned as his Excellency has done, at $\frac{304}{15} = 21$, the actual height

of each will be 19 feet, and the estimate must be for 21 Aqueducts of 19 feet each, instead of 27 of 15 feet — In the former case 500 ℔. per Evening Yard would be sufficient, as each Aqueduct instead of being a mean between the ~~tides~~ tides of Godavery and Kistna would be the actual difference in the levels — the actual difference in the levels would therefore be that due to this allowance in the mode of calculation, and would be practically different from that given in my letter —

This is wrong — In his Report Capt Haig states that the average height the Bed of the River is 4 feet above the Summer Level of the water and this plain meaning of this is that a dam or Aqueduct of 15 feet average height above the Bed of the River would have Summer level 15 + 4 or 19 feet — which must be added 4 feet for the fall of the river from the tank or Head Lock to the head of the other so that a dam 14 feet high would in round numbers raise the Summer level of the water 20 feet — We have nothing to do with

Excavation for Foundations — neither Inver Capt Haig can say whether there will be down 15 feet or 20 feet — The precautions per cubic yard is supposed to cover all this — The actual height above the bed of the River is all that we can get at — If then the Summer level is one foot deep, all that we require to add is 14 feet for 15 feet average is 15 feet and this might be done by adding 3 feet to the Dam or Aqueduct & allowing one foot for the fall of water — If then the whole height to be overcome is as stated 30 feet — 20 of 19 feet may be deducted from this for the fall in the stream — what would leave 20 feet to be overcome by the Aqueducts and 19 of these 1 foot annual height 15 feet would be sufficient — I stated this roughly before at 21 but having gone into it more carefully I find that Capt Haig has overestimated the amount of Aqueduct height by 120 feet and the number by 8 — so that his Estimate is made in excess to the extent of $\frac{8}{27}$ or as his estimate is £1,000,000 to the extent of £300,000

WR

I have read attentively the accompanying Report from Capt.n Hay and I have since bestowed over with that Officer several points connected with the prosecution of the works on the upper Godavery and am now prepared to submit certain recommendations with regard to these for the consideration of the Govt. of India, and of the Secretary of State—

My first impression on reading these Papers was that the Govt. was in possession of information sufficient to justify the adoption of any of the plans proposed, and I was rather inclined to blame Capt.n Hay - but it appears that in 1846 the Govt. in adopting a portion of his scheme limited him strictly to the improvement of the navigation of the River and postponed the consideration of the other portions of his scheme until the actual amount of information possessed by Govt. is in possession appears the 1st Re accurate survey

of the River from Dowlaishweram to Chandeka.

2nd A series of locks could also be executed on from the same plan as the Third Barrier.

3. Plans in detail with accurate sections of the ground at the first & second Barriers. —

4 Plans and Estimates of the works to be executed at the 1st of December Barrier upon the supposition that the dredger = ation that the 200 feet long & 45 feet wide.

5. Information sufficient for the construction of the Ram Roads round the 3 Barriers, probable time round the first & second Barriers and rapidity of = progress; and a good Bandy track will be made round the third. Should = it be possible that the Ram road will not be completed this year — work required & any additional works such as may required for the drainage of water to complete the Summer Navigation & to give additional depth

27

for Irrigation; the Head of Anicut at the exit from the Mountains as alluded to by Col Du Allotton, or any works required to complete the Irrigation from the Head of the Third Barrier to the point to which it may be considered advisable to carry the improvement of the River, may be likewise the information of the most general description — bearing them to the work as one calculated to open up a large tract of country in the interior of India, and which, if properly carried out, might, in addition to the benefits conferred by the improve = ment of the Navigation, afford an opportunity of Irrigating a large extent of country, and thereby a certain return for the Capital ex = pended, I should say that Govt in 1856 imposed the narrow a limit upon the work to be performed, and I now propose before bringing the whole question again under consideration before however I do this I must allude briefly to some of the statements made

by Capt" Hay with refe-
-rence to the comparison
advantages of the two modes
rendering a River navi-
-gable, and especially to
the estimate of the actual
amount of Anicut work
to be executed - in paragraph
9 he states that the average
height of the bed of the River
at each place, where it was
intended to place an
Anicut, is probably 4
feet above the lowest
Summer level of the water
that is the average soun-
-dation or point from
which the heights of the Dam
is to be calculated is 4 feet
above the existing surface
of the water not 4 feet below it
The actual amount of
the actual amount of
work is said to be 304 feet
Capt" Hay has pro-
-vided for 420 feet height
of Anicut to overcome this
divided among 27 Anicuts
whereas he would only
require 21 Anicuts with
an average height of 16
feet. This would also
one make a reduction
of 600000 £ in the
Pecuniary Estimate
I merely however allude
to this for the purpose

12
21

shewing that no dependence
can be placed on a rough
comparison of this kind
given by Capt" Hay.
and I affirming my
conviction that the whole
question requires the
most careful examination.
The Godavery is a River
draining a very large
tract of country. It has
discipon in the Hills
bordering the West Coast
of the Peninsula, and
is subject therefore to the
action of the S.W. monsoon.
during the 3 months of
June July August &
Sept" it pours down
a vast volume of water
the rise of the surface
ranging from 20 to 50 feet
& upwards - during the
dry season the discharge
diminishes rapidly till
for a few weeks pre-
-vious to the setting in
of the S.W. monsoon the
quantity discharged
does not exceed 200000
Cubic feet per hour -
During the monsoon
an enormous amount
of silt is brought down

the coarser & heavier portions of which form Land-banks & shoals in the bed of the River wherever an eddy is ~~formed~~ created by any interruption to the stream - the finer portions are carried down the River, and are discharged into the Sea, forming the protecting Spit of Land to the South of Coringa & blocking up the Harbour, or rather Anchorage of Coconada, which is gradually shoaling, the deep water being pushed to the Northward by the continuous addition of Silt to the Land which has been formed to the South - This Silt however passes into the Irrigation channels, and is distributed over the Delta - acting thereby as a manure to the Irrigated land -

Several years ago the Govt acting under the advice of Sir A Cotton decided to avail itself of this means afforded by the River of irrigating the Delta formed by the diverging branches of the River, and each of the Canals brought as much water within the reach of the water raised by an Anicut at Dowlaisheram - This work was accordingly commenced - The Anicut a large portion of the distributary Channels & Locks for Navigation have been completed, & have been and the returns have yielded a very large Interest upon the Outlay - 31

that the application of water to the Land yields an ample return for the money invested we know; that there will be traffic sufficient up and down the River to pay not only the cost of Transport, but also a fair Interest upon the Capital expended in improving the Navigation we only infer; in fact we have no data upon

whilst to form an Estimate. It appears to me therefore that in carrying out the works for the improvement of the Navigation we should have an eye to the various profitable uses to which the water may be turned, and should frame the scheme upon such a comprehensive Plan as would enable the Government to form an Idea of the benefits which the country is likely to derive from it; & the cost which such a scheme would entail, & the time it would require for its completion.—
When the whole is thus clearly placed before the Govt. it will be in a position to decide whether the advantages held out are such as would justify the outlay of any given sum of money. whether such money should not be borrowed upon the security of the Govt. in order that the work should be prosecuted with the utmost activity, and not be left dependent upon the amount which

might be raised from the annual Revenue & various other questions connected with the principle details of the work would also be considered — 33
In order to this however this must be done & employ several parties to complete the survey
1st — to complete the survey of the River from the head of the 3rd Barrier to Brisbane —
2nd — to survey and level the Land to the right and left of the River below the Logs of the River below the Brisbane from the Broom-stairs in order to ascertain the character of the Land which will be brought under the action of the Locks & disposing the Cuttings to be raised &c &c
3rd to inspect the Country to the Northward & Westward about the heads of the Tributaries of the Brisbane — for the purpose of ascertaining the most favourable positions for storing up water to be passed down the stream in the dry season for Irrigation purposes, and

for that of maintaining a sufficient ~~depth~~ depth of water for Navigation & to inspect the course of the River between it's exit from the Mountains and Meigenphat for the purpose of determining the rate at which it would be desirable to construct Locks which should this work rendering the River Navigable be considered preferable to that proposed by Capt" Hay —

I may say here that I am by no means convinced by the reasoning of Capt" Hay, that his plan by keeping up an average current of 1½ Knots an hour over the whole distance, & should the average speed of steamers be 5 Miles per hour, it would be reduced to six by the current in going up the stream: and that a current of this would require steamers of greater power, these would require larger boats

plan is the most advantageous

impracticable

a great obstacle to the up traffic is created;

&c — so that although I quite admit that the system of slack water Navigation by means of Locks would be the most expensive yet I am certain that the ratio between the cost of the two systems will not be even so much as that given by Capt" Hay — when the Govt have all the data before it. The question of the mode in which the work is to be completed can be fully discussed in the mean time it may be reached what is to be done at the Falls when Capt" Hay has commenced work?

It must be borne in mind that whatever plan is ultimately to be adopted, the mode proposed by Capt" Hay possesses many & great advantages over any other Project that may be brought forward — it is the only one that will admit of the work being carried on during the winter months — Locks & Canals must form part of any scheme for the improvement of the Navigation of the River they would be

must do will be to complete the road round the Basin when he has thus secured the means of bringing down the Cotton of 1862 during the Monsoon freshes - he can proceed to work the Anicuts & to other with as rapidity as the means placed at his disposal will allow - the only question which is of any importance with relation to these is what shall be the dimensions of the locks? Under the circumstances stated by Capt" Hay I am disposed to recommend that he should be allowed to make these locks of the dimensions since recommended viz 200 feet long & 30 feet wide - this will of course require a corresponding width of the piers of the Canal, but though it might be possible to canoe the traffic with smaller locks, and though smaller may eventually be found to answer yet with a view to the removal of all chance of failure in getting

4 That the Survey of the River should be completed thoroughly a special survey being made of the site which Anicuts may have to be constructed -

Locomotives and the Basin at all times of year I should recommend that the additional expense should be incurred - The substance of my recommendation is 1st that Capt" Hay should be empowered to carry out the work at the three barriers on the scale mentioned above that is that the locks and Anicuts should be made capable of passing steamers 200 feet long & vessels 30 feet wide -
2nd That he should be directed to revise his Estimates for the work at Pudicherry substituting a 30 feet lock for the 20 feet one shown on his Plan which are 45 feet wide -
3rd That he should be directed to send in as soon as possible detailed plans & Estimates - for the work at the 2nd & 3d Barriers
4th That a distinct party should be employed in Survey the upper parts of the Godavery with a view to finding out where Anicuts might be erected -
5th That a separate party of Surveyors should be detached to the Survey of the site of the

Ancient at the exit of the
River from the mountains
and for that of the Land
to the right & left of the River
which might be brought
under the influence of
the Water recently diverted
by that
Instructions should also
give to Capt Hay directing
him to keep the cost of
the execution of this work
altogether separate from
that of the preliminary
Surveys, Levels &c and
also from that of the
conveyance of Goods
preparations had likewise
to be made at once for
the possible traffic which
may pass down the
River - The entry of the
Steamers navigating
between this harbour - that
of the Boats constructed,
or being constructed, should
be restricted to suffer
time for the said Bills to
pass from the Commencement
of Nov 1862 -
Should the Govt consider
it necessary that a Reference should
be made at once to the
Govt Engineer in Council for
Canada employed until
parties as I have alluded

to in the different Surveys -
The Chief Engineer should
then estimate the cost
of the work, and should the
Sanction of the Govt be
obtained the work should
be pushed forward with
all possible speed in order
that in the coming
present year sufficient
information may be
obtained to enable the
Govt to come to a definite
understanding upon
the whole scheme

W Dennis

C. of Jud. Let. to Govt. 2
dd. 11 April 1862 No. 23

Public Works 1862 Depart.
Pro. of Govt. for February
No. 387
Minute by the Honble
the President.

Dated 10th Feby 1862
Received 13th " "

Submitting certain
recommendations with
regard to the works
on the Upper Godavery.

No. 408.

C. Jud. Feby 27th

No. 324 - 28th Feb.

Madras 3rd February 1862.

41

From,
Captain F. J. Haig
District Engineer
Upper Godavery.

To,
Lieutenant Colonel J. Ouchterlony
Acting Deputy Chief Engineer
Northern Circle

Sir,

With reference to O.G. No. 83, of 21st January, I have the honor to submit my views upon the several points laid down for my consideration in His Excellency the Governor's Minute of that date.

2. These points are

1st The relative advantages and disadvantages, without reference to cost of execution, of the two following methods of rendering the Godavery navigable from the Coast upwards to Berar during those months of the year when the diminished volume of the stream affords a depth more or less insufficient for navigation.

1st What may be called the dam and slack water system, and

2nd The Reservoir system.

The removal of all impediments in the shape of rocks and rapids in the river bed is assumed as necessary in either case, and the suitability of the works originally proposed and now under execution for this purpose is admitted. In fact the feasibility of the original scheme, estimated to cost 30 lacs, and which had reference chiefly to the monsoon navigation of the river being granted. the Government is desirous to know which of the above methods, between which alone our choice seems to lies, it will be best to adopt with a view to extend the period of navigation so as to embrace the whole year.

The 2nd point is the probable cost of each of the two systems proposed.

Lastly the question is raised whether it would not be advisable, in the first instance at least, to construct the locks and canals at the three barriers of much smaller dimensions than was at first proposed, making them of a size sufficient for the passage of cargo boats only, the operations of steamers being confined to towing in the navigable reaches between the barriers.

3. With regard to the first point.

Apart from the question of expense, the consideration which must decide between the claims of the two proposed systems of improvement, is the comparative facilities which each will afford for cheap, regular, and uninterrupted communication..

I proceed therefore to an investigation of this point. The object in view is to secure a continuous navigable channel, with a fixed minimum depth of water, clear of all obstructions, and with such dimensions and slope as may afford the best possible navigation which the nature of the stream will admit of.

4. The two methods proposed for attaining this object are.

1st To construct a series of dams or Annicuts along the whole length of the river, so placed that the pool or slack water formed by each shall extend to the one next above it. These annicuts would be furnished with locks for the passage of boats and steamers, the lower sills of which would in every case be laid at a

certain

certain fixed depth below the crown of the annicut next below, that depth being the minimum which it is desired to maintain in the navigable channel.

2nd. To regulate the course of the stream, and confine it within certain limits at those points where it has a tendency to wander, by means of low wing dams and training walls, and to pour in from reservoirs constructed on the head waters of the river a stream sufficient to afford the requisite depth for navigation.

5. It will be necessary in the first place to determine what this minimum depth is to be. I will take it at 5 feet, as I consider that will be quite sufficient for all purposes.

Dam and Slackwater system.

6. With regard to the first of the two proposed methods, the first point for consideration is the height to be given to the annicuts.

This would probably vary from 15 to 20 feet above the general level of the bed, according to the height to which the floods rise in

in each particular part of the river. It is manifestly desirable to have as few annicuts as possible, in order to diminish to the utmost the detention of boats in passing them. The greater the average height the less the number required.

The less the average height, the greater the number, the greater the difficulties of lockage (owing to the great rise of the floods) the more frequent the detentions, & the more numerous the points at which injuries to the works may take place, to the obstruction, if not actual interruption, of the navigation.

7. The general velocity of the stream in full flood being 6 miles an hour, annicuts obstructing about a third of the flood section, or 15 to 20 feet in height, would be about as high as a due regard to the cost and security of the structures would render it advisable to adopt. Great accuracy not being required, or in fact in the present state of our knowledge of the localities, attainable

in

in the present paper, I shall assume the above as the average heights for the annicuts in all the calculations which follow.

8. Between Purshetaputnam at the entrance of the Hills, and Deva. nagilly the lower terminus of the Canal at the first barrier, the full to be overcome in the river bed is 48 feet. That between the first and second Barriers 69 feet. Between the 2nd & 3rd 82 feet. Between the 3rd and Hingenghat 105 feet. Total fall in open parts of the river between Purshetaputnam and Hingenghat 304 feet.

9. The average height of the bed at each place is probably about 4 feet above the lowest summer level of the water. Allowing then that each annicut shall raise the water to a height of 5 feet on the sill of the lock in the annicut next above, or in other words that its crown shall be 4 feet above the sill of lock, leaving 1 foot for the slope in the surface of the water, we find that the number of annicuts required would be

In the 1st reach of the above named reaches	3 of 20 feet high	60
2nd reach	7 of 15 feet	105
3rd reach	8 of 15 feet	120
4th reach	9 of 15 feet	135

10. In this calculation I have made a deduction of about 35 feet from the total height to be overcome, being that portion of it which the annicuts at the three barriers will probably surmount. No doubt these heights would be varied more or less to suit the varying fall of the bed, and possibly in the 2nd and 3rd reaches it might be found that the number of annicuts might be reduced by increasing the height of one or two of them. It would also be a question for consideration whether it would not be worth while to give an additional height of 3 feet to each by means of moveable shutters, but I think it doubtful whether such would be the case. At any rate for our present purpose we may reckon that 3 Annicuts of 20 feet, and 24 of 15 feet in height in addition to the three at the barriers would be required.

Re

11. The next point to be considered is the arrangement of the locks in the annicuts. This is a very difficult part of the scheme. The great height to which the floods rise, from 40 to 80 feet, presents great difficulties and objections to locks placed in the river bed. On the one hand if the floods are to be excluded from the lock, the gates must be made of immense height, viz 32 to 66 feet, which is objectionable, and on the other if we make the locks submersible we are met by the more serious difficulty of the deposit of silt within and around them.

12. Without entering into any discussion of different modes of overcoming this difficulty I may just state that I am sure it is by no means insurmountable, and that the plan I would propose (from such consideration of the question as I have been able to give to it) is to place two or more locks side by side in the annicut, their sills being laid at different levels from that of the lowest lock intended for the summer navigation to about 25 feet below the highest flood level.

This

13. This arrangement is shewn in outline in Fig.

The lower lock would be the one in use for about 9 months of the year, viz during the time when the river is not more than 10 feet deep on the annicut. When the rise of the flood exceeds this level, the gates of this lock would be fastened open by means of a pair of skeleton gates, with moveable planking, placed in front of the upper gate, and the flood allowed to sweep through it while the other two locks are in use. One of the latter, the lowest of the two, would in its turn be submerged as the river rose, but as it would only be so for a few days, it might not be necessary to provide for fastening its gates open, as the quantity of silt deposited in that time in its chamber, raised as the latter would be so many feet above the bed would probably be trifling. When the flood had risen above the walls of this lock, the third would come into use. It seems to me however very doubtful whether, for the few days that the river would overtop the second lock, it would be worth while

to

to provide for the ascending navigation. A detention of a few days to up going steamers in that state of the river, when the current would render their progress so slow, would not be of much consequence. It is questionable therefore whether there would be any necessity for a third lock.

14. In this way I should hope to keep the lowest lock with the Channel immediately above and below its free from silt. There would be a deposit in front and rear of the other two, but this would be of no consequence as it would not interfere with the navigation and might be removed every year during the summer.

15. The outer lock of the three would have a wall carried 200 or 300 yards up stream from the extremity of its outer wall, and another downstream for a shorter distance, to guide steamers in and out during the freshes. Similar guard walls of shorter length would probably also be required for the two inner locks.

16. Undersluices, or what might

probably answer the purpose as well, a shoot of capacious dimensions made in the annicut, with its top 6 feet below the crown of the latter, would be required to maintain a proper scour along the navigable Channel to and from the locks. The shoot would enable descending steamers to pass the annicut without the locks during a good part of the flood season, and would be closed by shutters, by some such arrangement as that of the French Barrage Mobile on the subsidence of the freshes.

17. I may here remark that the upward passage over the annicut would never be practicable for any but fast passenger steamers and them only at the top of the flood. Annicuts even 10 feet only in height would occasion an overfall of six inches at that time, and a current of nearly 7½ miles an hour. Hence locks are indispensable for the up navigation.

18. Having thus disposed of the annicuts and their appurtenances,

the

the next question is whether any and
what kind of works would be required
in the pools between for the maintenance
of a navigable Channel of the required
depth. This is the most difficult question
of the whole, and one on which a
great amount of obscurity still rests.
It is one in which the experience of
other countries will not afford much
light, for though it is certain that
many rivers have been treated successfully
in the manner now under consideration, it
is at the same time true that their physical
characteristics were very different from those
of the Godavery, which from the velocity
and enormous weight of the floods which
it rolls to the sea, as well as from the
immense masses of sand which are swept
by its tributaries into its channel, acts
upon its bed in a way which so far as I
am aware no other river improved as now
proposed affords an example of.

19. The question however I would repeat is not whether the dam and slack water system could be worked out on the Godavery

Godavery or not, I have no doubt it might be, were the requisite funds available. But the question is whether a considerable amount of stone work might not be required in the pools between the annicuts, for the regulation of the currents and the fixation of the deep channel. Ordinarily such work is unnecessary, but on the Godavery with its shifting bottom I am convinced that it would be required.

20. We cannot proceed further in the consideration of this part of our subject without a distinct understanding of what the actual state of things in the Godavery is, what the nature of its banks, of its bed, and of its shoals.

21. In the first place, the Godavery differs from the Ganges in two very important particulars. Its banks are but little liable to erosion, and subject to little change. The changes which take place on the Ganges in the course of a few weeks or months would be on this river the work of a century, or rather

it

it would be more correct to say that the country along its banks presents incontestable proof that no material alteration has taken place in the position of its channel for ages. In the second place, the material of which its bed is composed is a large coarse grained sand totally unlike the fine powdery sand of the Ganges, and therefore requiring a very much more powerful current to displace it.

22. Two important consequences result from these conditions, the first is that the position of the shoals is for the most part fixed and invariable from year to year, the second that the length of each shoal undergoes but little extension during the months that intervene between the time of its deposition and the next flood season.

23. The exceptions to the first of these rules, and even they are but slight in degree, are met with in the part of the river between the Dowlaiweram Anicut and the Hills, and that between the 1st and 2nd Barriers.

In

In these places the banks being either of a more yielding material or unprotected as in other parts of the river by protruding groins of rock, have in the course of years been cut away to such a degree that the river Channel is widened to much beyond its natural dimensions. The consequence has been the raising of the bed, and the formation of high sand banks and if islands out of the loose silt deposited by the river. These banks and islands change their shape from year to year, and with them change the position and shape of the deep Channel of the river. Here consequently the shoals shift their position also, though within narrow limits.

24. It is proper to remark that the aggregate length of these two parts of the river amounts to only 60 miles out of the 500 which it is proposed to render navigable.

25. It is most important to bear these two points distinctly in mind in the consideration of the question before us, the fixed positions of the

shoals

shoals, and the solid, permanent, and unyielding character of the banks, from whence results permanence in the position and dimensions of the river channel itself.

26. The next point to be cleared up is what causes the shoals, and where are they generally met with. Shoals are formed wherever, whether from the peculiar shape of the river or from obstructions caused by rocks in the bed, the position of the deep channel during the flood season varies very much from that which it takes during the low water months. The river generally takes a gently winding course, so that the deep channel except when the river is very full follows one bank or the other. All such parts of it are free from shoals, excepting where rocks occur to interrupt the uniform flow and scour of the stream and to obstruct its channel by the deposits which they encourage. But where the deep Channel passes from one side of the river to the other, as it must do occasionally, there a

shoal is sure to be met with, as the direction in which the stream takes at these points during the floods differs very much from, and usually crosses at a considerable angle, that which it follows on their subsidence. The few exceptions to this rule are where the turn in the river is very abrupt or its channel very confined.

27. The only other places where shoals are formed are in those parts of the river already mentioned where the bed has been widened to very much beyond its usual dimensions, where the slackened current favors deposits, and the stream at low stages of water instead of being confined within a well defined channel spreads irregularly over a wide and shallow bed.

28. We are thus thoroughly acquainted with the nature of the shoals and with the causes which lead to their formation. The present question is the effect which damming the river into a series of pools may be expected to produce in its bed at those points where these obstructions are now met with, whether they would entirely disappear, or whether further works in the shape of groins and training walls would be required to remove them. My own opinion is that these works would be required, and that without them no permanence either of the depth or of the direction desired in the navigable Channel could be relied on. The experience at the Dowlaiswarum Annicut shews that the deposits of sand in the pools above annicuts

annicuts in a river of this class, are very irregular,
shoals, and that while an undersluice may secure the
unyiel existence of a deep Channel immediately above it,
whence yet that this effect is but local, and is not to be
position always depended upon to a much greater distance
Chann above than that to which the groins or training walls
26. extend which confine the stream flowing to it.

up 29
where I should further expect to find
I shoald the effect of such walls for confining or directing
from the stream much less when placed in the position of
or fr an annicut than when in an open river, inasmuch
the as the time during which the stream would have
Chan sufficient velocity to scour its channel effectively
would be so much less in the one case than in
the other. For it must be remembered that the use
very of the undersluices would be very much more limited
than in the case of annicuts erected only for irrigation
the purposes or to feed a canal or canals led off from
takes them. In such cases it matters not what amount of
deep silt may be swept into the river Channel below the
very sluice provided that above it is kept clear, and the
All sluice may be set in operation at any time of the year
free without objection. But in the case proposed its use would
occu be confined to only certain times during five months of the year;
and at all other times its peculiar effect could only be produced
at the risk of obstructing the Channel below it by the
its deposits swept down from that above. It follows that
enc the deep Channel in the pools must be formed almost
entirely by the scour due only to the surface slope of the stream,
prow which being much less than that of the river in its
natural state, the scour will be proportionately less effective,
the and will require a correspondingly increased amount of C.

Without therefore attempting to estimate to what extent such assistance in the shape of groins and walls would be necessary, I think there can be little doubt that a considerable outlay would have to be incurred on its account.

Reservoir System

30 I proceed to consider the second method of improvement proposed, viz. that by means of reservoirs and regulating walls in the river bed.

The works that would be required in this case would be,

1st Reservoirs constructed about the heads of the valleys of the principle affluents, sufficient to store the quantity of water required to produce a stream of the volume and depth desired, and

2nd " Regulating walls in the river bed, formed either of stone or brushwood and piles, or a combination of both, for restraining and directing the flow of the stream.

The removal of isolated rocks in different parts of the bed, and groins here and there for securing the river banks against the attacks of the stream, might be added, but do not call for particular notice here, being works of no difficulty and which would be required under either system of improvement.—

31 As we are now dealing with this question without reference to expense, I need only remark that there could be no difficulty in finding suitable sites for reser=voirs capable of holding all the water that might be required about the heads of the valleys of the Wurdah and Wyne Gunga, which alone drain an area of 50,000 square miles. Within an area of only about 1,500 square miles in the Western Ghauts, Mr. Frazer, Civil Engineer, some years ago surveyed and examined the sites for 33 reservoirs, 10 of which were capa=ble of holding together 1260,000,000 cubic yards of water. There can therefore be no question that with the immense area we have in which to select sites in the two rivers mentioned, to say nothing of the valley of the Godavery proper, which is of equal extent, we should find no difficulty in storing any quantity of water. The cost of doing so is a separate question. And as all will admit that the river is now navigable when there is a certain body of water in it, no one will be disposed to deny that it will be so at all times if we keep up the discharge to that amount by artificial means. We need therefore enter no further at present into this part of the subject for the purpose of comparing this mode of improve=ment with the former.

32 The work to be done in the river bed, after it had been thoroughly cleared of all rocks in the line of the deep channel, would consist of a number of detached walls of stone, by means of which a permanent and fixed position would be given to the channel at those points where by nature it is shifting, and by which also the stream would be confined within narrower limits at the few places where it now spreads over too wide a surface.-

33 The success which has attended this method of regulating the deep channel of a river has varied with the character of the rivers on which it has been tried, the degree of skill with which it has been applied, and the amount of improvement sought to be obtained by its means, as compared with what it is really capable of affording unsupple=mented by an increased supply of water artificially provided.

In America the only large river on which it has been tried is the Ohio, but the attempts made there have been so few, so des=ultory, and so ill sustained, that it is not surprising that they have had little success.

In France it has produced excellent effect on the Saone, where the river is now navigable for steamers drawing 3 feet water with a discharge under 300,000 cubic yards per hour. It is now being applied to the

Rhone

Rhone also. On the Loire it has only been tried fairly at two places, at one of which it has succeeded well, and at the other has greatly benefitted the navigation, tho' the attempt in this case has been made to compel the channel contrary to nature to follow the convex bank in a bend of the river, viz at Orleans, where the town lies on that side. On the Danube, as far as it has been carried out, the system has answered well, though the stream has a much greater velocity than the Godavery.

34 On the other hand it is certain that the system has yielded but poor results in some cases, but this has, I believe, always been either where such utter violence was done to nature in the planning of the works that certain failure might have been anticipated, or where too much was attempted by their means. It is evident that to attempt to confine the low water stream of a river within two continuous walls in a channel much smaller than its natural one, and merely to direct and regulate its course here & there as proposed for the Godavery, are two very difficient things, and that the difficulty of the undertaking in the one case is but a fraction of what it is in the other. It is the latter mode (63) which I propose to use in the Godavery, confining the stream only at those places where it is apt to spread over too wide a surface, and increasing its flow from artificial lakes to the extent required to give the desired depth for navigation.-

35 The general fall in the open parts of the river being less than 1/4 foot per mile, the average current, with the depth which it is proposed to maintain, would be 1 3/4 miles per hour.- (+5 feet.)

36 We may now compare the two methods of improvement. In the one case we have a series of pools, with little or no current in them during more than half the year, connected by locks; in the other a continuous navigable channel with an average current of 1 3/4 miles per hour in the summer months, and considerably more in the freshes.-

37 The first plan has the advantage of affording greater facilities to the up traffic by reducing the current in the pools, and this is I believe its sole claim to superiority, while it has the disadvantage of immensely increasing the risks of delay and interruption of the navigation by interposing at every

few miles an annicut and locks which must always be more or less liable to injury or accident. The diminished current would of course facilitate the progress of up going steamers, but would proportionably retard that of those going down, and as the up traffic may be expected to be both smaller in amount and of higher value than that down, and consequently better able to bear a higher charge for carriage, the natural arrangement by which the force of gravity acts in the direction of the heaviest tonnage is decidedly the best so long as that force does not oppose any very serious obstacle to the ascent of the stream. This certainly would not be the case on the Godavery; as an adverse current of 1¾ miles per hour is perfectly compatible with very cheap navigation. Moreover, the advantage gained by the diminution of the current would be to a certain extent counterbalanced by the loss of time in passing the locks, as well as by the liability to occasional detention either from accidents deranging the working of the locks, or from the accumulation of silt in their neighbourhood, a source of delay which it would be impossible wholly to obviate.—

It should be remembered too that the passage of the locks would be an obstruction to the down trade also during the greater part of the year.

With every possible precaution, locks in a line of great traffic must always be more less liable to accidents. Even in canals where boats can be led in and out of the locks with so much more precision than in an open river, accidents occasionally happen. A better arrangement of the locks than I have proposed may very possibly be devised, but if not, it should be borne in mind that the lowest lock in each annicut which would be the one in use during three-fourths of the year, would have an extra liability to injury, during the time of its submersion in the freshes.

38 I am of opinion therefore that these defects, which are inseparable from the dam and slackwater system of improvement, more than counterbalance any advantages it may afford, and that the preference should be given to the reservoir system, which, while it would afford an open and unobstructed channel at all times of the year, would afford a steady current in the direction of the heaviest traffic, and that not too great for the ascending navigation. I forbear

here to notice the incidental advantages of the use of the water for irrigation after its work in the river bed is done, and the possibility of restraining the floods by means of the reservoirs, as well as the advantage in points of expense which this system would afford, as I think the reasons above adduced are sufficient to decide the question in its favor.

Comparative Expense of the two Systems.

39 We have next to compare the two systems in point of expense. The materials are wanting for anything beyond a rough approximation to the cost of the works required in either case. On the one hand the price of labor is rising so rapidly all over the country that it is difficult to forsee what increase on present rates should be allowed in estimating for works which will take many years to complete; and on the other we are uncertain even as to the sufficiency of our present rates on the Godavery, as the whole of the labor has to be imported from considerable distances, and the wages offered during the year that has elapsed since the works were commenced have attracted much fewer numbers than we require. The cost of storing water on a large scale is also variable, and much more careful and detailed measurements and observation of the discharges of the river will be necessary before we can be in a position to form reliable estimates of the quantity of water required to maintain given depths in the navigable channel.

40. With regard then, first to the probable cost of a series of Annicuts with locks and other subsidiary works; In estimating the probable number of annicuts that would be required, I have [para. 7] assumed average heights of 15 and 20 feet. As the number of those of 20 feet is only 3, I propose to substitute for them 4 of fifteen feet to simplify the calculation of the total cost. I find from the map of the river* that the aggregate length of the Annicuts required will be close on 20 miles. This gives an average length for each of 1260 yards.

* herewith forwarded

The

The question then is the cost of an Annicut of this length and 15 feet in height obstructing nearly one-third of the flood section in a river with a flood velocity of 6 miles per hour, and furnished with locks of the kind already proposed. I am inclined to think that the undersluice might be dispensed with, and that an opening in the Annicut near the locks, with its crest depressed 6 feet below that of the Annicut, would answer the same purpose, while it would cost less money, and would serve as a shoot to pass downward bound steamers in the freshes.

41. With regard to the cost of the Annicut we have two very reliable guides in the Doulaishwarum and Bezwarah works. The first of these has cost, as nearly as I can ascertain, about 200 Rupees per running yard in length of Annicut without undersluices or locks. It is 14½ feet in height, obstructing three-seventhsof the flood waterway in a stream with a velocity of 3½ miles an hour.

The second or Kistna Annicut has cost about 350 Rupees per yard Run of Annicut without sluices or locks.

It is 14 feet in height, obstructing one-half the waterway of a river with a flood velocity (where the Annicut is built) of about 7 miles per hours. The annicut now under consideration for the upper river is to block up one-third the flood waterway of a stream running 6 miles per hour, and its height to be 16 feet.

42. If we take the trial to which the Godavery Annicut is exposed as 1, that of the Kistna would be 5½, and that of the proposed Annicut 2¼ - the extreme flood velocities over each being respectively 6 miles, 14 miles, and 9 miles per hour. Supposing the rates for works to be the same in all three cases, the probable cost of the proposed Annicut would be about the mean between the other two, but taking into consideration the fact that the prices paid at the Kistna were about 30 per cent higher than those paid at the Godavery, the cost at the Kistna rates would be about 310 Rupees per yard Run. We are however, now giving 50 per cent higher wages than were given at the Kistna, and by the time the series of Annicuts on the Godavery (20 miles in length) had been completed it is hard to say to what extent wages would have risen. It is also to be considered that there were remarkable facilities at Bezwarah for constructing the work there, such as we shall scarcely meet with at more than one or two out of the 28 Points on the Godavery.

Taking

Taking these things into consideration I do not think we can reckon on the Annicuts on this River Costing less than 500 Rupees per running yard, and accordingly I have taken this rate in the Estimate which follows. This covers all Expenses, Superintendence, Plant, and Contingencies included.

43. In the next place I allow for a rise of flood of 30 feet above the lowest Summer level, and for only two locks, placed one beside the other in the manner already described, the gates of the first to be raised to a height of 14 feet above the Annicut, those of the second to a little above the flood line.

Skeleton gates are also provided for.

I allow 200 feet by 30 feet for the dimensions of the lock Chamber for reasons to be stated hereafter.

Under these conditions the quantity of rubble masonry in the locks would not be less than 2.3000 Cubic yards. Their cost I estimate as follows.

	Rupees
23000 C.yds Masonry @ 6 Rs.	1.38.000
Guard Walls 12.500 C.yds @ 6 Rs	75.000
Well Foundations	10.000
Cut stone 2000 C.yds @ 10 Rs	20.000
Gates	16.000
Total of locks	2.59.000

Total of locks — 2.59.000

Add for 1260 yards in length of Annicut @ 500 Rs. per yard — 6.30.000

Wing Walls 5000 C. yards @ 6 Rs. — 30.000

Total for one Annicut — 9.19.000

This Amount includes every charge.

44. The next item to be estimated for is the stone work in the bed for regulating the streams.

The extent that might be required of this is very doubtful, but we may perhaps take it at one third of what would be necessary under the reservoir system, which, as will hereafter be seen, amounts to 31½ lacs, a third of which is 10. lacs.

45. Water would have to be stored to provide for the lockage, evaporation and absorption. That required on the first account would be insignificant in quantity, but that for evaporation and absorption would be considerable. I allow for an annual Consumption on this account equal to a depth of 4 feet on a width of 500 yards and a length of 250 miles equal to 300 million Cubic yards, which at 500 Cubic yards per Rupee would cost 6 lacs.

46. The Expense of removing all detached rocks

rocks from the navigable channel and of groins for the protection of the river banks I estimate roughly at 3 lacs.

47. So sum up then the total probable cost of the dam and slackwater system we have

28 Annicuts with locks @ 9 lacs each —	252 lacs
Stonework for Regulating Streams —	10
Clearing Channel and groins for protecting banks —	3
Storing water —	6
Total	271 lacs.

Cost of Reservoir System.

48. The cost of the reservoir system would be as follows.

1st. Training walls in the river bed.

The total length of the open parts of the river between and above the three barriers is 330 miles. Of this 100 miles, above the 3rd Barrier is of such width that the stream which I would propose to throw in would fill the river channel from bank to bank, so that scarcely any stone work in the bed would be required.

Of the remaining 230 miles, 60 are deep pools where there is at all times a sufficient depth.

The other 170 miles would require, as well as I can judge from observation of the part of the river below Budrachellum, 100 miles at most of training wall. 73

49. I would propose to make these walls 2 yards in height with a width of 1½ yards at top and slopes of 1½ to 1. Their contents would be 15,840 cubic yards per mile. The cost I think may be safely taken at Rupees 2 per cubic yard inclusive of all charges, or 31,680 Rupees per mile, or for 100 miles 31½ lacs.

50. With regard to the quantity of water which it would be necessary to store I would remark that the calculations made in my Report of May 1856 of the discharge required to maintain given depths in the shoals give results wholly inapplicable to the problem under the conditions in which we are now considering it. In that report I assumed

1st. that the Channel was to be unconfined and the water allowed to spread over the natural surface of the bed, and

2d, that the profile of the river bed at the shoals continued the same whether the stream passing over it were 300,000 cubic yards per hour

hour or 1,500,000, which is manifestly an error. The average fall of the bed at these shoals when the river is at its lowest is about 3 feet per mile, but this only happens because the stream has either not been sufficiently concentrated to plane down the bed to slopes approximating to the average declivity of the whole River, or because its volume diminishes too rapidly for it to produce this effect.

The shoals are all humps in the bed, which, if the stream is suffered to spread over at will, it has not the power to remove, but which, if it be concentrated and sustained in volume, it cuts down soon after the subsidence of the freshes. This might have been supposed beforehand, but it has been fully confirmed by the effect of a groin constructed last year at Kudrameta, by which a shoal which was then the worst on the whole River has in great part disappeared.

In my present estimate therefore I assume a width of channel of 300 yards, and a fall not exceeding 1½ ft. per mile. Such a channel would require a stream of about 1½ Million Cubic yards per hour to afford a depth of 5 feet for navigation.

Contains 1260 Lacs

151/The

51. The following table shews the quantity of water which it would be necessary to throw into the river to keep up the discharge to this amount.

Months	Average hourly discharge of river in Cubic yards in the driest years below the last affluent.	Difference between amounts in preceding column and a discharge of 1500.000 C. yds per hour.	Daily	Monthly
			Deficit which must be supplied from up a constant 1,500,000 Cubic yards	would have to be reservoirs to keep discharge of yards per hour.
			Cubic yards	Cubic yards.
December	2,250,000			
January	1,075,000	425,000	10,200,000	316,200,000
February	550,000	950,000	22,800,000	638,400,000
March	375,000	1,125,000	27,000,000	837,000,000
April	275,000	1,225,000	29,400,000	882,000,000
May	225,000	1,275,000	30,600,000	948,600,000
1st half of June	200,000	1,300,000	31,200,000	468,000,000
Total quantity to be provided in reservoirs				4,089,200,000

Between the 1st Barrier and the mouth of the Kranbeela it might be necessary to contract the navigable channel to rather smaller dimensions than those allowed for it below the Sebbery, to compensate for the diminished flow of the stream in that part of the River, the discharges here given in Column 1 being those below the confluence of the Sebbery.

52. The question now is the cost of storing such a quantity of water. The only thing that seems tolerably certain upon this point is that the cost

the cost would not exceed 1 Rupee per 500 Cubic yards, and that it might be very far below that amount, as much as one-half or one-fourth; as sites have been found where 1000 to 3000 Cubic yards might be obtained per Rupee. The presumption is that the cost of storing water on the principal affluents of the Godavery would be small, both because of the gentle declivity of their valleys, and the immense area in which to select sites. Any estimate now formed before the examination of a single site or even the search for one, must be mere guess work; but we may confidently reckon on 1 Rupee per 500 Cubic yards as the very extreme cost, with full expectation of accomplishing our object for one-half that amount.-
At this rate the above quantity would cost 80 lacs. If however we wish to compare the cost of this mode of improvement with that of dams and slackwater, this extreme figure should not be taken, but rather one more within the limits of probability. Perhaps 60 lacs might be assumed for this purpose.

53. It is important however to point out here, how enormously the cost of the improvement is increased by making the river navigable for 12 instead of 10 months. The above table shews that the quantity of water to be artificially provided for the last two months of the hot season would be 1916 millions Cubic yards, or almost one-half that required for the whole year. In other words the extension of the time of navigation for this short period doubles the expense of the most costly part of the works.
It is quite probable that it will eventually be worth while to pay 20 or 30 lacs more to make the communication perennial, but nothing seems to me more certain than that this is a consideration which may be wholly set aside at present as of no importance whatever, and that a 10 months navigation for boats drawing 4 feet of water will meet all the wants of that part of India for at least a generation to come.

54. The value of the water for irrigation has also to be taken into account. Probably three-fourths if not the whole of the quantity which it is proposed, as above, to throw into the river, would be required for the Delta lands alone, especially if the Anicut proposed by Sir A. Cotton be constructed at the outlet of the Hills, by which probably another 200,000 acres would be irrigated. Already though only a part of the land under the Dowlaishwaram Anicut has been brought under irrigation, the deficiency of the

demand

summer supply of water is beginning to be seriously felt, and has been in one year at least a cause of actual loss of revenue. Without therefore taking into consideration the requirements of the upper country, portions of which at the three barrages will no doubt be eventually watered by extensions of the navigation Canals at those points, it appears that the greater part, if not the whole cost of the scheme now under consideration for the improvement of the river might be charged to the irrigation, as it is certain that the water so applied would be abundantly remunerative.

55. I can only briefly glance at the incidental but most important benefit which attaches to this system of affording a means of restraining the violence of the floods. We are not yet in a position to discuss this part of the subject, but the materials are gradually accumulating for an accurate investigation of it. In France the problem of checking the devastations caused by the floods of the Loire by this method was in 1859 being carefully worked out by one of the most Eminent of the Corps des ponts et Chaussées and will no doubt furnish valuable results. A similar investigation was, I believe, being conducted in the valley of the Rhone.

In this

In this Country it would be interesting to know the actual amount of damage done by a single flood. I suppose that of the Godavery in the present year has cost the Government 50,000 Rupees in the Delta alone, while no estimate can be formed of the value of the property destroyed along the whole length of the River.

However, half a Lac is the interest on 10 Lacs, and as there was a more destructive flood only 11 years ago when the remissions of Revenue in consequence in Rajahmundry were heavy, probably 30 Lacs would be the principal represented by the loss to Government from the Lacs during the brief period of 10 or 12 years.

56. I will offer but one consideration in this part of the subject.

The Godavery in the delta when in full flood has a width of about 2½ miles, and a surface velocity of 4½ miles per hour. The last 2 feet of its rise it has maintained for more than 48 hours, and is during this time that all the damage is done

To prevent the river rising the last two feet we should have to draw off from it for 48 hours at the rate of 11,616,000 Cubic yards per hour, or 55 7/12 millions of Cubic yards altogether. To what extent may the retention of 4000 millions Cubic yards in reservoirs be expected to contribute towards such a result?

57. There is one more Consideration worthy the attention of those who may still doubt the possibility of making an Indian river navigable during the low-water months by any Method or at any expense, and that is the safe because progressive character of the method we have been investigating.

It is easy to ascertain what quantity of water over and above that which the river supplies in the dry months we require for irrigation, and having Dams and Constructed the necessary reservoirs, we can then pour this quantity into the river, and ascertain by actual observation the effect it produces on the navigation as it passes on its way to the land it is intended to fertilize or reclaim. If the result is unsatisfactory we shall have lost nothing. If on the contrary our expectations have been realized, we shall have our improved Navigation for nothing and may proceed with confidence in the same course to whatever extent the exigencies of the trade and the requirements of the Country may demand. There need be no fear of our embarking in an unlimited expenditure upon works of doubtful utility. Our work will pay as it proceeds, and its efficiency be practically tested at every step.

We may now compare the cost of the two systems, which is as follows

	Dam and Slackwater.	Reservoirs
Anicuts	252 lacs	
Training Walls	10	31½
Clearing Channel and protecting banks	3	3
Storing water	6	60
Total	271 lacs	94½ lacs

But if, as we may fairly do, we charge the whole cost of the water in the one case, and half of it in the other, to irrigation, the respective costs would be 265 and 64½ lacs.

If to these amounts we add 40 lacs for the works at the Barriers, allowing for a probable increase of one third above the rates in the original estimate, we find the whole cost of rendering the river navigable to be

	Lacs
1. by Dam and Slackwater for 12 months.	305
2. by Reservoirs. for Do. —	104
3. by Do. ——— for 10 months.	89

Of course this is merely an approximation, but it should be borne in mind that while the cost in the first case would not be less than that stated, there is a fair probability of its being considerably less in the other two.

59 On a review of all that has been said for and against the two systems proposed, I think there can be no question of the superiority of that of Reservoirs, and I am accordingly

recommend it for adoption. It is very possible that it might be modified in some of its details as additional information is obtained. The Anicut at the entrance of the Rajahmundry Hills has been strongly recommended, and an examination of that project by means of levels and surveys might be undertaken whenever there are men available for the purpose. On the Wardah also it might be found that Anicuts might be constructed with advantage as the fall of that river is slight and its width narrow. All these are details which a careful instrumental examination of the localities will alone decide, and they need not occupy our attention at present. The first thing to be done is to open the Mantoor navigation by means of the works at the three barriers, the next to clear and regulate the channels in the open parts of the river, and the next to increase the flow of the streams to the extent required in the first instance for irrigation in the Delta and afterwards for the navigation in that tower

degree the latter may be found to require.

These improvements may be carried out successively or simultaneously according to the amount which the Government may see fit to allot annually to the purpose.

60. Any discussion of the value of the Communication to improved would be foreign to the object of the present paper, and indeed unnecessary, as the Government is, I believe, fully satisfied on this head.

61. It only remains to consider the question of the size that should be given to the locks at the barriers and that of making the canals at those points practicable for cargo boats only.

With regard to the former, I think that the width of opening between the gates which originally recommended, 45 feet, might very well be reduced to 30 feet, and that steamers of equal power might still be used by employing them instead of side-wheelers. There are some important advantages belonging to the former class of vessels, which the experience of the North American rivers, where they have been many years in use, and are now found literally by hundreds of all sizes up to 600 and 800 tons, fully establishes.

Owing to the full lines with which they are built at the stern, where the width is but little less than Amidships, they carry an equal load on a less draught of water with the side wheelers, an important consideration in a navigation of limited depth. They have also another peculiarity, which has been fully proved, that in the ascent of a rapid current they make better way than side-wheelers of equal power.

In the case of the Godavery their adaptation to Canal navigation would be an especial recommendation, for at the three barriers there will not be less than 55 miles of Canal, and in the event of the construction of an additional anicut in Rajahmundry, another 60 miles from thence to the Port.

The latter however would be only a boat Canal in the first instance

but might eventually be adapted to the use of steamers.

62. A steamer with side wheels requires a broad channel to work in safely, and is at all times liable to injury wherever it is compelled to pass through narrow passages, such as locks and canals of limited width, a liability which of course increases with the increase of traffic.

A sternwheeler on the contrary may pass with safety through any passage a few inches wider than her own clear width amidships. The wheel is removed from all chances of damage from collision with another steamer in a canal or with the wall of a lock, or with the bank of a river in rounding to, in a current at a landing place. The action of the wash produced by the passage of a steamer on the canal banks would also be less in the case of a stern-wheeler than of a side-wheeler.

63. There are no practical objections to such steamers. They have long been used, as I have said, on the

American rivers, and on the Upper Ohio and smaller tributaries of the Mississippi are more in vogue than any other class of boats. They are not generally built for speed, being used chiefly as cargo boats, but have usually a speed of 9 to 11 miles an hour. There is no reason however why they should not be built with a much higher speed than this.

64. I am the more inclined to accede to the reduction in the size of the locks proposed by the Chief Engineer, from the fact that with such diminished widths greater lifts would be practicable than those originally proposed, a consideration which is important as excluding the flood water as much as possible from the locks, to prevent silting, strongly recommends.

× 10 feet.

65. I would propose therefore 30 feet by 200 feet in the clear for the dimensions of the lock chambers.

66. The Government wish me to revise my estimates for the works at the 1st Barrier by diminishing the section of the Canal and the lift

of the locks to that which would be sufficient to pass the largest Cargo boats which are likely to be employed in the river. I am of course prepared to do this if the Government should still think such an alteration of the original design desirable, but I am myself opposed to it for the following reasons.

67. The only thing that would be gained by such a course would be the saving it would effect in the time and first cost of Construction, but I am disposed to think that such saving would be Comparatively trifling while it would involve an ultimate increase of expence in the Cost of the works, and for a time in the Cost of transport by the river.

68. The Canal runs parallel to the river and within 200 to 300 yards of the bank, which is intersected at short intervals by deep gullies formed by the drainages which empty themselves into the river at these points. My intention has been to make use of these openings for the

purpose of running off the earth excavated from the Canal out into the river on trucks, instead of raising it by hand in the usual manner heights of 18 to 24 feet. I calculate on a Considerable saving of expence by this Method, which would be applicable to about half the total excavation of the Canal, and my estimates were made accordingly. If however we cut the Canal in the first instance to only half (8 yards at bottom instead of 15) its full width, we should eventually complete it at a greater expence than would be necessary if the whole were done at once. This is not perhaps a very important Consideration if the gain in the time of opening the Communication were Considerable, but the probability is that the saving would not amount to more than 2 or 3 years for the whole line, during which time we should have the railroads now under Construction as substitutes for the Canals.

It is true that the Cost of Carriage by the former would be greater than

by the latter, but on the other hand by making the Canals and locks of their full size at once we shall be ~~xxx~~ hastening the time when Continuous navigation by steamers will be practicable, when it will no longer be necessary to have them stationed in the reaches between the barriers, and when the additional expense which this arrangement involves will be done away with. I look upon this as a most important Consideration, one with which the saving in expense in Carriage by Canal instead of tramway is of little consequence.

69. I think that if it were known that for many years to come steamers could only ply in the navigable reaches between the barriers it would act as a great discouragement to private enterprize, for in order to do the same amount of work it would be necessary to have nearly double the number of steamers in the one Case as in the other. A disabled steamer in one reach could not be replaced by one from another under a year in most cases, so that there would either be the constant risk of complete interruption of the Communication for that time, or additional steamers must be stationed in each reach to provide against such a contingency. Were the trade on the river considerably developed the extra expense which this would involve would not be so great, but a Company starting with four or five steamers would, if Continuous Navigation were impracticable, have to provide eight to do the same business.

Extra establishments would also be required at the three Barriers and probably workshops for repairs, while there would be a frequent loss from detention of the steamers in Consequence of the inevitable unpunctuality in the times of arrival and departure at eight instead of only two termini.

All these inconveniences and sources of extra expence would of Course attach to the working of the river with

the tramways, but the sooner we can dispense with them the better, and the saving which would be effected for two or three years by Canal instead of tramway Carriage would not in my opinion by any means justify the postponement of the works required for the Completion of the project according to the original design.

70. It is certainly the case that there has hitherto been the greatest difficulty in procuring labor for the works at the 1st Barrier, and that the supply during the past year has been lamentably inadequate to our wants and expectations; but on the other hand we can scarcely judge from the result of the first year's operations only, in a country so inaccessible and so new to the inhabitants of the more populous districts surrounding it, what our future prospects in regard to the supply of labor are likely to be. Moreover, if the Government carry out their present intention of prosecuting the works at all the three barriers simultaneously, a largely increased amount of labor would certainly be available.

The Construction of the tramways at the two upper barriers has already attracted from 1500 to 2000 people from the neighbouring districts, who would most probably not have come 100 or 150 miles further down river to the work at the 1st Barrier.

I know in fact that large numbers of those employed at the 2nd Barrier refused to come down to Dumaguete, even when tempted with the offer of an additional rupee per month.

I believe therefore that were the permanent works commenced at these three points at once very much larger numbers would be attracted than would be the case if the field of operations were limited to its present extent.

I would therefore respectfully suggest that the Government should reconsider this part of the proposed arrangements, and that the Canals and locks should be at once constructed of the full size which it is intended

to give them -

I have the honor to be
Sir
Your most obedient Servant
Thos. J. Captain
District Engineer Mobile Godsam.

Chepauk
3rd February 1862.

No 8.

From,

Lt. Colonel Buckleburg
Ag. Deputy Chief Engineer
Northern Circle

To,

Lt. Colonel Moseley
Chief Engineer & Secy to Govt.
D.P.W.

Sir,

With reference to Order of Government No 83 under date 21st January 1862, I have the honor to submit for their consideration the accompanying letter from Captain Hall, District Engineer of the Cuddapah Godavery, of this days date.

I have the honor to be
Sir,
Your most obedient servant

Hall Buckleburg Lt. Colonel
Ag. Dep. Chief Engineer
Northern Circle.

Recommendation

Captain H. L. Hall
District Engineer
Cuddapah Godavery.

Lt. Colonel Buckleburg
Ag. Chief Engineer
Chepauk.

Date 3rd
Rec'd February 1862

P.W.D. 24/62.

Submitting the above letter from Captain Hall for consideration & the Government Resolution as noted in the margin.

Signature illegible

Public Works Deptt

No 324.

Proceedings of the Madras Government

Under date the 28th February 1862.

Read the following

papers.

From the Actg Secy Chf Engr N.C.

Submits letter from

Captain Haig setting forth

his views on the several points (Here enter 3 February 1862

laid down by the Governor in No 81

his minute on the Cossyer

Godavery works.

Minute by the Honorable the

President (Here enter 10 February 1862)

The Governor in

Council having attentively

considered the Report drawn

up by Captain Haig in

reference to the Proceedings

of Govt No 83 dated 30th

January 1862 they are now

prepared to submit certain

recommendations

Rec'd 30 January 1862 & Para 103-104.

Submitted 12 Feby 1862.

From the Actg Secy Chf Engr N.C.

Submits letter from

Captain Haig

Recd 30 January 1862.

Read the following papers.

Minute by the Honorable the President

Recorded in Consultation Book

No 8.

Recd 12 Feb 1862.

Fabricius Pillai

Assistant Secretary

Forwarded for information with reference to the Proceedings of Govt No 83 of 30 January 1862

12 Feb 1862

Rec'd 14th Feby 1862.

No 324 - 28 Feby

Para 103.

recommendations with Regard to the prosecution of the Works in the Upper Godavery for the consideration of the Govern- -ment of India and of the Right Honorable the Secretary of State for India.

The Govt having in Ex minr Corr No 961 dated 19th May 1857 directed "that the plans for improving the Summer Navigation should not now be taken up, but that Captain Haig's attention should be confined to the improvements of the Monsoon navigation, the information in their possession at present which may be relied upon is limited to the latter part of the subject and is as follows:-

1st An accurate survey of the River from Sowlaishwaram to Chanda.

2nd A series of levels which have been verified and can be depended on from the same place to the third Barrier;

3rd Plans in detail with accurate sections of the ground at the first and second Barriers;

4th Plans and Estimates of the Works to be executed at the 1st or Sinteralla Barrier upon the supposition that the Locks were to be 200 feet long & 45 feet wide;

5th Information sufficient for the construction of the Tram Roads round the 3 Barriers, of which those round the first and second Barriers are rapidly progressing. &c &c

A good Bandy track will

will be made round the
third, — as it is possible
that the Tram roads
will not be completed
this year.

As respects ad-
-ditional works required
for the full development
of the Project, such as
those for the storage of
water to complete —
summer navigation,
and for the extension
of irrigation; the
anicut at the exit —
from the Mountains
suggested by Colonel
Sir A. Cotton and
its subsidiary works;
and the works requi-
-site to perfect the
navigation from the
Head of the S. Barrier
to the point to which
it

it may be considered
advisable to carry
the improvement
of the River, say
to Hingni ghat,
the information is
of a more general
description.

That the
application of water
to the land yields
an ample return
for the money invested
is a fact well known
and one which has
been abundantly —
proved by the very
large returns already
made by the Anicut
and Delta works
in the Godavery Dis-
-trict; that — there will
be traffic sufficient —
up

up and down the River
to pay not only the cost
of transit but also the
interest upon the capi-
-tal employed in im-
-proving the navigation
can at present only be
inferred, as the Govern-
-ment have no data
upon which to form
an Estimate. The Hon'ble
the Governor in Council
therefore is of opinion
that in carrying out
the works for the im-
-provement of the na-
-vigation, the various
profitable uses to which
the water may be
turned should be kept
in view; that the
scheme should be
framed upon such
a comprehensive plan
as

as will enable
Government to form
a correct idea of
the benefits which
are likely to result
from it to the Country
and that a reliable
Estimate should
be prepared of
the outlay which
such a scheme
would entail, and
of the time it would
require for its
completion.

When the
whole is thus
clearly placed
before the Govt
it will be in
a position to
decide

decide whether the advantages held out are such as would justify the outlay of any given sum of money, and whether that money should not be borrowed on the security of the Government in order that the work may be prosecuted with vigor, and brought to completion in the shortest possible time.

To obtain the requisite

requisite information it is necessary
1st to employ parties to complete
the Survey of the River from
the head of the 3d Barrier to
Singenghati
2dly to Survey and level the
Country to the right and
left of the river below it's
debouchure from the
mountains in order to ascertain
the Character and extent of
land which could be brought
under Cultivation supposing
the anicut to be raised 25
feet above summer level;
3dly to inspect the Country to
the Northward and westward
about the heads of the
affluents of the Godavery

for

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3dly to inspect the Country to
the Northward and westward
about the heads of the
affluents of the Godavery

for

for the purpose of ascertaining the most favorable positions for storing water to be passed down the river in the dry season for irrigation purposes, and at the same time to maintain a sufficient depth of water for navigation; —

4th to inspect the Course of the river between its exit from the mountains and Singanghat for the purpose of determining the sites at which it would be desirable

desirable to construct anicuts and Locks, should this mode of rendering the River navigable be considered preferable to that proposed by Captain Haig.

As respects the works to be proceeded with in the meantime, it must be borne in mind that whatever plan it may be decided eventually to adopt, the mode proposed by Captain

Captain Craig of surmounting the three Barriers is the only one worth consideration; the Anicuts Locks and Canals at these points is must form part of any scheme for the improvement of the Navigation- The first thing Captain Craig has to do is to Complete the tramroads round the 3 Barriers- When he has thus secured the means of bringing down the Cotton of 1862 during the monsoon freshes he can proceed to the

the Anicuts and other works at all 3 Barriers, as rapidly as the means placed at his disposal will allow- The only question which is of any importance in relation to these is the dimensions to be given to the Locks

Under the circumstances stated by Captain Craig the Govt are disposed to think that in order to avoid all chance of failure in getting Steamers above the Barriers, at all times of the year, it will be better to make these Locks of the dimensions now recommended, viz 200 feet long by 30 feet wide

wide. This will of course necessitate a corresponding width being given to the Canals

The following then is a summary of what I would recommend to be done for the improvement of the navigation and irrigation of the Godavery:-

1st That Captain Haig should be empowered to carry out the works at the three Barrais on the scale mentioned above that is, that the Locks and Canals should be made capable of passing Steamers of

of nearly 200 feet long and 30 feet wide;

2nd That he should be directed to revise his Estimate for the works at the Sinteralu Barrier, substituting Locks 30 feet in width for those shewn in his original plan, which are 45 feet wide;

3rd That he should be directed to send in as soon as possible detailed Plans & Estimates for the works at the 2nd & 3rd Barrais;

4th That the Survey of the river should be completed thoroughly, a special Survey being made of the Sites —

where Anicuts may
have to be constructed;
5th That a distinct
party should be em:
:ployed to survey the
upper part of the afflu:
:ents of the Godavery
with a view to the
discovery of spots where
water may be stored
in large quantities;

6th That a separate
party or parties
should be detailed for
the survey of the site
of the Anicut at the
exit of the river from
the mountains and
for that of the land
to the right and left
of the river which
might

might be brought under
the influence of the
water passed by the
Anicuts;

7th That Captain
Haig should be
directed to keep the
cost of the execution
of the work altogether
separate from that
of preliminary sur:
:veys and Levels, and
also from that of the
Conveyance of Goods.

The cost of the Steamers
now lying between the
barries and that
of the boats con:
:structed or being

constructed should be
debited to Traffic
and this had better
be done from the
commencement of the
Calendar year 1862.
It is desirable that
preparations should
be made at once
for the possible traffic
which may pass down
the river during the
next monsoon freshes.

Reference will
be at once made to the
Governor General in
Council for leave
to employ such parties

as have been mentioned above in the different surveys, on estimate of their cost being furnished by the Deputy Chief Engineer, and should the sanction of the Government of India be obtained thereto, the work should be pushed forward with all possible speed in order that in the course of the present year sufficient information may be obtained to enable the Govt. to come to a definite understanding upon the whole scheme —

E. W. P.

To
The Deputy Ch. Engr. N. Circle with 2 Plans
" Chief Engrs Dept 28th

Copy of Letter & Ltr. 1862 No. 23

29-11-11 B.II

Regarding the Upper Godavery Works

Public Works 1862 Dept.

Pro: of Govt. for Feby.

No. 324.

Pro: of the Madras Govt.

D/ 28: Feby/62.

Letter from the Deputy Chief Engineer Northern Circle on the subject of Godavery works with an order thereon.

No. 437 at 439.

Ch. 1 Feby 27th