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# REPORT

ON THE

# TANSA

WATER SUPPLY PROJECT.

OCTOBER 1885.

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MUNICIPAL COMMISSIONER'S OFFICE,  
BOMBAY, 13<sup>th</sup> October 1885.

TO THE CHAIRMAN, MUNICIPAL CORPORATION.

SIR,—I have the honor to submit, for the information and consideration of the Corporation, the result of Mr. Clerke's revision of Major Tulloch's Tansa Project, together with Mr. Forde's remarks thereon. For details and technical information I rely upon a reference to Mr. Clerke's careful report and Mr. Forde's comments. I will briefly lay before the Corporation the main features of the scheme and the points to which I think special attention should be directed. The three important particulars in which a modification is proposed in Major Tulloch's original project are—

- (a.) The alteration necessary for commanding the present reservoirs, which did not exist and were not contemplated when Major Tulloch prepared his report.
- (b.) The plan of crossing the Bassein Creek by means of a bridge instead of a tunnel.
- (c.) The substitution, as far as possible, of conduits for tunnels.

2. The area of the proposed lake,\* with the dam raised to the highest level ultimately contemplated—and this is the area which it is now proposed to acquire—is 8 square miles; the area from which the rainfall is to be collected is over 52 square miles; the available supply is, after making deductions for evaporation, &c., equal to 68 million gallons per diem for 365 days, and is practically equal to 100 million gallons per diem, because, notwithstanding the draw off during the rains, the rainfall† is sufficiently abundant to ensure the lake being full at the end of the rainy season, and thus the supply stored is only required, until replenished by another rainfall, to meet the demand of 240 days instead of 365. Thus it may be taken as certain that the capacity of the lake is amply abundant for all future requirements. The height of the dam adequate to impounding the maximum quantity of water will be 425 T.H.D., or, in other words, 133 feet above the bed of the Tansa River at the site of the dam. It is proposed so to construct the dam, the minimum height being in the first instance 401 T.H.D., or 109 feet above the river bed, that if not carried to the full height in the first instance, it may admit of being raised hereafter as may be found expedient.

Lake and dam.

Means of communication from the dam to Bombay.

3. From the site of the dam to the boundary of the Island of Bombay the distance is 53½ miles. The means proposed for conducting the water from one point to the other are tunnels for 2½ miles, conduits for 26½ miles, and iron pipes for the remaining 24½ miles. The water will be so brought into Bombay as to command both the existing reservoirs at Malabar and Bhandarwada Hills, and the estimates provide for subsidiary pipes being laid of adequate capacity for this purpose.

Capacity of tunnels.

4. The capacity of the tunnel as designed is sufficient to deliver 33 million gallons daily, or about 45 gallons per head (in addition to all present sources of supply) according to the population returned in the last census. The reason for constructing a tunnel of a larger capacity than may be required in the first instance to deliver a supply adequate to the immediate wants of the population is, as explained by Mr. Clerke, twofold; first, the enlargement of the tunnel hereafter would be impossible without stopping the supply; and, secondly, a tunnel of less dimensions than those proposed would probably not be less expensive to construct.

\* NOTE.—The proposed lake is situated behind the Mabul range, noticeable from the main line of the G. I. P. Railway between Wasind and Atgam stations, the latter being the station nearest to the site of the dam.

† Mr. Clerke has estimated the rainfall at 100 inches, and Mr. Forde agrees that this is a safe estimate. The rainfall of the present monsoon—not a favorable season—is shown by actual gauging at Borala in the centre of the catchment area to have been 108 inches up to date.

Capacity of conduits.

5. The capacity of the conduit as designed is sufficient to deliver 26 million gallons daily, or about 34 gallons per head (in addition to all present sources of supply) according to the population of the last census. This, no doubt, will prove amply sufficient for many years to come, but as the difference in the cost of constructing the conduit in the first instance to the same capacity as the tunnel would only be two lakhs, whereas it would be far more expensive to make the alteration afterwards, and because "it would not be an easy matter to do it

Mr. Clerke's Report, para. 50.

afterwards without interfering with the water-supply of the city," I entirely agree with Mr. Forde that the extra height should be provided in the first instance.

Quantity of water available.

6. We thus have a lake area capable of giving 100 million gallons daily; and 23½ miles of tunnel and conduit capable of giving 35 million gallons daily; and the cost so far, (i.e. of acquiring the lake area and of constructing the tunnels and conduits) inclusive of contingencies, will according to Mr. Clerke's estimate, be Rs. 34,33,000. The variable quantities which now have to be determined are the height to which the dam should in the first instance be raised and the size of the pipes which should in the first instance be laid. The determination of these points must rest upon a consideration of the probable wants of the population and upon financial possibilities.

Quantity required per head.

7. Experience of the inadequacy of the present supply, even with recent improvements, to meet increased local requirements, and a study of similar experiences in other cities, has convinced me for some time that the needs of the city demand a supply not far, if at all, short of 30 gallons per head, and therefore I have from the first urged that no new scheme should be considered which would not ensure a *minimum* delivery of 10 gallons per head in addition to our present supply. A supply of 8 million gallons daily would yield, according to the population by the last census, 10·34 gallons per head, and, according to the most recent computation, our present supply per head of the same population is 18·43 gallons. The total available quantity would thus be 28·77 gallons per head daily. The height of dam capable of impounding the *minimum* addition so calculated must, as already stated, be 401 T.H.D., or 109 feet above the river bed, and the cost of this dam as estimated will be, inclusive of the proportionate share of contingencies, Rs. 29,00,000. The cost—similarly calculated—of iron pipes (a 36" main will be required to bring this minimum quantity to Bombay) will be Rs. 35,33,000, and the cost, also inclusive of contingencies, of crossing the Bassein Creek will be Rs. 3,44,000. Thus the entire cost of the work to meet the lowest possible estimate of present requirements will be Rs. 1,02,10,000. Of this sum, we may take, as common to any scheme that may be adopted, the cost of the dam up to the minimum height and the cost of bridging the Bassein Creek, in addition to the items mentioned in the preceding paragraph.

Cost of eight million gallons scheme.

Requirements of increasing population.

8. The shortest possible time which may be expected to elapse between the commencement and the completion of the work is, I think, six years. By the end of that period the population, at the rate of increment observable between the last and the preceding census (and appearances do not justify the assumption of any lower rate of increment), will be 950,000. To this population the existing sources of supply will yield only 15 gallons per head, and the addition of 8 million gallons from Tansa will yield 8·42 gallons per head. The total supply per head upon the completion of the work would thus be 23·42 gallons per head. Though I would most strongly advocate that a scheme, capable such as this is of almost illimitable expansion hereafter, should be immediately undertaken to give even this addition to our supply an addition the need of which will be felt increasingly year by year I must avow, after mature consideration, that I do not think this addition will suffice for our wants; and to avoid disappointment, delay, and greater expenditure hereafter, I venture to urge upon the Corporation the wisdom, if financial difficulties can be overcome, as I hope they may be, of proceeding with the larger scheme explained by Mr. Clerke in his report and recommended by Mr. Forde—that by which 17 million gallons of water may be brought in from Tansa in the first instance. This would involve the construction of the dam to a height of 408 T.H.D., or 116 feet above the river bed, and the substitution of 48" for 36" iron pipes. The additional cost on account of the former item would be Rs. 3,40,000 and of the latter Rs. 17,50,000, and the total cost of the project as thus extended would be Rs. 1,23,00,000. I must not omit to notice a con-

Cost of seventeen million gallons scheme.

sideration, which the Corporation will concur with me in thinking one of very great importance, namely, that although the 17 million gallons scheme would cost only Rs. 20,90,000 more than the 8 million gallons scheme if adopted from the commencement, the cost of subsequently converting the smaller into the greater would be, if the price of iron remains as at present, Rs. 38,50,000. This difference is attributable to the fact that the aggregate cost of two mains is far greater than the cost of one main of equal carrying capacity. No sooner would the 8 million gallons scheme be completed than the Corporation would find themselves face to face with the necessity of extending it at an expenditure of 17½ lakhs more than the larger project would have cost if undertaken in the first instance.

9. Before I proceed from the question of subsequent extensions to other branches of the subject, I may give certain information as to the future capabilities of the project which will have more than a passing interest to the Corporation. It has been explained that the maximum carrying power of the proposed tunnels and conduits is 33 million gallons daily. I will state what approximately the cost would be, supposing either the 8 million gallons scheme or the 17 million gallons scheme to be adopted in the first instance, of extending it afterwards to the full carrying capacity of the conduits, as also to an intermediate quantity of 26 million gallons.

Subsequent extensions and disposal of surplus water.

- (1) Supposing the 8 million gallons scheme to be in existence, it would be necessary, (a) in order to extend the supply to 26 million gallons, to raise the dam 7 feet (the same height as would be required for the 17 million gallons scheme in the first instance) and to lay an additional 48" main to Bombay; and, (b) in order to extend the supply to 33 million gallons, it would be necessary to raise the dam 10 feet and to lay two additional mains to Bombay, one of 48" and the other of 36". The cost\* of these extensions would be 54 and 85 lakhs, respectively.
- (2) Supposing the 17 million gallons scheme to be in existence, it would be necessary, (a) in order to extend the supply to 26 million gallons, to lay an additional 36" main to Bombay; and, (b) in order to extend the supply to 33 million gallons, it would be necessary to raise the dam 3 feet and to lay an additional 48" main to Bombay. The cost\* of these extensions would be 33 and 58 lakhs, respectively.

Mr. Forde has alluded to the likelihood of finding a market for the profitable disposal of surplus water. As to this I am not at present in a position to offer any opinion, but the greater publicity that can be given to the capabilities of the project the better; and in relation to them I may mention that if the dam were raised to the full ultimate height proposed (425 T.H.D.),—and, supposing the 17 million gallons scheme with dam to the height of 408 T.H.D. to be adopted in the first instance,† this could be done at an additional cost of 5½ lakhs—there would be a stored balance of water, over and above the 17 million gallons available for consumption, equal to 1,000 horse power, at the foot of the dam, and equal to 800 horse power even after the daily draw off should have been extended to 33 million gallons. Below is a note‡ which at my request Mr. Clerke has given me on this subject. As the Corporation are probably aware, a company has already been formed for utilizing the water-power below the dam of the Kharakwasla lake.

\* In each of these estimates is included the cost of a corresponding increase in the capacity of the mains to Bombay to the reservoirs; also contingent and establishment charges.

† Mr. Clerke's note is as follows:—"The dam, if raised to proposed final height, that is, full supply level at R.L. 420, would give an available supply of 25,000 million of gallons, which is equal to 68 million gallons per day for 365 days (see clause 1, para. 45 of report); 25,000 million gallons is equal to 4,000 million cube feet.

"Suppose the consumption for Bombay is 17,000,000 gallons per day, and that it is required for 240 days; this would consume 654 millions of cube feet, and the stored balance would be 3,546 millions of cube feet. This balance is equal to 161 cubic feet per second for 240 days. Taking the water level of the lake at 10 feet above sill of outlet, or R.L. 390, and assuming the water to be converted into power at a height of 38 feet above the bed of the river, or R.L. 350, it would give 660 H.P. according to the rule adopted by the Government of India, namely, that 15 cube feet per second falling through 1 foot is 1 H.P. If calculated on the ordinary standard of 33,000 foot pounds per minute, it would give more than 1,000 H.P. Suppose the consumption in Bombay is 33,000,000 gallons per day, and that it is required for 240 days; this would consume 1,298 millions of cube feet, and the stored balance would be 2,902 millions of cube feet. This balance is equal to 130 cube feet per second for 240 days. Converting this into H.P. as before, it would give, according to Government of India's standard, 516 H.P., and according to the ordinary standard 800 H.P.

‡ The extra cost of raising the dam from full supply level 405 to full supply level 420 would be 5½ lakhs of rupees."

Financial require-  
ments: terms and  
period of loan.

10. It has been shown that, on the lines proposed, an 8 million gallons scheme is estimated to cost Rs. 1,02,10,000, and that a 17 million gallons scheme is estimated to cost Rs. 1,23,00,000, and it is believed that the estimates are in both cases based on rates amply sufficient to leave a safe margin. The capital would be required in instalments, the probable amounts of which are shown below, spread over seven years. Considering the nature and magnitude of the proposed work, I think that sixty years, commencing from the end of that period, will not be regarded as an unduly long term for the repayment of the required loan, principal and interest. I assume, however, that the interest due on each instalment, as it is taken up, will be met out of the Municipal Fund, and therefore no addition need be made to the loan capital on account of interest during the period of construction, as might be inferred from the 20th paragraph of Mr. Forde's report. The following table exhibits the payments which would devolve upon the Municipality for either the smaller or the larger scheme, the rate\* of interest being either  $4\frac{1}{2}$ , 5, or  $5\frac{1}{2}$  per cent.

Year from commencement of Work.	8 Million Gallons Scheme to cost Rs. 1,02,10,000.			17 Million Gallons Scheme to cost Rs. 1,23,00,000.				
	Capital required in Lakhs.	Annual payment on account of Loan with Interest			Capital required in Lakhs.	Annual payment on account of Loan with Interest		
		At $4\frac{1}{2}$ per cent.	At 5 per cent.	At $5\frac{1}{2}$ per cent.		At $4\frac{1}{2}$ per cent.	At 5 per cent.	At $5\frac{1}{2}$ per cent.
1st Year .....	6	14,850	16,500	18,150	6	14,850	16,500	18,150
2nd " .....	18	71,550	79,500	87,450	20	76,500	85,000	93,500
3rd " .....	20	1,57,500	1,75,000	1,92,500	20	1,66,500	1,85,000	2,03,500
4th " .....	20	2,47,500	2,75,000	3,02,500	25	2,47,275	2,74,750	3,02,225
5th " .....	20	3,37,500	3,75,000	4,12,500	25	3,86,775	4,29,750	4,72,225
6th " .....	14	4,12,650	4,58,500	5,04,350	20	4,80,000	5,40,000	6,00,000
7th " .....	4	4,50,720	5,00,800	5,50,880	7	5,34,825	5,94,250	6,53,675
8th year and succeeding 59 years.	59	4,94,718	5,39,375	5,85,105	...	5,95,988	6,49,786	7,04,677

11. It is questionable whether the Municipality would be able to obtain on terms at all suited to their means the large sum required for the Tansa project except with the assistance of Government. I have made a representation to H. E. the Governor in Council on the subject, but am not yet in a position to say what measure or manner of assistance the Government of Bombay or the Government of India would be willing or able to render. I venture to think that the Municipality have good grounds for asking for assistance, both in consideration of the restrictions at present imposed upon them in respect to borrowing, investment and repayment, and still more in consideration of the circumstances under which the need arises for the loan which is now contemplated. If Government would agree themselves to advance the necessary funds at the rate of  $4\frac{1}{2}$  per cent., this is the form of assistance which would be most beneficial to the interests of the Municipality. The annual sum then payable from the completion of the work to extinguish the debt, supposing the 17 million gallons scheme to be adopted, would be, according to the foregoing table, Rs. 5,95,988. But it is also a matter for consideration whether Government should not be asked and might not be induced to allow the remainder of the present Vehar debt to be extended over the same period as the new Tansa debt. As the Corporation are well aware, the present annual payment on account of the Vehar debt is Rs. 1,75,000, and, according to the Government decision with respect to the recent controversy on the subject, thirty such annual instalments remain to be paid before that debt will be extinguished. So at the end of the seven years above mentioned (see table) the Corporation would be paying this annual sum for twenty-three years in addition to the Tansa annual instalments, whilst for the remaining thirty-seven years of the Tansa debt they would be paying the latter instalments only. It seems to me fairer that the burden should be equalized over the whole period of sixty years, and this might be done by extending the term for the re-payment of the balance of the Vehar debt, at the same rate of interest as at present, over the same period as the Tansa debt. As an illustration I may assume that the Tansa instalment

\* Note.—The forty lakhs recently taken up on account of the Sanitary Works Loan sanctioned in 1883 have been obtained at an average rate of  $5\frac{1}{2}$  per cent. interest.

is Rs. 5,95,988, as above calculated : for the first thirty years of this debt the burden on the Municipality in respect of their two great sources of water-supply will be (Rs. 5,95,988 + Rs. 1,75,000) Rs. 7,70,988, whereas if the period of the two debts be equalized, the annual payment will be (Rs. 5,95,988 + 1,14,922) Rs. 7,10,910 ; in other words, the new burden actually imposed will be Rs. 5,35,910.

12. The foregoing financial summary provides, I believe, for every head of outlay which is *absolutely essential* to the acceptance and introduction of the Tansa project, large or small. The Corporation have already before them my suggestions and the Town Council's recommendations as to the sources from which revenue may be most equitably and conveniently allotted to meet such an outlay, and my present report therefore need not deal with that branch of the subject. There are, however, two matters of no little importance to which special consideration must be given. The one is the acquisition of, or power of control over, the catchment area of the proposed lake; the other is the construction of a storage reservoir or a service reservoir, or both.

13. Over and above the 8 square miles in which water will be ultimately impounded when the dam is raised to the highest level, there are 44½ miles of water-shed. For more than one reason I regard the purchase by the Corporation of this large area as quite beyond the range of present practicabilities. Mr. Forde suggests that special powers should be obtained to ensure sanitary control, and also that the whole of the land might be reserved for forest. I doubt whether the latter course would be found feasible, and whether the hardship and expense entailed by it would not be more than commensurate with the advantage gained. As far as power of control is concerned, no legislative action is required, for Sections 144 and 146 of the present Municipal Act are at any rate as stringent and comprehensive as can possibly be desired. There is but one village of any size, and as this is on the extreme edge of the basin, its drainage will be carried away from the lake. The body of water impounded will be, as has been mentioned elsewhere, greater than that at Kharakwasla. In the watershed of the latter lake, which is more thickly populated than the catchment area of Tansa, no exceptional precautions have been adopted, and, as far as I am aware, no evil results have been anticipated or experienced. Having regard therefore to the large volume of water, the extreme sparsity of the population, and to the special powers which, in case of necessity, can be brought into operation under the present law, I think that no special estimate or provision on this account is necessary.

14. The question of reservoir accommodation is one that requires careful examination, and I have repeatedly discussed it, in relation to the Tansa project, with Messrs. Clerke and Forde, as well as with Messrs. Walton and Braham, whose intimate knowledge of our present means and requirements is most valuable. I am most anxious in anything that I say to avoid giving rise to the impression that I attach but little importance to the expediency of providing reservoir accommodation. I attach the very greatest importance to it, but I wish the Corporation clearly to understand that this consideration is not inseparable from the Tansa project. The issue is really one of financial ability. It will be incomparably better to proceed at once with the project, designed, as it is, to command the existing reservoirs on Bhandarwada and Malabar Hills than to delay it, because there may be great difficulty in financing the cost of a reservoir in addition to that of the lake and ducts. For years the city has had the boon of Vehar water without any reservoir, and when the Tansa water is brought in, the want of a reservoir for it will not be more but less urgent than in the case of Vehar. A reservoir is wanted for three purposes—storage, filtration and distribution—and I will briefly consider each requirement separately.

15. I think it is very much to be desired that there should be a storage reservoir capable of holding a week's ample supply, say, 210 million gallons. The reason for proposing Ghât-Kopar as a site for such a reservoir, as Mr. Clerke, in adopting Major Tulloch's proposal,\* has done, is that no nearer site will give so large an area at so high a level. A reservoir, however, at the level proposed cannot be commanded by the Vehar Lake, and it is a matter for grave consideration whether for *storage* purposes—that is to meet an emergency—the advantage of a site which can easily be commanded by Vehar does not

\* NOTE.—Major Tulloch, however, proposed a reservoir with draw off only at 230 T.H.D., whereas Mr. Clerke has proposed to draw off at 275 T.H.D.



outweigh the advantages of the higher level. Since Major Tulloch wrote his report, the two existing reservoirs have been constructed, and their joint capacity (including settling tanks, filter-beds and service tanks) exceeds the quantity which can in one day be delivered from Vehar and Tulsī together with the proposed 17 million gallons from Tansa. Therefore, when the Tansa works are completed, we can rely upon one day's ample supply being ready in reserve. If a very serious accident were to happen, say, for instance, an interruption to the means of crossing the Bassein Creek, not even a week's storage might suffice to remedy the deficiency, and then it would be found of the greatest service that the storage reservoir of the city should be capable of being replenished from Vehar, as it could be if it were placed at a lower level, and if a junction were made, as Mr. Forde proposes, between the Vehar and Tansa mains, where they run side by side near Kurla. A storage reservoir, such as I now speak of, would be emphatically an emergency reservoir, and the city would be in a much better position to meet an emergency by having a more assured supply at a moderate level than a less assured supply at the highest level. If on the grounds I have mentioned the balance of advantage be held to lie in favor of a storage reservoir that can be commanded in case of need by Vehar, the estimation of that advantage may justly be enhanced by this consideration, viz., that a site for such a lower level reservoir might be obtained much nearer at hand. There might be circumstances under which it would be of the greatest possible moment to have our reserve of drinking water within the island instead of beyond it, but apart from such special circumstances, it must always be better to have a reservoir as near as possible to the point where the water is required for consumption, because the expense of the delivery main (always larger than the supply main) is so much the less, and because, to use a colloquialism, the nearer the cup is to the lip the less danger is there of a slip. Again, if it be determined that the balance of advantage is not in favor of having a storage reservoir at the higher level proposed, but little would be gained by placing it at Ghât-Kopar, for Ghât-Kopar is only 4 miles nearer than Vehar itself, and it would possess as a reserve few advantages over the Vehar Lake. For these reasons I am not, as at present advised, disposed to recommend the Corporation, even if funds can be provided, to sanction any expenditure on a reservoir at Ghât-Kopar.

Filtration.

16. Next, I have to consider the question of filtration: and here I must again remind the Corporation that without any means of filtration the city will be no worse off in respect of the Tansa water than up to the present day it has been in respect of the Vehar water, and, *ceteris paribus*, the greater the volume the greater the purity. We have at our two existing reservoirs filter bed accommodation for about 12 million gallons, and new filter beds for 2 million gallons are already in course of construction at Vehar. There is also on the ground already belonging to us at the two reservoirs and now unused enough space for the construction of additional filter beds sufficient for the filtration of 12 million gallons, and such additional filter beds could be constructed, if necessary, at a cost not exceeding four lakhs. Moreover, the filter beds at Vehar can with ease be extended, and as more Tansa water is filtered at the Bhandarwada reservoir, so more Vehar can be filtered at Vehar: or the whole of the Tansa water can be filtered at Tansa, without any appreciable loss of head, at a cost not exceeding two lakhs, and can be served to the city direct or through the service tanks of the two existing reservoirs.

Distribution.

17. The scheme provides, as has been explained, for mains leading into both these reservoirs and capable of discharging 5½ million gallons into the Malabar Hill Reservoir and 11½ million gallons into the Bhandarwada Reservoir; it may be found desirable to increase the former and reduce the latter quantity. This arrangement will at any rate ensure these reservoirs being kept full, and any balance not required for them can be served through the mains direct, as until last year was done in the case of the Vehar water. But the service tank (filtered water basin) of the Malabar Hill Reservoir is already sufficiently capacious\* to accommodate the extra quantity which it is proposed to put into it, and at Bhandarwada a further extension of the service tank to suit the increased supply can, if necessary, be made on ground which has already been acquired by the Corporation. It may, however,

\* NOTE.—It will be necessary, however, to enlarge the outlet main from this reservoir, but this should be done in any case.

for this and other purposes be desirable to acquire the small remaining portion of the hill. As an alternative, though not a satisfactory one for a continuance, the present settling tank at this reservoir could be converted into a service tank for Tansa (it would be ample for the purpose), and the Vehar water could be delivered direct into the filter bed channel, for which the necessary means of communication have already been provided.

18. I have now said enough on the subject of reservoir accommodation to show (1) that any new expenditure on this account is not an indispensable feature of the Tansa project ; (2) that this subject still requires on its own account the most careful and comprehensive investigation ; (3) that, if necessary, the water can be delivered filtered at a cost of two lakhs of rupees. A complete inquiry will be made into the merits of various possible alternatives, and surveys are now in progress which will form the basis of a further report as to the most eligible site for a reservoir or reservoirs for all purposes. I think it is very probable that a site may be obtained in the Island of Bombay capable of giving sufficient area both for a service reservoir at the maximum level proposed and for a large storage reservoir which can be fully commanded by Vehar. But the subject is one which I wish to put before the Corporation deliberately and distinctly from the present one.

19. I see no object in entering into a discussion as to the comparative merits of the Shewla or Kaman projects as a new means of water-supply to Bombay. The Corporation are well acquainted with all that Major Tulloch said on the subject, and they now have the unbiassed opinion of Mr. Forde and Mr. Clerke. It would, in my opinion, be waste both of time and money to enter upon a new series of surveys and reports. Next month Mr. Clerke will proceed to lay down the precise line of duct from the Bassein Creek to Bombay, and will have the necessary surveys and borings taken, in order to prepare a detailed

Actual work should be begun this season.

Para. 33 of Mr. estimate of the bridge for carrying the pipe over Clerke's Report. the creek. He is now engaged in making ready the detailed drawings and specifications for the dam, tunnels, conduits and pipes. There is nothing, therefore, to prevent tenders from being invited for the longest and most important parts of the work as soon as I receive the necessary authority from the Corporation and from Government ; and if the Corporation approve of the project as now submitted to them, it is of the highest importance that the ensuing season should be utilized for laying the foundations of the dam in the bed of Tansa River.

I have the honor to be,  
 Sir,  
 Your most obedient servant,  
 E. C. K. OLLIVANT,  
 Municipal Commissioner  
 for the City of Bombay.

BOMBAY, 22nd September 1885.

FROM ARTHUR W. FORDE, ESQ., M. INST. C.E.,  
Consulting Engineer to the Bombay Municipality,

To E. C. K. OLLIVANT, Esq., C.S.,  
Municipal Commissioner.

SIR,—I have the honor to enclose herewith Mr. Clerke's report on the subject of the Tansa project for the water-supply of Bombay, which he has requested me to forward to you after perusal.

2. As it is a very important matter, I have considered it very carefully, and gone into the matter as fully as the materials at my disposal would admit of, as the surveys are unfinished and the report a preliminary one. In the following remarks I have taken his paragraphs seriatim.

3. In his 3rd para. he states that Major Tulloch's project requires some alterations to adapt it to the present condition of Bombay, as it did not command Bhandarwada or Malabar Hill Reservoirs. I had already informed you of this, and that his 8½ million gallon scheme would only deliver 6½ million gallons into Bhandarwada daily, his 13 million gallon scheme only 9½ millions, and his 17 million gallon scheme only 14 millions, and that the proposed Kurla Reservoir did not command the Malabar Hill Reservoir at all.

4. In para. 6 Mr. Clerke states that he considers Major Tulloch has over-estimated the average annual rainfall of Tansa as well as the run-off from the catchment area. As regards the former, I agree with Mr. Clerke, and as Major Tulloch based his opinion on the experience of Vehar, I am at a loss to understand his assuming an average there of 102 inches, when the statistics of the ten previous years showed an average of only 87 inches. Mr. Clerke has taken two averages, one of ten and the other of six years, making them respectively 77·28 and 74·89 inches. But the average for the last twenty-four years is 80·37 inches. Although, therefore, Mr. Clerke's average for Vehar is under-estimated, I am inclined to adopt 100 inches as a fair and safe estimate for Tansa.

5. As regards available run-off, the experience of Vehar shows that Major Tulloch's estimate of one-half is correct, and that Mr. Clerke's estimate of one-third is consequently too low; and although Mr. Clerke considers it of little importance, as the Tansa supply is so much greater than any possible wants of Bombay, I consider it of no little importance as will be shown hereafter. The statistics of Vehar show that the annual quantity stored has been about 4,800 million gallons with an average rainfall of 74·76 inches. Taking the average area of the lake and gathering ground this works out at about 59 per cent. of run-off from the gathering ground. In this I have only taken those years when the lake did not overflow, and have also excluded those years when the Tulsi water was diverted into Vehar before the pipes were laid to the Malabar Hill Reservoir. No rule can be given, even on the same ground, as to the percentage of run-off, for I have calculated numerous instances from statistics of Vehar with all varieties of rainfall. In one instance the lake was filled to overflowing in 49 days with only 41·3 inches of rain as registered. In another instance it overflowed in 70 days with 95·3 inches of rain. In the former almost the entire rainfall reached the lake, and in the latter only 35 per cent. The amount of run-off is greatest with short heavy breaks and least with long average falls of rain.

6. In para. 7 Mr. Clerke discusses the section of the proposed masonry dam, taking for the purposes of calculation 150 lbs. as the weight of a cubic foot of masonry. The specific gravity of the Tansa stone is doubtless the same as the Tulsi stone, where the masonry is 155 lbs. per foot.

7. The method of drawing off water from the reservoir proposed by Mr. Clerke is preferable to that designed by Major Tulloch, being less expensive and less complicated.

8. In para. 10 the question of ducts is discussed and the conduits proposed by Major Tulloch. This portion of Major Tulloch's scheme I always considered faulty. Tunnels would, in my opinion, require lining, which would add greatly to their cost. This opinion I more than once expressed to yourself and pointed to it as an item requiring serious revision, and I certainly considered, as Mr. Clerke does, that tunnels were to be avoided as much as possible. Mr. Clerke takes off the water from the Tansa Reservoir at 330 T.H.D. and gives only a fall of 6 inches per mile to his conduits. This enables him to deliver the water in the Kurla Reservoir at 300 T.H.D. instead of 260 T.H.D. of Major Tulloch, who takes off the water from Tansa at 360 T.H.D. and gives a fall of 12 inches per mile to his conduits. This gives Mr. Clerke's scheme a command of the two service reservoirs, but requires a larger sectional area of conduit.

9. The crossing of the Bassein or Tanna Creek is discussed in paras. 12 and 13, and I agree with Mr. Clerke in rejecting Major Tulloch's proposal to carry the duct under the creek, a bridge being preferable.

10. Paras 15, 16, and 17 describe the Tansa catchment area, where Mr. Clerke recommends that the Municipality should absolutely acquire all the land inside the contour of 425 T.H.D., containing an area of 5,113 acres.

11. Para. 18 describes the levels at which it is proposed to draw off the water and the available capacity of the reservoir between 380 and 405 T.H.D., viz., 14,323 million gallons. Six feet of vertical mean area is then deducted for evaporation and absorption, leaving 9,923 million gallons per annum for consumption, or 27 million gallons a day for 365 days.

12. This deduction for evaporation and absorption seems to me to be excessive. If the average daily draw from Vehar was calculated in this way, it would leave only  $8\frac{1}{2}$  million gallons per day for distribution; and by Major Tulloch's plan of first deducting 2 feet 6 inches for evaporation and deducting one-third of the remainder for unaccountable waste, only  $7\frac{1}{2}$  million gallons would be available. I should, therefore, say that on the supposition that Bombay supplied with  $9\frac{1}{2}$  million gallons daily from Vehar, 5 feet should be deducted for evaporation and absorption on Mr. Clerke's system, or one-sixth the remainder after deducting for evaporation on Major Tulloch's system. On this basis the quantity available of the total of 14,323 million gallons at Tansa would be 10,656 and 10,325 million gallons respectively. For estimating the daily supply this would give, Mr. Clerke divides it by 365 days, but with such a surplus as there would be at Tansa, the reservoir would invariably be full at the end of the rains, and have only to give 240 days' supply on the average, or 270 days as a maximum, which would give about 40 million gallons daily.

13. Paras. 20 to 28 describe details which I need not discuss now, but para. 29, where it is proposed to lay the pipes above ground, may provoke comment, as such a proposal did on a former occasion with regard to Mr. Aitken's steel main. It may, therefore, be well to state that our experience of the Tulsi main shows that no fear need be apprehended of any serious increase of the temperature of the water, and this practical test is supported by theoretical calculations. As regards the construction of metalled roadways, I think that light tramways might be little more expensive and reduce the cost of transit of materials more than one-half.

14. Paras. 30 to 32 describe junctions of siphons with conduits, thickness of pipes, and their location, which I need not discuss now.

15. Para. 33 refers to the crossing of Bassein Creek, but anything more than a concurrence with Mr. Clerke's views generally would be premature, as the surveys and bridge design are not yet complete.

16. Paras. 34 to 37 are a continuation of the description of the lines of conduit and siphons to a point near Kurla where it is proposed the conduit shall terminate at 300 T.H.D. At this point Mr. Clerke proposes (see paras. 37 to 42) to construct what he describes as a service reservoir, if no more favorable site can be obtained. This reservoir is to contain about ten days' supply of 17 million gallons per day. This might, I think, more aptly be described as a *safety reservoir*.

17. This reservoir is advisable to provide against contingencies consequent on the number of siphons between Tansa and Kurla, as the number of junctions increases the chances of accidental stoppages. Between Kurla and Bombay Mr. Clerke proposes to lay pipes of such capacity as will deliver the required quantity in 24 hours of constant

flow. A service reservoir I interpret to mean one that supplies the full demand as it is required with a service pipe that will deliver three times the average quantity.

18. This part of Mr. Clerke's scheme requires revision and careful consideration, for although it is advisable that the scheme should command both Bhandarwada and Malabar Hill Reservoirs, they cannot be used for the distribution of the Tansa supply, as they have only filter beds and service pipes for the quantities supplied from Vehar and Talsi, and their sizes would not admit of any great addition to those quantities. An additional service reservoir will be required for Tansa, and I would suggest that it be constructed on Cumballa Hill, north of Altamont and west of the Flagstaff, with a capacity about double that of the Malabar Hill Reservoir and a top level of 220 or 230 T.H.D. I would prefer the former, as it would be commanded by the Vehar lake. My object in advising this is that in case of any accident to the Tansa duct involving a stoppage of more than eight days, which would nearly exhaust Kurla Reservoir, Vehar could supply a service reservoir at 220 T.H.D. with a daily, though reduced supply, by laying a pipe from Vehar to the main between Kurla and Bombay. In fact, if there were no reservoir at Kurla, Vehar could be utilized as a safety reservoir for the few days it might be required in each season, if required at all, in which case the main would be continued from the end of the conduit to the service reservoir with smaller branches to Bhandarwada and Malabar Hill.

19. Paras. 45 and 46 contain a summary of Mr. Clerke's revised project, and in it he states that the dam at Tansa could be increased in height so as to give 68 million gallons daily for 365 days, which would be about 100 million gallons for 240 days, the average length of the dry season. He also states that the carrying capacity of the conduit is 26 million gallons daily, and that of the siphons 17 millions daily, and that an additional 30-inch siphon would make the latter 26 millions also.

20. Estimate A gives the cost of these (exclusive of the raising the dam to the full height and of the 30-inch main) at 126 lakhs, including contingencies and establishment charges, but not including interest on capital during construction, which would amount to about 13 lakhs. This estimate is for a supply of 17 million gallons daily. Major Tulloch's estimate for the same quantity delivered at a much lower level, or for 14 millions delivered into Bhandarwada Reservoir, was 115½ lakhs.

21. Estimate B, amounting to 100 lakhs, is for a curtailed project to supply only 8 millions daily and with no reservoir at Kurla. This Mr. Clerke does not recommend, nor do I.

22. In para. 50 he states that if the depth of the conduit were increased 1 foot, its capacity would be 33 million gallons daily at an additional cost of only 2 lakhs. This I would strongly recommend.

23. In paras. 51 and 52 Mr. Clerke compares Tansa with two other schemes of Major Tulloch's, viz., Shewla and Kaman, but the comparison can be only approximate. That between Mr. Clerke's Tansa estimate and his revision of the Kaman project is only a guess, as no surveys have been made to Bombay direct. An accurate survey of the Shewla project might show that there was little difference in the two estimates, but I certainly prefer Tansa.

24. As a general scheme Tansa is certainly the best, on condition that all the water capable of being stored is used and none wasted. If Government would give the Corporation the power not only to supply towns outside Municipal limits, such as Callian, Bhowndi, Tanna, Kurla, Bandora, &c.; but to rent the water power at the reservoir and to use all surplus water there for irrigation in the immediate neighbourhood of the reservoir or elsewhere, the Corporation might secure an ample water-supply at a very much reduced cost. The wants of Bombay for a long time to come are not likely to exceed 17 million gallons additional daily, which I calculate would leave at least 60 million gallons daily for other purposes. It was for this reason that the project was considered one more suitable for a public Company than the Corporation. *Even without these helps the 17 million gallons can be brought to Bombay at a cost of only 1½ annas per 1,000 gallons, and any surplus could be sold for commercial purposes, and the irrigation of market gardens, at a rate so much below the present one as would ensure a very large consumption and profit to the Corporation.* To give an idea of the magnitude of the Tansa scheme I may mention that the supply of water is about the same as that from Kurrackwasla or Lake Fife, near Poona.

25. In para. 56 Mr. Clerke states that it would take from six to seven years to complete the project. I should certainly be disappointed if it exceeded five years. He also recommends the dam to be built departmentally, but I am of opinion that departmental work requires quite as much supervision as contract work, and the only cases in which I would recommend departmental work are when contractors combine to raise prices or really good contractors cannot be obtained. The great disadvantage in departmental work is that it introduces an element of uncertainty as to the cost of the work.

26. In para. 59 Mr. Clerke states that he has not been able to revise the whole project in detail, but the plans and estimates are complete in full detail as far as Bassein Creek, and this includes the most important part of the works. The principal matters to be now estimated and considered are—

1st.—Arrangements as to the catchment area.

2nd.—Survey and detailed estimate of the crossing of Bassein creek.

3rd.—Details of the Kurla Reservoir, should it be considered necessary.

4th.—The construction of a service reservoir.

5th.—The question as to the power of the Corporation to apply the surplus water to other purposes, such as water-power and irrigation.

27. The first item requires some explanation, as I find I have not yet alluded to it. On examining the plan I find villages marked close to the boundary of the proposed reservoir, and one of some considerable size called Khardi within, but close to the edge of the catchment area and to the railway station of that name. I find, on discussing the matter with Mr. Clerke, that all the villages except Khardi consist of a few huts, and the population of each is about 40. It is, however, important that the waters of the reservoir should not be polluted, and I think that powers should be obtained which would give the Corporation control over the catchment area, not only to prevent the erection of huts, but to eliminate by degrees those which are already there. As to Khardi, it is so close to the boundary of the catchment area that Mr. Clerke thinks with me that the drainage might be carried over the ridge. The area of the catchment area, exclusive of the reservoir, is about 28,500 acres, and it is this area that should be under the control of the Corporation as regards its sanitary condition. The most effectual way of dealing with it would be for Government to constitute it forest land with a complete system of forest conservancy. This would most likely ensure a good rainfall, and the water would run off into the lake in a purer state than off bare land or land under cultivation, the soil of which would be constantly washed into the streams and the reservoir.

28. As to other schemes, the only one that might compete with Tansa as to cost is Kaman, and I should have liked an estimate to have been made from actual survey had time permitted. The water from Kaman could only be delivered in Bombay at a low level, and would have to be pumped by steam-power into the service reservoir, and there would be no surplus water either for water-power or irrigation. I must, therefore, repeat that the Tansa scheme in its entirety is, in my opinion, the best and cheapest scheme.—I have, &c.,

(Signed) A. W. FORDE,  
Consulting Engineer.

*Note*—The drawings referred to in this report are deposited in the office of the Municipal Commissioner. Copies, on reduced scales of drawing Nos. 2, 3, 4, 5, 8, 9 and 10, are attached hereto.

BOMBAY, 13th August 1885.

FROM W. CLERKE, Esq., M. INST., C.E.,  
Executive Engineer on Special duty Tansa Survey.

TO THE MUNICIPAL COMMISSIONER  
FOR THE CITY OF BOMBAY.

SIR,—Having reference to your No. 12173 of 1884-85, dated the 29th February, I have now the honor to report on the subject of the Tansa project for the water-supply of the City of Bombay.

2. The late date in the working season at which I was appointed to this duty did not allow me sufficient time to complete the surveys which are necessary for a thorough revision in detail of the project, but I have had enough done to enable me, I hope, to place the subject before you in such a way that the Municipality can come to a conclusion as to the merits of the Tansa project for adoption as a final water-supply for the City of Bombay.

3. The Tansa project as put forward by Major Tulloch requires some modification in important details, in order to adapt it to the present condition of Bombay. When Major Tulloch proposed his scheme, Tulsi had not been constructed, neither had the Malabar Hill nor Bhandarwada Hill Reservoirs. Any scheme for a gravitating supply which would not fully command both these reservoirs should not, in my opinion, be entertained.

4. In Major Tulloch's scheme the R.L. of the outlet of the service reservoir at Kurla is 230 and the R.L. of full supply 259.50; the R.L. of the full supply of Malabar Hill Reservoir is 255.78, from which it is apparent that the scheme does not command that reservoir.

5. The valley of the Tansa is very suitable as a gathering ground for a large water-supply. Major Tulloch took the catchment area as 45 square miles. I find it is 52½ square miles. I have had the advantage of the maps of the Konkan Topographical Survey, which have been of great assistance to me both in the survey of the catchment and along the whole line of my surveys from the Tansa to Ghât-Kopar.

6. Major Tulloch has, I think, over-estimated the rainfall on and run-off from the catchment. He started with the assumption that the average annual rainfall at Vehar is 102 inches, and he increased this by 33 per cent. for the average rainfall of the Tansa catchment, making it 136 inches. I find the average rainfall at Vehar for ten years 1875—84 was 77.28 inches. For the six years 1879—84 the average was 74.89 inches, and for the same period the average fall at Kussara, at the foot of the ghâts east of the Tansa valley, was 106.75 inches. This latter figure is probably higher than what the average rainfall in the Tansa valley is; it does not, most probably, exceed 100 inches. Major Tulloch assumed that the available run-off would be one-half of the rainfall. This also, I think, is too high, and I would not put it down at more than one-third. These questions are not, however, of much importance, for a run-off of 33 inches from the catchment would (after making allowance for loss by evaporation and absorption in the storage) provide over 60 million gallons per day for a whole year. There can, in my opinion, be no question as to the capabilities of the gathering ground of the Tansa project being sufficient for any demands Bombay may ever make on them.

7. Major Tulloch has proposed to adopt the section known as "Rankine's Section" for the dam. This section gives an excess of

material, and the section which I would adopt makes a considerable saving in the quantity of masonry as compared with "Rankine's Section." Nevertheless, even assuming the dam to be built on the more economic section and raised to the height as fixed by Major Tulloch, namely, to R.L. 390, he has considerably under-estimated its cost. I have not got Major Tulloch's calculations, but it does not appear that any trial-pits were sunk along the line of the dam, and it was assumed that sound rock would be met with close to the surface throughout, but this is far from being the case as I have ascertained from actual trial-shafts. No item for excavation of foundation of dam appears in Major Tulloch's estimate. Taking this into consideration, taking a line for the foundations derived from the trial-shafts, taking the more economic section for the dam and adopting Major Tulloch's rate for masonry, Rs. 25 per 100 c. ft., I estimate the cost at 19 lakhs, while Major Tulloch estimated its cost, though built on Rankine's Section, at only 11½ lakhs.

8. The method proposed by Major Tulloch for drawing off water from the lake appears unnecessarily elaborate. In the case of an earthen dam it is doubtless advisable to make the outlet through the solid natural ground on one of its flanks, but in the case of a masonry dam this is not necessary. The water may be drawn off at different levels by outlets through the dam. This will be explained in detail, further on, when I am considering the revision of the project.

9. I fully concur with Major Tulloch as to the expediency of minimizing the use of iron pipes, as far as practicable, in a duct for bringing water from a long distance.

10. Major Tulloch has proposed that the greater part of the duct\* should be in tunnels. The cross section of the tunnels he proposes is 5 feet wide by 6 feet high; he has assumed that they would not require lining for the greater part of their lengths, and he has estimated the cost at Rs. 80,000 per mile.

11. This proposal does not commend itself to me. The formation of the hills through which the tunnels would be bored is trap, which is a most uncertain rock to deal with, and it is very probable that the greater part of the tunnels would require lining. The size of tunnel proposed is much too small to work in conveniently, and it would, in my opinion, cost as much as one of about 8' x 6', which is about the smallest size that can be conveniently worked. For such a tunnel, including the probable lining, it would not, I think, be safe to estimate at less than Rs. 1,60,000 per mile. Moreover, the size of the tunnel proposed is insufficient for the purposes of the proposed supply. An unlined† tunnel, 5 feet wide with 4 feet depth of water and with a fall of 1 foot per mile, would give only 11 million gallons in 24 hours.

12. Major Tulloch has proposed to cross the Bassein Creek (called by him Tanna Creek) by a cast-iron pipe laid in a tunnel driven 50 to 100 feet below its bed. This is a method of crossing the creek which I could not recommend, and I believe his estimate of the cost, Rs. 3,00,000, is inadequate.

13. The difficulties in carrying out such a work would be considerable. The probabilities are that water would be met with in large quantities, and it is impossible to say what the cost might run to. But supposing the tunnel to be constructed and the pipe laid in it, there would still be the constant risk of a very serious interruption to the water-supply to Bombay. Assuming that the tunnel and shafts would be made perfectly water-tight (which is very doubtful), there is

\* To prevent frequent explanations in what follows I will lay down the following somewhat arbitrary definitions:—

"Duct" the means by which the water is conveyed from a storage lake to the service reservoir or distribution system. It may consist of—

Conduits,  
Aqueducts,  
Tunnels,  
Iron pipes or Siphons.

"Conduit" consists of a masonry culvert built in a trench excavated in the natural ground in which the water flows not under pressure.

"Aqueduct" consists of a masonry culvert, carried on arches across rivers or ravines in which the water flows not under pressure.

"Tunnel" is a boring through the solid ground. It may be lined with masonry or not, according to the nature of the material through which it passes. The water flows through it not under pressure.

"Iron pipes or Siphons" may be laid either under or above ground, and may be carried on any suitable structure across rivers, &c. Water usually flows in pipes under pressure.

† It will be readily understood that an unlined tunnel, 5 feet wide with 4 feet depth of water, will give a smaller discharge than a lined tunnel of the same dimensions owing to the friction being greater.



still the probability of a pipe bursting, and should this happen, the tunnel would be at once filled with water, as the pipe forms part of a siphon 10 miles long. The tunnel must then be pumped dry before the broken pipe could be repaired, and a long interruption to the water-supply would be the probable result. The pipes through the tunnel would be more liable to accident than those in any other part of the line, as they would be under a head of pressure of some 100 feet in excess of those anywhere else.

14. Having thus briefly noted the principal points in Major Tulloch's project which appear to call for special remark, I will proceed to explain the details of the project as I have revised it.

15. The accompanying plan, drawing No. 1, shows the catchment area of the Tansa. It is 52.5 square miles. There is no record of the rainfall in the catchment. I have established a gauge at Borala near its centre, and the fall of this year there can be compared with that at Kus-sara, where the rainfall has been recorded for some years, and from this comparison an approximate estimate of the average rainfall at Borala can be arrived at. But, as I have stated in para. 6 preceding, there can be no question as to the sufficiency of the Tansa valley as a gathering ground for a final water-supply for the City of Bombay.

16. On the same plan, drawing No. 1, is shown the proposed line of dam, which is almost the same as that selected by Major Tulloch.

17. On this plan, is shown also contour of R.L. 425, which is the final height to which the dam may at some future time be raised. But the Municipality should, I think, in the first instance, absolutely acquire all the land inside this contour. I have had this contour surveyed and marked out on the ground, and I find the area enclosed is 5,113 acres (8 square miles). I have also had the contour of R.L. 380 (at which I propose to draw off) surveyed, and find its area is 2,100 acres; both these areas are in excess (about 12 per cent.) of the areas which Major Tulloch has given for the same contours. In considering the capacity of the lake I shall, therefore, be on the safe side in adopting Major Tulloch's figures.

18. As I have pointed out in para. 4 preceding, the level at which water would reach Kurla according to the original project is too low. In my opinion it should reach there at or about R.L. 300, and this is what I aimed at from the beginning of my surveys. To effect this I have had to draw off at R.L. 380 instead of 360 as in Major Tulloch's project. In the scheme I put forward for present adoption I propose making the full supply level of the lake at R.L. 405. If the draw-off is at 380, the available capacity will be between R.L. 385 and 405.

	Gallons.
This is .....	14,323,307,200
<i>Deduct</i> for loss by evaporation and absorption	
—6 feet vertical on mean area R.L. 395 ...	4,400,000,000
	9,923,307,200
Available quantity .....	9,923,307,200

which is equal to 27 million gallons per day for 365 days.

19. As shown in the last para., the available capacity of the proposed lake is 14,323 millions of gallons; this is equal to 2,291 millions of cubic feet. The whole catchment area is 52.5 square miles. The mean area of waterspread of the lake is 4.2 square miles. The whole of the rain falling on the latter would be collected, and assuming that one-third of the rain falling on the balance of the catchment would be collected, a fall of 49 inches would furnish the quantity necessary to fill the available capacity of the lake, thus:—

$$4.2 \times 640 \times 43,560 \times \frac{49}{12} = 477,000,000 \text{ c. ft.}$$

$$48.2 \times 640 \times 43,560 \times \frac{49}{12} \times \frac{2}{3} = 1,834,000,000 \text{ ,,}$$

$$\text{Total...} 2,311,000,000 \text{ c. ft.}$$

The above calculation tends to confirm opinions I have already expressed regarding the capabilities of the Tansa gathering ground, for, even in years of exceptionally small rainfall, there is no probability of the rainfall in the Tansa valley being nearly so low as 49 inches or less than half the probable average as shown in para. 6.

20. The accompanying drawing No. 2 is a longitudinal section along the proposed site of the dam, which has been marked out on the ground with permanent marks. I had several trial-shafts sunk along the dam site, and their positions and the levels at which rock was found are shown on the section. From the information derived from these trial-pits, the probable rock line shown on the section has been put in. But in a trap

formation until the whole length of foundations has been opened it is impossible to say how the line of rock may run. On this drawing is shown the top of the dam R.L. 408, as I now propose to build it with full supply level at R.L. 405, and also the height to which it may at some future time be raised with full supply level at R.L. 420.

21. Provision for the escape of flood-water, after the lake has filled, is made by keeping 1,800 feet in length (total length being 8,430 feet) near the south end of the dam at full supply level R.L. 405 as shown on the drawing. I have taken the maximum flood as due to a run off of  $\frac{1}{2}$  inch per hour from the whole catchment; this is equal to 25,000 c. ft. per second. The escape or waste weir is 1,800 feet in length, and taking the co-efficient of discharge at .7, the calculated maximum flood would rise 2'50" above its crest. Even should a much greater flood occur, it would not in any way affect the security of the dam or works. The escape-water will be broken in its fall by the sloping face of the dam and will reach the solid rock foundation without any violent action, and thence it will pass into the river, at a point some distance below the dam, by a natural depression in the ground.

22. The section I propose for the dam is shown in drawing No. 3. This is for a dam having its top at R.L. 408 and full supply level R.L. 405. The maximum height is 118 feet, and this is allowing for the foundations being carried 2 feet below the rock line as derived from trial-shafts. The lines of resistance and the pressures are shown on the section, and it will be seen that the dam has considerable excess of stability. But I have designed it so that it may at some future time be raised, if required, to impound water up to R.L. 420. On drawing No. 4 is shown what the section of the dam would be when raised to its final height. The lines of resistance and the pressures are shown, and it will be seen that the dam when raised to the final height would still possess a good margin for stability. The maximum pressure on the downstream face is 125 lbs. per square inch. M. Bouvier, whose methods I have made the basis of my calculations, has shown that masonry built of good hydraulic mortar after it is ten years old may safely be subjected to a pressure of 187 lbs. per square inch.

23. The method I propose for drawing off water from the lake is shown in drawing No. 5. As I have shown in para. 19, the R.L. of draw-off is 380. At the point on the south side of the river where the rock foundations of the dam are at this level I put in a pair of sluice ways, each 2'5" x 2' through the dam, and close them by cast-iron sluice gates fixed on the inner side of the dam and worked by screw gearing from its top; they discharge into the circular cistern from which the duct will lead off. These two sluices, with only 1 foot of head, are sufficient to draw off the greatest quantity of water that will ever be required, and nothing further would be necessary were it not for the desirability of drawing off from different levels according to the level of the water in the lake. For this purpose I put in a single sluice of the same pattern at each of the points where the rock foundations of the dam are at R.Ls. 390 and 400. Each sluice discharges into a small square cistern, and these two cisterns are connected with the circular cistern above mentioned by a masonry channel built along the outer toe of the dam as shown on the drawing. The upper sluice should be used until the water had fallen to such a level that the sluice did not discharge a sufficient quantity; it should then be supplemented by the middle sluice. As soon as water had fallen to R.L. 400, the middle sluice alone should be used until the water had fallen to such a level that it could not discharge the quantity required; it should then be supplemented by the lower sluices. As soon as water had fallen to R.L. 390, the lower sluices would alone be in use.

24. The upper sluice would be exposed every year, and could be examined and kept in perfect order. The middle sluice would also most probably be exposed, or, at all events, would have so small a depth of water over it that it could without difficulty be examined. The lower sluices should never be exposed, and in course of time they would require renewal or repair. To obtain access to them I propose building a well round them, having its top at R.L. 395, as shown on the drawing. This well communicates with the lake by two openings, each 4' x 4'. Should it be desired to examine the sluices, as soon as the water in the lake has fallen to R.L. 395 the openings can be closed by needles or vertical bars of timber 4" x 4" let down through grooves left in the wall of the well for the purpose.

25. The duct leads off from the circular cistern which receives the water from the outlet sluices. I have had the line surveyed and staked

out as far as the east bank of the Bassein Creek, a distance of about 33 miles from the head. The first 5 miles of its course are shown on plan, drawing No. 1, and the remainder up to the Bassein Creek on plan, drawing No. 6. From the Bassein Creek to Ghât-Kopar I have had a careful trial survey made, and the course of the duct as derived from this survey is shown on plan, drawing No. 7. I have also laid down on these plans the line of duct proposed by Major Tulloch. Longitudinal section of the first 33.2 miles is shown on drawing No. 8, and longitudinal section thence to Ghât-Kopar on drawing No. 9.

26. As I have explained in para. 11, I do not approve of the proposal that the greater part of the duct should consist of tunnels. I propose bringing it in conduits where possible. The line for the conduits has been laid out, as far as practicable, on a contour line, giving 10 feet of cutting to the floor. The cross section I propose is 7 feet wide with 5 feet depth of water as shown on drawing No. 10; the fall is 6" per mile, and its discharging capacity, using Bazin's coefficient, is 48 c. ft. per second, which is equivalent to 26 million gallons per day. The conduits will be provided with manholes every 220 yards and with means of washing out and scouring at convenient places about half a mile apart.

27. Some tunnelling on the line of duct is unavoidable, that is, the length of conduit which would be required to avoid it would be so much in excess of the length of tunnelling as to be more costly. Tunnels when lined will have the same width as the conduit, but will be 1 foot higher. Where lining is not necessary, the cross section will be 9.5 feet wide by 6' high; the fall will be 6" per mile, and the discharging capacity 83,000,000 gallons per day. Cross sections of tunnel are shown on drawing No. 10.

28. Where the line of duct crosses valleys, it will consist of cast-iron pipes 48" diameter with a fall at the rate of 3.20' per mile. The discharging capacity of this pipe calculated by Eytelwein's formula is 17 million gallons per day. It is a recognized fact, in the profession, that large mains, especially when new, discharge a larger quantity than that given by the usual formula. Following the researches of Mr. Fanning, U.E., of Boston, U. S. A., on this subject I calculate that the above main would discharge—

When clean.....	21,500,000	gallons per day.
Slightly tuberculated .....	20,500,000	"
Foul .....	19,500,000	"

but, to be quite on the safe side, I will assume the discharge to be that given by the ordinary formula, namely, 17,000,000 gallons per day.

29. I propose laying the main entirely above ground. I would form a regular track or roadway on which to lay it, and where the line of pipes does not go alongside an existing metalled road I would make this track of sufficient width to carry a metalled roadway 14 feet wide to facilitate the carriage of the pipes in the first instance and afterwards to be used, in the case of pipes bursting, for carrying pipes for renewals from the nearest depôt of spare materials. These metalled roadways along the lines of siphons will be connected with existing metalled high roads at the most convenient points for making junctions.

30. At the commencement and end of each line of piping where it joins the conduits the junction will be formed by a masonry cistern or siphon head 15 feet in diameter as shown on drawing No. 10, from which the pipe will take off at its head and into which it will discharge at its tail. Immediately outside the wall of the take-off cistern a sluice valve will be provided, by which the supply can be cut off from the siphon in the event of a pipe bursting, or whenever it may be desired to do so from any cause. Each cistern is provided with an overflow or escape for passing off water to the nearest nalla in the event of the siphon valve being closed. In laying the lines of pipe down and up the steep sides of the hills from and to their junctions with the conduits special precautions will be necessary. At short intervals the pipe should be built into heavy pillars of masonry, founded on hard ground, to counteract the tendency to sliding or creeping. Scouring valves and air valves should be provided at the principal depressions and summits along the lines of pipes.

31. The heads of water in different lines of pipe differ considerably, varying from 104 to 256 feet. I propose using pipes 1½" thick for each line in which the maximum head exceeds 190, and in each line where the maximum head is less than 190 feet pipes of 1¼" thick.\*

\* For 7 miles the main of lighter dimensions will suffice; the difference in cost may be taken approximately at Rs. 20,000 per mile.

32. Following the line of duct on the plans and section, drawings Nos. 1, 6 and 8 (referred to in para. 25), it will be seen that for the first 3.2 miles it is a conduit following the contour, except in a few cases where, in order to avoid the great length that this would necessitate, a ridge has been crossed by a short tunnel or deep cutting and a ravine or nalla by an aqueduct. At 3.2 miles the tunnel under the Kosta Khind is met; this is the most serious obstacle on the line of duct. The tunnel will be 1.2 miles long, and will have to be worked from both ends without any intermediate shafts. From the end of the tunnel to 6.9 miles the duct is in conduit following the line of contour generally except where ridges or ravines are occasionally crossed by cuttings or aqueducts. At 6.9 miles the first iron pipe or siphon is met; it crosses the low-lying ground between the Dumria and Kumbari nallas and is 2.7 miles in length. From its termination the duct is carried in conduit on contour along the "Mainda" hill up to miles 10.3, where the second siphon begins. It crosses the Padshapur valley and is 2.5 miles long. From the end of this siphon, at 12.7 miles, the duct has been surveyed for a conduit on contour along the slope of the hills lying to the west of Tulsī (in the Bhowndi Taluka). The line of this survey is shown on the plan. The side of the hill on which the survey was carried out is very rugged, and owing to the number of ravines the length of contour is great. On considering the question I have come to the conclusion it will be more economical to substitute a tunnel for part of this conduit as shown on the plan. The length of conduit for which I propose to substitute a tunnel is 2.4 miles and the length of substituted tunnel 1.2 mile. The third siphon commences at 16.7 miles; it crosses the valley of Khabling Budruk, and the duct again gets on the contour at 18 miles, which it follows in conduit up to 20 miles, where the fourth siphon commences. This siphon crosses the Agra road near Borevli, and the contour is again taken up at 20.9 miles, and the duct follows it by conduit up to 22.8 miles, where the fifth siphon, which is only .2 mile long, occurs. Between the fifth and sixth siphons there is .2 mile of conduit on contour, and the sixth siphon begins at 23.2 miles. It crosses the Yevai valley, and the duct again gets on the contour on the hills lying east of Bhowndi at 24 miles. The duct follows the contour in conduit up to 26.3 miles, where the seventh siphon commences. This is by far the longest siphon on the duct; it crosses the Bassein Creek, the east bank of which it reaches at 33.2 miles.

33. The pipe has to be carried across the Bassein Creek. The time at my disposal for survey work did not admit of my closely investigating this question, that is, I was not able to get soundings, borings, &c., taken so as to enable me to determine what is the best method to adopt for crossing it. As I have pointed out in para. 13, the proposal to carry the pipe in tunnel under the creek is one which I would not adopt. The pipe must be carried over the creek on a bridge, and the question to be determined is what kind of bridge. The bridge will be of considerable length, nearly 2,000 feet. I incline to the opinion that a light girder bridge on screw pipes will be the best method, but if the foundations should not turn out favorable for this, a suspension bridge may be adopted.

34. Having crossed the Bassein Creek the line of duct is shown on the trial plans and sections, drawings Nos. 7 and 9. The seventh siphon is continued over the low ground on the west of the creek and up the side of the range of hills till the contour level is reached, which is at 37.4 miles, making the length of the seventh siphon 10.1 miles. The duct is thence in conduit along the contour up to 43 miles, where the eighth siphon commences. This siphon crosses the road leading from Tanna to the Vihar Lake, and it ends at 43.15 miles. The duct is then in conduit on contour up to 44.1 miles, where a short siphon is shown. This siphon can, I believe, be avoided when finally locating the line of duct and a conduit substituted for it. From this point the duct is in conduit up to 45.4 miles, where there is a line of siphon .9 miles long, which crosses the road from Bhandup to Poi. This siphon ends at 46.3 miles, and from that point to its termination, as surveyed, the duct is in conduit.

35. The terminal point is marked Z on the plan. It is distant from the head  $48\frac{1}{2}$  miles; this length can, I think, be reduced by about two miles when the line of duct on the west of the Bassein Creek is being finally located on the basis of the trial survey. The R.L. of the bed of the conduit at its terminal point is 300.06; this level will be slightly raised by the shortening of the line on its final location referred to above. Of the total length,  $48\frac{1}{2}$  miles,  $28\frac{1}{2}$  miles consist of conduit and

tunnel and  $19\frac{1}{2}$  miles of siphon. In Major Tulloch's project the corresponding figures are :—

Total length .....	44 $\frac{1}{2}$
Conduit and tunnel .....	29 $\frac{1}{2}$
Siphon .....	15

36. There are several points still to be considered. They are common to any project for bringing a gravitating supply from outside of Falsette.

37. It is most desirable, if not essential, that in a case where the storage reservoir is at a long distance, there should be a service reservoir capable of holding about ten days' supply, and into which the duct would lead, and which would still have command of the Malabar Hill and Bhandarwada Reservoirs.

38. The site of the Upper Kurla Reservoir, which formed part of all Major Tulloch's projects, is close to terminal point of the duct referred to in para. 35, and it (the site) is indicated on the plan, drawing No. 7. It is not a favorable site for a service reservoir; it is a V-shaped valley, which would require a dam of dimensions out of proportion to the capacity obtained. However, the practicability of constructing a service reservoir there, capable of containing about ten days' supply at 17,600,000 gallons per day, is established, the draw-off from the reservoir being at R. L. 275 06.

39. For a service reservoir I prefer a structure entirely of masonry for the following reasons :—

*Firstly.*—The water stored for reservoir comes solely by the duct, while in the case of a service reservoir formed by damming a valley, at certain times, run off from the hills surrounding the reservoir, is stored.

*Secondly.*—The loss by percolation and absorption in a well-constructed masonry service reservoir is practically nil, while in a service reservoir formed by damming a valley, the loss from these causes may be considerable.

40. In the present case the difficulty is to find a suitable site at the proper level on which to build a masonry reservoir. A reservoir of capacity to hold the requisite supply, with a depth of 25 feet, would cover an area equal to a square having its sides 1,000 feet long, and it does not appear practicable to obtain this except at a very heavy cost.

41. Acting on your suggestion I turned my attention towards the high grounds on the north of the Island of Trombay. I had not much time to devote to this enquiry. The results of my superficial survey were not encouraging; but the idea should not, I think, be abandoned without a more searching investigation.

42. For present purposes I will assume that the construction of the service reservoir at Ghât-Kopar (Upper Kurla) may be decided on. As has been shown in paras. 35 and 38, the R.L. of the bed of the duct and of the outlet of the service reservoir are 300.06 and 275.06 respectively. Assuming that the total quantity of water be divided in the proportion of the present supplies to Bhandarwada and Malabar Hill Reservoirs,  $11\frac{1}{2}$  million gallons should be supplied daily to the former and  $5\frac{1}{2}$  million gallons to the latter. The R.L. of the inlet to Bhandarwada Reservoir is 166.25 and its full supply level is 190; its mean level, say, is 178. The distance is 11 miles, and it would require a 33" main to convey the above quantity. The R.L. of the inlet to Malabar Hill Reservoir is 255. The distance is 12 miles, and it would require a 33" main to convey  $5\frac{1}{2}$  million gallons in 24 hours.

43. For the two separate 33" mains, one 48" main might be substituted for a distance of 6 miles, thence separating into two branches of 30" and 39" for Bhandarwada and Malabar Hill respectively. The saving in cost of adopting the latter method would be very trifling.

44. In either case the mains or main leading from the service reservoir should also be connected direct with the termination of the duct, and from this they would usually receive their supply with the advantage of the full head due to the duct, the service reservoir being kept full for use in the event of an accident on the duct and for occasional use at other times, so as not to allow the water to remain stored for too many days without change.

45. The revised project which I now propose may be summarized as follows :—

1st.—To construct a lake or storage reservoir on the Tansa with full supply level at R.L. 405 and the sill of draw-off at 380. This lake would have an available capacity equal to

27,000,000 gallons per day for 365 days. The dam is so designed that it may hereafter be raised to impound water up to R.L. 420, which would give an available capacity of 68,000,000 gallons per day for 365 days.

2nd.—To bring the water by means of a duct consisting of conduits, tunnels, and siphons to a point near Ghât-Kopar, where it would be delivered at R.L. 300.06. The carrying capacity of the conduits is 26,000,000 gallons per day, of the tunnels 33,000,000 gallons per day, and of the siphons 17,000,000 gallons per day, that is, by laying an additional pipe of 36" diameter on the siphon lines a delivery of 26,000,000 gallons per day at Ghât-Kopar could be obtained.

3rd.—To make a storage reservoir of Ghât-Kopar capable of containing 170 millions of gallons with outlet at R.L. 275.06 and to carry the supply of 17,000,000 gallons per day, thence to Bhandarwada and Malabar Hill Reservoirs in the proportions  $11\frac{1}{2}$  million gallons to the former and  $5\frac{1}{2}$  million gallons to the latter. The mains to these reservoirs to be also connected directly with the termination of the duct.

46. The cost of these works I estimate at Rs. 1,26,00,000, as per abstract estimate marked A attached. The details of the estimate are recorded in this office. I have carefully considered the rates which I have employed in framing the estimate, and I believe they are ample. In some cases the rates I have used are in excess of what my own experience leads me to believe the work can be done for. But as the work will have to be carried out in some cases under peculiar conditions, I have thought it best to estimate at liberal rates so as to be on the safe side. The rates for siphon lines are based on the price at which pipes are now being delivered in Bombay, and they include carriage, laying, formation of the road referred to in para. 29, masonry pillars referred to in para. 30, siphon heads, valves, &c. The provision of 10 per cent. contingencies allows for the ordinary contingencies on works, and in it are also included such items as the construction of a metalled road from Atgaum Station to the dam site, the construction of a bungalow and offices at the head, &c., &c. The charges for establishment have been based on what the actuals would probably be, assuming the work to extend over  $6\frac{1}{2}$  years.

47. Major Tulloch's estimate (No. 3 in his report) for the same quantity of water, but delivered at a lower level, was  $115\frac{1}{2}$  lakhs of rupees. As I have pointed out in para. 7, he very much under-estimated the cost of the dam, and to this a great part of the excess in my estimate is due. Major Tulloch also omitted to make any provision for establishment which I have included. As I have shown in para. 11, he has, I think, under-estimated the cost of his conduits, and in this item also my estimate is in excess. In the item of siphons my estimate shows a saving owing to the lower rates now obtaining for iron.

48. In abstract estimate marked B attached (amounting to 100 lakhs) I give what the cost of the project curtailed as under would be. The lake to be made with its full supply level at R.L. 398 (using the same section of dam) having an available capacity of 14,000,000 gallons per day for 365 days. The duct not to be altered as regards conduits and tunnels, but the siphons or iron pipes to be capable of giving only 8,000,000 gallons per day. No service reservoir to be provided, but the water to be led direct from the end of the duct to the Bhandarwada and Malabar Hill Reservoirs in the proportion of  $5\frac{1}{2}$  million gallons to the former and  $2\frac{1}{2}$  million gallons to the latter.

49. I do not recommend the adoption of the curtailed project. With such a supply available I do not think it would be wise to bring in only 8,000,000 gallons per day, even in the first instance, unless on account of the absolute impossibility of providing funds for the more complete project. To increase this supply up to 17,000,000 gallons per day afterwards would cost a good deal more than if it were done at first.

50. As I have shown above, the carrying capacity of the conduit is 26,000,000 gallons per day, equal to 26 gallons per head on a population of one million. I have also shown that the available supply derivable from the gathering ground is over 60,000,000 gallons per day, equal to 26 gallons per head on a population of  $2\frac{1}{2}$  millions. It will most probably be a very long time before a supply in excess of the capacity of the proposed conduit, namely, 26,000,000 gallons per day, will be required. If the depth of the conduit were increased from 5 to 6 feet, its capacity would be 33,000,000 gallons per day, equal to 25 gallons

per head on a population of  $1\frac{1}{2}$  millions. The additional cost of giving the conduit this capacity would add Rs. 2,00,000 to the abstract estimate marked A, and it may be a matter for consideration whether it would not be wise to construct the conduits with this carrying capacity at first, as it would not be an easy matter to do it afterwards without interfering with the supply to Bombay.

51. In accordance with your instructions I have applied myself almost exclusively to a revision of the Tansa project only, nor was there time to make any detailed investigation into the other projects which have been brought forward. But I have carefully considered the several new schemes referred to in Major Tulloch's report, and I have no hesitation in saying that I consider the Tansa project by far the best for a final supply for the City of Bombay.

52. Of the projects which have been put forward there are, I think, only three which could be seriously considered as a final supply for the city. These are Tansa, Shewla, and Kaman. The two first are gravitating projects; the last is low level, and the water should be pumped by steam-power to the required height. Other conditions being nearly equal, there can be no question as to the superiority of a gravitating supply over a supply which has to be pumped up by steam-power. For comparison I will take Major Tulloch's estimates for a supply of 17 million gallons per day from Tansa (by gravitation) and from Kaman pumped by steam in Bombay to R.L. 190. The former is  $115\frac{1}{2}$  lakhs and the latter  $116\frac{1}{2}$  lakhs. Major Tulloch has, I think, over-estimated the cost of pumping; he has assumed the price of coal in the above estimate to be Rs. 30 per ton. According to present rates it may safely be taken at Rs. 20. Revising his estimate according to this rate it would amount to  $106\frac{1}{2}$  lakhs. As I have already shown, about one-third of the whole supply should be pumped to R.L. 255 instead of 190. Making allowance for the extra work which this would involve, and taking coal at Rs. 20 per ton, I make Major Tulloch's estimate thus revised amount to 110 lakhs.

53. Were the Kaman project for the supply of 17 million gallons per day investigated and revised on lines similar to those I have adopted in treating the Tansa project, I am of opinion that it would compare very unfavorably with the latter. The estimate for the Kaman dam would probably require revision to a much greater extent than that for the Tansa. The bed of the river at the dam site is at mean sea level, and in trial-pits which were sunk to a depth of 20 feet no rock was met with, but water came in such quantities that it could not be kept down by baling (see page 200, Major Tulloch's report). Judging from its situation I should not be surprised if rock was at such a depth as to render the construction of a dam there financially impracticable. The remarks I have made with reference to Major Tulloch's proposed duct for the Tansa project would apply equally to the duct for the Kaman project, and the estimate for it would probably have to be considerably increased.

54. In comparing the Tansa and Shewla projects almost everything is, in my opinion, in favor of the former. The catchment area of the Tansa is more than double that of Shewla. As regards rainfall, they are, judging from their situations, probably on equal terms. Shewla is at a slightly greater distance from Bombay than Tansa is. The nature of the country from Shewla to Bhowndi does not admit of the duct being brought in conduit to the same extent as from Tansa to Bhowndi, and this is a great disadvantage. There would be about 7 miles more siphon than on the Tansa duct, and to reach Ghât-Kopar at the same level that I propose for the Tansa duct, it would be necessary to draw off from Shewla at about R.L. 397. The full supply level of the lake as proposed by Mr. Russel Aitken is 418; nor would the nature of the ground admit of water being impounded to a much higher level. The area of the lake at this level is, according to Mr. Aitken's plans, 4,000 acres, and the available depth for draw-off would be only 16 feet. The area of the Tansa lake at the level at which I propose to impound water in the first instance (R.L. 405) is 3,300 acres and the available depth for draw-off is 20 feet. The area of the Tansa lake at the height to which water may eventually be impounded (R.L. 420) is 4,300 acres and the available depth for draw-off 35 feet. Regarded, therefore, as a project providing finality in the matter of a water-supply for Bombay, Shewla cannot compare with Tansa.

55. Mr. Russel Aitken proposed an earthen dam 96 feet high, the cost of which, without contingencies, he estimated at 10 lakhs of rupees. I do not think that in the present day many Engineers would recommend the construction of an earthen dam

of that height. I have not had an opportunity of examining the site, and I do not know what facilities it offers for the construction of a masonry dam. Judging from the section given in Mr. Aitken's report, the dam would not be a long one, but the high portion would bear a large proportion to its entire length.

56. It would take from six to seven years to complete the project which I propose for adoption, and the provision to be made year by year for expenditure would be approximately as follows:—

1st year .....	6 lakhs.
2nd " .....	20 "
3rd " .....	20 "
4th " .....	25 "
5th " .....	25 "
6th " .....	20 "
7th " .....	10 "

57. In carrying out these works I would recommend that the work of the dam be done departmentally. It is a work of considerable magnitude, and one in which any unsoundness in materials or workmanship might prove disastrous. There are, I know, contractors who, if entrusted with the work, would use every endeavour to have nothing but thoroughly sound work done, but among the lower members of a contractors' staff there are often men who have no sense of their responsibility in getting sound work done, and whose whole anxiety is to get through the work with the greatest possible pecuniary profit to their employers. The amount of supervision required in such cases is very great, and in some instances it is almost impossible to exercise it. Still there is no reason why minor contracts in connection with the dam works should not be given, such as excavation of foundations, supply of materials, lime kunker, &c. The lime should be prepared departmentally. The arrangements required to carry out such a work successfully are extensive and necessitate the provision of a considerable quantity of plant, such as mortar mills, steam-engines, tramways, winches, derricks, &c.

58. As regards the other works included in the project—tunnels, conduits, aqueducts, formation of pipe track, &c., &c.—they may, I think, with advantage be carried out by contract. The supply of pipes for siphons must, of course, be carried out by contract.

59. As I have explained in para. 2, I have not been able to revise the whole project in detail; still the surveys and plans for the dam and for the first 33 miles of the duct (as far as the Bassein Creek) are sufficiently complete to admit of work being actually started on any part within a few weeks.

60. The work which will necessarily occupy the longest time are the dam and the tunnels. Assuming that the work will be put in hand at once, I would suggest that the foundations of the dam across the river bed be got in in the working season 1885-86, and that the dam across the river be raised as high as practicable during the season, so that it may impound a store of water sufficient for all requirements on the works during the succeeding season. The actual quantity of work done cannot be large, but arrangements, such as opening quarries, laying tramways, providing all the necessary plant, &c., can be made so as to start work in full strength in the season 1886-87.

As I have recommended in para. 58, I think the tunnels may be carried out by contract, and though much real work could not be done during the season 1885-86, the contractors could make arrangements to be in full swing in 1886-87.

61. The rates now obtaining for iron are low, and the time is favorable for entering into contracts for the supply of cast-iron mains. Assuming that the works will be proceeded with, I would suggest that no time be lost in inviting tenders for pipes.

I have the honor to be,

Sir,

Your most obedient servant,

(Signed) W. CLERKE, M.I.C.E.,  
Executive Engineer,  
Tansa Survey.



**A**

ABSTRACT ESTIMATE of the Cost of the Tansa Project. The Lake with full supply at B L. 405, and the Duct to be capable of delivering 17 millions of gallons per day.

Quantity.	Description of Work.	Rate.		Amount.	TOTAL.
	<b>LAKE AT TANSA.</b>	Ps	Ra.	D Ra.	Ra.
4,084,347 c. ft.	Land Compensation .....	.....	.....	1,20,000	
10,038,591 "	Excavation in foundations...	100	3	1,22,530	
	Rubble masonry in dam ...	100	27	27,10,420	
	Outlet Works .....	.....	.....	8,000	29,60,950
	<b>DUCT TO GHAT-KOPAR.</b>	Mile.	200	9,600	
48 miles.	Land Compensation.....				
26 25 "	Conduit (including Aque- ducts).....	"	86,000	22,57,500	
2 5 "	Tunnel .....	"	1,70,000	4,25,000	
7 1 "	Siphon, 48" diameter 1½" thick	"	1,30,000	9,23,000	
12 6 "	" " 1½" "	"	1,50,000	18,90,000	
	Bridge across Bassein Creek	.....	.....	3,00,000	3,00,000
	Service Reservoir at Ghât- Kopar.....	.....	.....	5,00,000	5,00,000
23 "	33" Mains from Ghât Kopar to Bhandarwada and Ma- labar Hill .....	.....	79,000	18,17,000	18,17,000
	Contingencies 10 per cent....	.....	.....	.....	1,10,83,050
	Establishment Charges.....	.....	.....	.....	11,00,000
					4,16,950
				Total...Ra.	1,26,00,000

**B**

ABSTRACT ESTIMATE of the Cost of the Tansa Project. The Lake with full supply level at B.L. 398, and the Duct to be capable of delivering 8 millions of gallons per day.

Quantity.	Description of Work.	Rate.		Amount.	TOTAL.
	<b>LAKE AT TANSA.</b>	Per	Ra.	Ra.	Ra.
4,014,819 c. ft.	Land Compensation .....	.....	.....	1,20,000	
8,894,100 "	Excavation in foundations .	100	3	1,20,444	
	Rubble masonry in dam ...	"	27	24,01,413	
	Outlet Works .....	.....	.....	5,000	26,46,857
	<b>DUCT TO GHAT-KOPAR.</b>	Mile	200	9,600	
48 miles.	Land Compensation .....				
26 25 "	Conduit .....	"	86,000	22,57,500	
2 5 "	Tunnel .....	"	1,70,000	4,25,000	
9 8 "	Siphon, 36" diar., 1" thick	"	86,000	8,25,600	
10 1 "	" " 1½" " ...	"	97,000	9,79,700	
	Bridge across Bassein Creek	.....	.....	3,00,000	3,00,000
23 "	24" Mains from Ghât-Kopar to Bhandarwada and Ma- labar Hill.....	Mile	56,000	12,88,000	12,88,000
	Contingencies 10 per cent .	.....	.....	.....	8,70,000
	Establishment Charges.....	.....	.....	.....	4,07,743
				Total ..R.	1,00,10,000

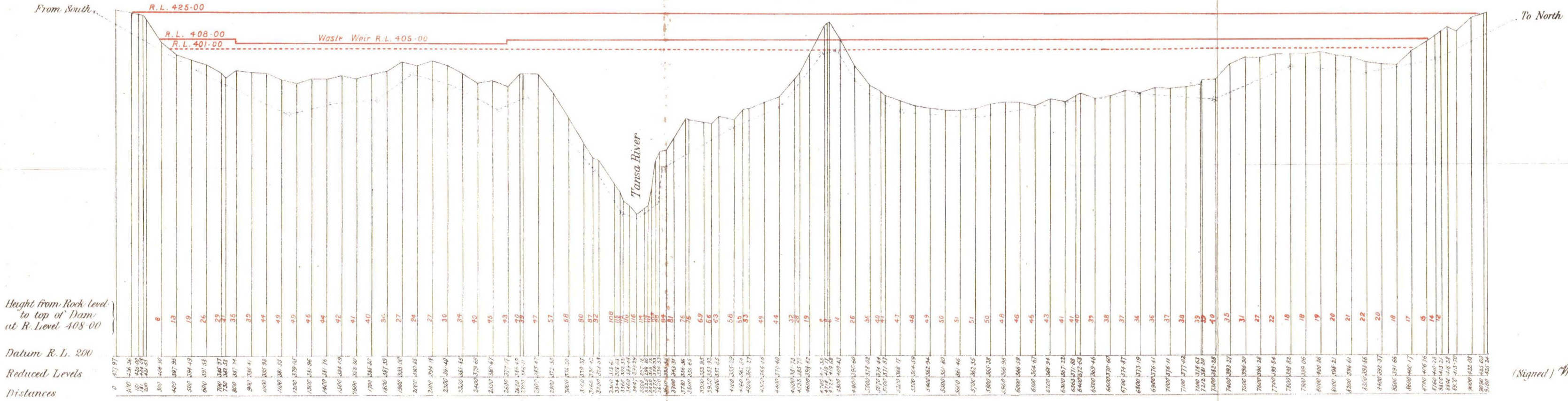
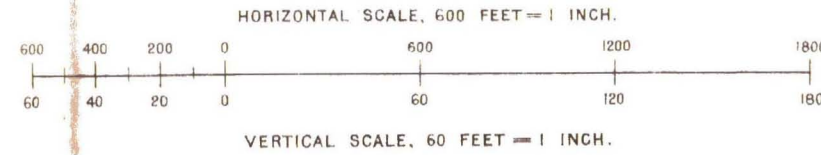
BOMBAY, 13th Aug. 1885.

W. CLERKE, M.I.C.E.,  
Executive Engineer,  
Tansa Survey.

# TANSA PROJECT LONGITUDINAL SECTION OF DAM

NOTE. Blue circles show the actual sites of trial pits taken along the Dam line.  
Blue line shows the probable rock surface derived from the Trial Pits.

NOTE. The levels are referred to Town Hall Datum.  
A B.M. has been cut in the solid rock in the bed of the River about 350 feet to the west of the line of Dam, and its value 298.18 engraved on it.



Height from Rock Level to top of Dam at R. Level 408.00

Datum R.L. 200

Reduced Levels

Distances

Reduced to Scale  
Civ. Photogram. Office, Hong. 1935

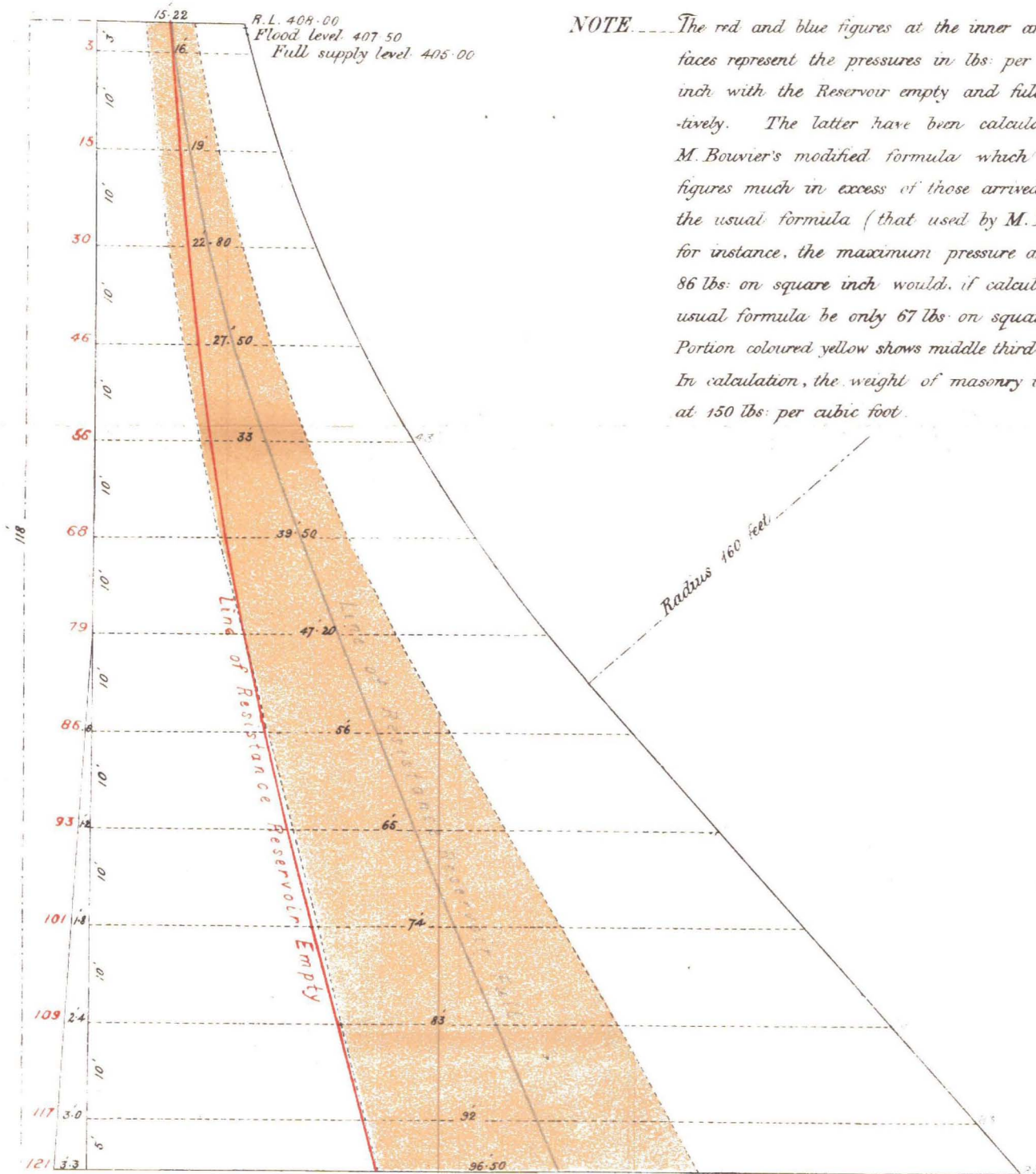
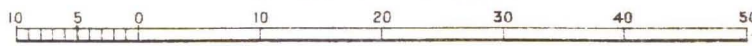
(Signed) W. Clarke, M. Inst. C.E.  
Executive Engineer  
Tansa Project

# TANSA PROJECT

DRAWING N<sup>o</sup> 3

DESIGN FOR DAM  
 RAISED TO R.L. 408  
 WITH FULL SUPPLY LEVEL AT R.L. 405  
 AND CAPABLE OF BEING FINALLY  
 RAISED TO R.L. 425

Scale, 16 Feet = 1 Inch



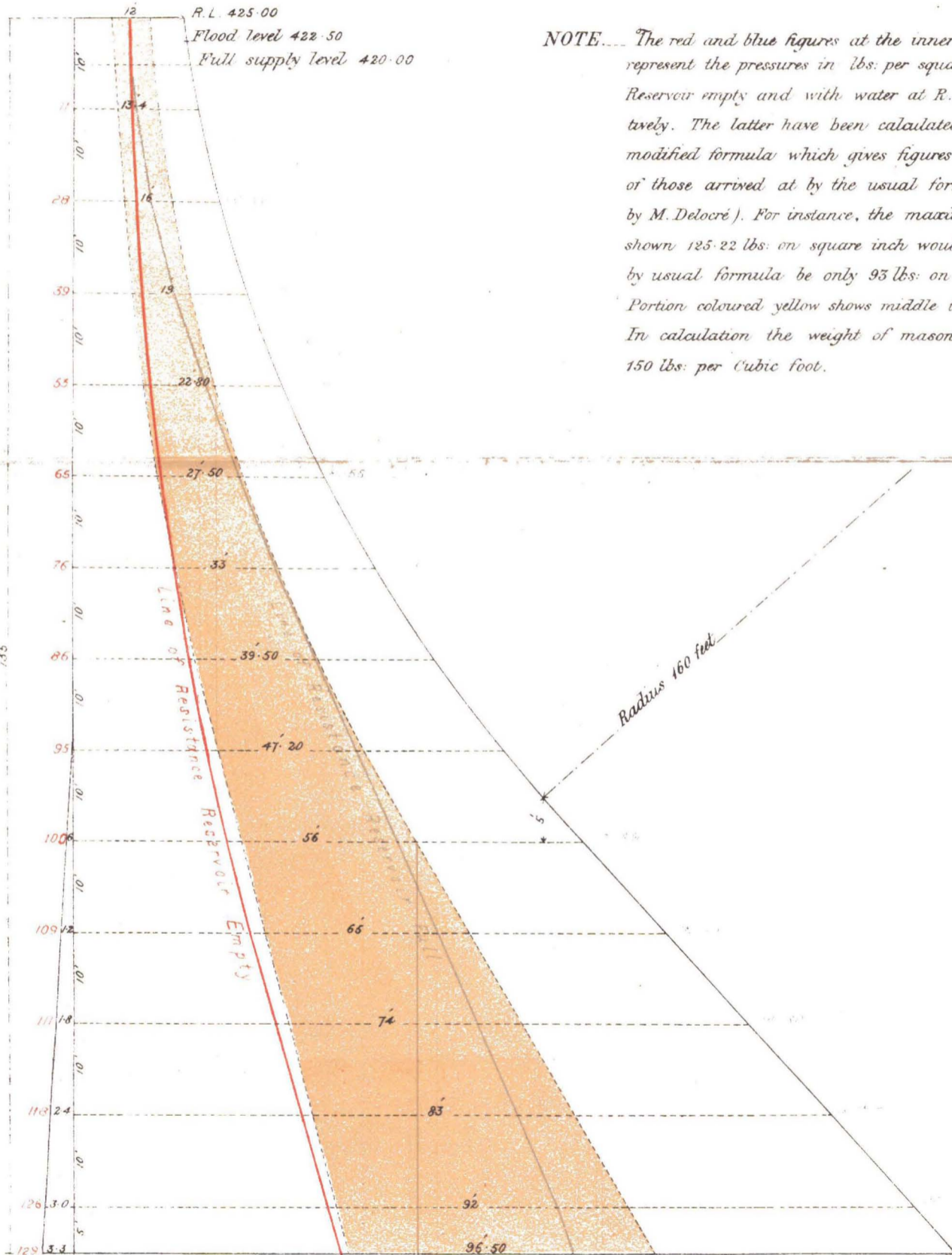
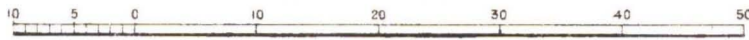
NOTE. The red and blue figures at the inner and outer faces represent the pressures in lbs. per square inch with the Reservoir empty and full respectively. The latter have been calculated by M. Bouvier's modified formula which gives figures much in excess of those arrived at by the usual formula (that used by M. Delocre) for instance, the maximum pressure as shown 86 lbs. on square inch would, if calculated by usual formula be only 67 lbs. on square inch. Portion coloured yellow shows middle third of Dam. In calculation, the weight of masonry is taken at 150 lbs. per cubic foot.

(Signed) *W. Clarke*, M. Inst. C.E.  
 Executive Engineer  
 Tansa Project

# TANSA PROJECT

DESIGN FOR DAM  
 RAISED TO R.L. 425  
 WITH FULL SUPPLY LEVEL  
 AT R.L. 420 T.H.D.

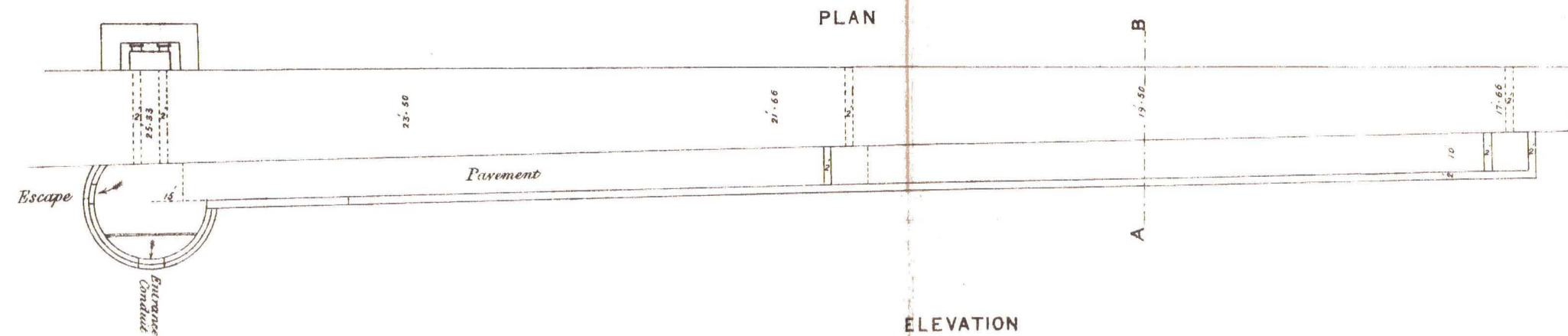
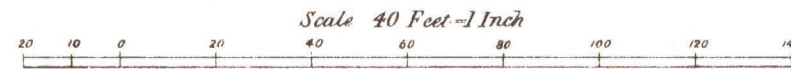
Scale 16 Feet = 1 Inch.



NOTE.— The red and blue figures at the inner and outer faces represent the pressures in lbs. per square inch with the Reservoir empty and with water at R.L. 422.50 respectively. The latter have been calculated by M. Bouvier's modified formula which gives figures much in excess of those arrived at by the usual formula (that used by M. Delocre). For instance, the maximum pressure as shown 125.22 lbs. on square inch would, if calculated by usual formula be only 95 lbs. on square inch. Portion coloured yellow shows middle third of Dam. In calculation the weight of masonry is taken at 150 lbs. per Cubic foot.

# TANSA PROJECT

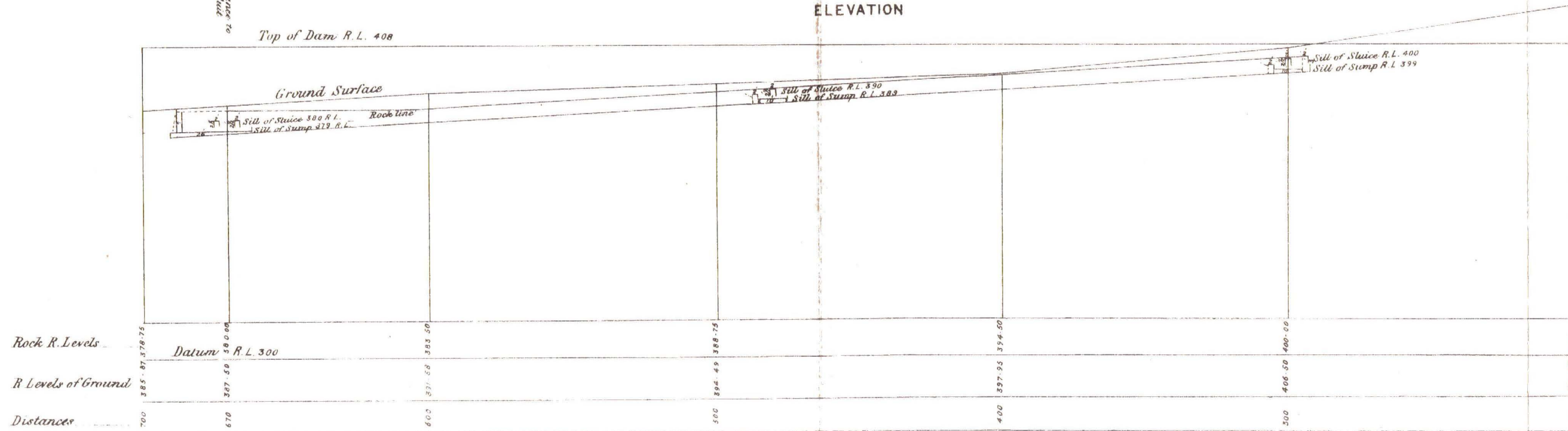
## OUTLET WORKS



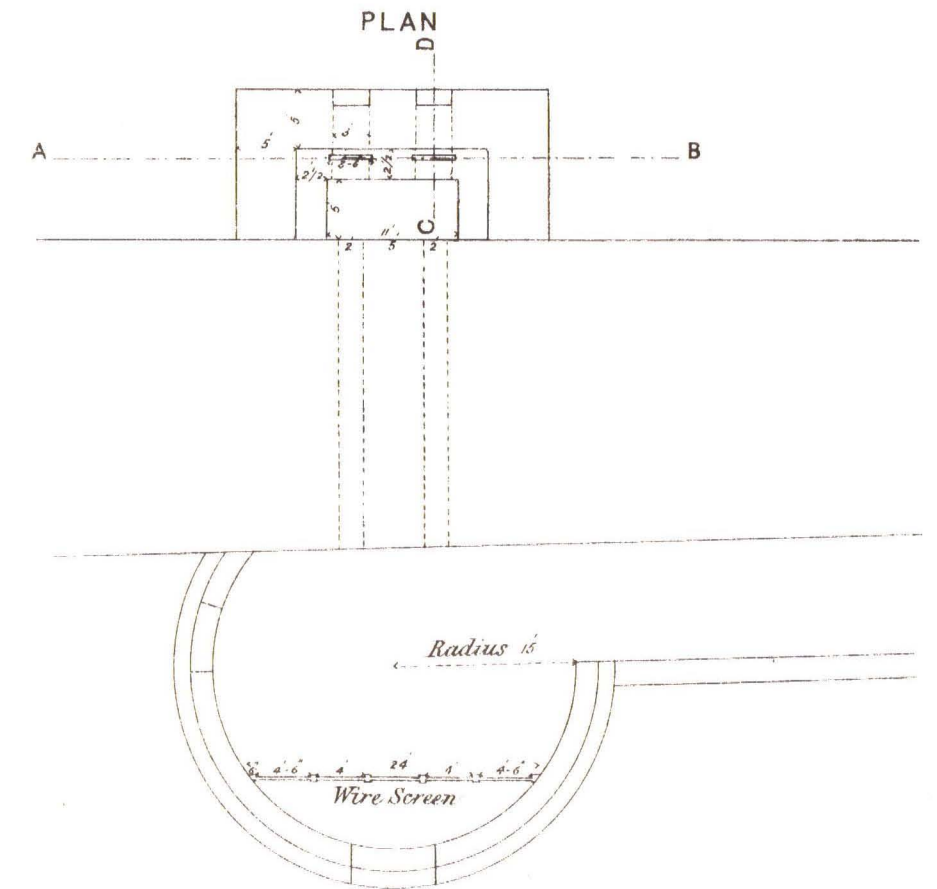
CROSS SECTION ON A. B.



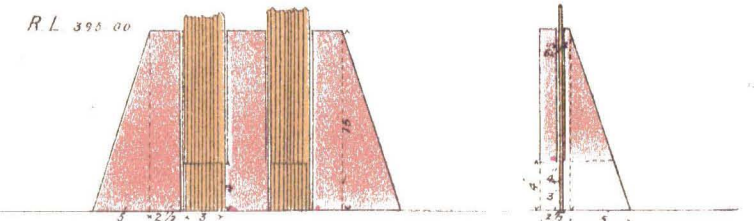
ELEVATION



ENLARGEMENT OF WELL & CISTERN



SECTION ON A. B. SECTION ON C. D.



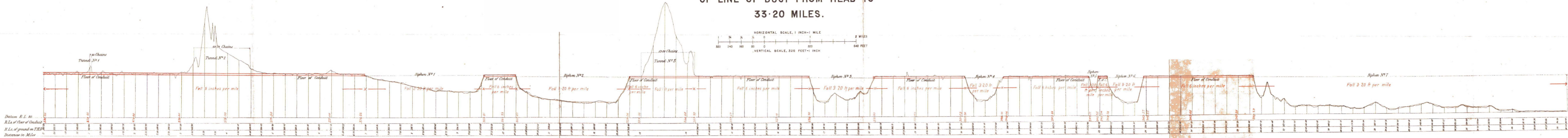
Scale 16 Feet = 1 Inch



(Signed) *W. Clarke, M. Inst. C. E.*  
 Executive Engineer  
 Tansa Project

Enlarged to 1/4 Scale  
 from Photostatic Office, Bombay, 1925

# TANSA PROJECT LONGITUDINAL SECTION OF LINE OF DUCT FROM HEAD TO 33.20 MILES.



Datum R. L. 80

R. Ls. of Floor of Conduit

R. Ls. of ground on T.R.D.

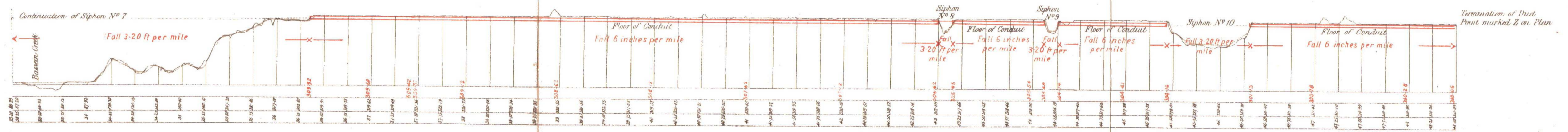
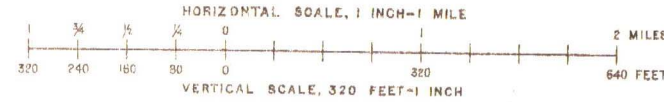
Distances in Miles

0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	14.9	15.0	15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.8	19.9	20.0	20.1	20.2	20.3	20.4	20.5	20.6	20.7	20.8	20.9	21.0	21.1	21.2	21.3	21.4	21.5	21.6	21.7	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6	22.7	22.8	22.9	23.0	23.1	23.2	23.3	23.4	23.5	23.6	23.7	23.8	23.9	24.0	24.1	24.2	24.3	24.4	24.5	24.6	24.7	24.8	24.9	25.0	25.1	25.2	25.3	25.4	25.5	25.6	25.7	25.8	25.9	26.0	26.1	26.2	26.3	26.4	26.5	26.6	26.7	26.8	26.9	27.0	27.1	27.2	27.3	27.4	27.5	27.6	27.7	27.8	27.9	28.0	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5	30.6	30.7	30.8	30.9	31.0	31.1	31.2	31.3	31.4	31.5	31.6	31.7	31.8	31.9	32.0	32.1	32.2	32.3	32.4	32.5	32.6	32.7	32.8	32.9	33.0	33.1	33.2	33.3	33.4	33.5	33.6	33.7	33.8	33.9	34.0	34.1	34.2	34.3	34.4	34.5	34.6	34.7	34.8	34.9	35.0	35.1	35.2	35.3	35.4	35.5	35.6	35.7	35.8	35.9	36.0	36.1	36.2	36.3	36.4	36.5	36.6	36.7	36.8	36.9	37.0	37.1	37.2	37.3	37.4	37.5	37.6	37.7	37.8	37.9	38.0	38.1	38.2	38.3	38.4	38.5	38.6	38.7	38.8	38.9	39.0	39.1	39.2	39.3	39.4	39.5	39.6	39.7	39.8	39.9	40.0	40.1	40.2	40.3	40.4	40.5	40.6	40.7	40.8	40.9	41.0	41.1	41.2	41.3	41.4	41.5	41.6	41.7	41.8	41.9	42.0	42.1	42.2	42.3	42.4	42.5	42.6	42.7	42.8	42.9	43.0	43.1	43.2	43.3	43.4	43.5	43.6	43.7	43.8	43.9	44.0	44.1	44.2	44.3	44.4	44.5	44.6	44.7	44.8	44.9	45.0	45.1	45.2	45.3	45.4	45.5	45.6	45.7	45.8	45.9	46.0	46.1	46.2	46.3	46.4	46.5	46.6	46.7	46.8	46.9	47.0	47.1	47.2	47.3	47.4	47.5	47.6	47.7	47.8	47.9	48.0	48.1	48.2	48.3	48.4	48.5	48.6	48.7	48.8	48.9	49.0	49.1	49.2	49.3	49.4	49.5	49.6	49.7	49.8	49.9	50.0	50.1	50.2	50.3	50.4	50.5	50.6	50.7	50.8	50.9	51.0	51.1	51.2	51.3	51.4	51.5	51.6	51.7	51.8	51.9	52.0	52.1	52.2	52.3	52.4	52.5	52.6	52.7	52.8	52.9	53.0	53.1	53.2	53.3	53.4	53.5	53.6	53.7	53.8	53.9	54.0	54.1	54.2	54.3	54.4	54.5	54.6	54.7	54.8	54.9	55.0	55.1	55.2	55.3	55.4	55.5	55.6	55.7	55.8	55.9	56.0	56.1	56.2	56.3	56.4	56.5	56.6	56.7	56.8	56.9	57.0	57.1	57.2	57.3	57.4	57.5	57.6	57.7	57.8	57.9	58.0	58.1	58.2	58.3	58.4	58.5	58.6	58.7	58.8	58.9	59.0	59.1	59.2	59.3	59.4	59.5	59.6	59.7	59.8	59.9	60.0	60.1	60.2	60.3	60.4	60.5	60.6	60.7	60.8	60.9	61.0	61.1	61.2	61.3	61.4	61.5	61.6	61.7	61.8	61.9	62.0	62.1	62.2	62.3	62.4	62.5	62.6	62.7	62.8	62.9	63.0	63.1	63.2	63.3	63.4	63.5	63.6	63.7	63.8	63.9	64.0	64.1	64.2	64.3	64.4	64.5	64.6	64.7	64.8	64.9	65.0	65.1	65.2	65.3	65.4	65.5	65.6	65.7	65.8	65.9	66.0	66.1	66.2	66.3	66.4	66.5	66.6	66.7	66.8	66.9	67.0	67.1	67.2	67.3	67.4	67.5	67.6	67.7	67.8	67.9	68.0	68.1	68.2	68.3	68.4	68.5	68.6	68.7	68.8	68.9	69.0	69.1	69.2	69.3	69.4	69.5	69.6	69.7	69.8	69.9	70.0	70.1	70.2	70.3	70.4	70.5	70.6	70.7	70.8	70.9	71.0	71.1	71.2	71.3	71.4	71.5	71.6	71.7	71.8	71.9	72.0	72.1	72.2	72.3	72.4	72.5	72.6	72.7	72.8	72.9	73.0	73.1	73.2	73.3	73.4	73.5	73.6	73.7	73.8	73.9	74.0	74.1	74.2	74.3	74.4	74.5	74.6	74.7	74.8	74.9	75.0	75.1	75.2	75.3	75.4	75.5	75.6	75.7	75.8	75.9	76.0	76.1	76.2	76.3	76.4	76.5	76.6	76.7	76.8	76.9	77.0	77.1	77.2	77.3	77.4	77.5	77.6	77.7	77.8	77.9	78.0	78.1	78.2	78.3	78.4	78.5	78.6	78.7	78.8	78.9	79.0	79.1	79.2	79.3	79.4	79.5	79.6	79.7	79.8	79.9	80.0	80.1	80.2	80.3	80.4	80.5	80.6	80.7	80.8	80.9	81.0	81.1	81.2	81.3	81.4	81.5	81.6	81.7	81.8	81.9	82.0	82.1	82.2	82.3	82.4	82.5	82.6	82.7	82.8	82.9	83.0	83.1	83.2	83.3	83.4	83.5	83.6	83.7	83.8	83.9	84.0	84.1	84.2	84.3	84.4	84.5	84.6	84.7	84.8	84.9	85.0	85.1	85.2	85.3	85.4	85.5	85.6	85.7	85.8	85.9	86.0	86.1	86.2	86.3	86.4	86.5	86.6	86.7	86.8	86.9	87.0	87.1	87.2	87.3	87.4	87.5	87.6	87.7	87.8	87.9	88.0	88.1	88.2	88.3	88.4	88.5	88.6	88.7	88.8	88.9	89.0	89.1	89.2	89.3	89.4	89.5	89.6	89.7	89.8	89.9	90.0	90.1	90.2	90.3	90.4	90.5	90.6	90.7	90.8	90.9	91.0	91.1	91.2	91.3	91.4	91.5	91.6	91.7	91.8	91.9	92.0	92.1	92.2	92.3	92.4	92.5	92.6	92.7	92.8	92.9	93.0	93.1	93.2	93.3	93.4	93.5	93.6	93.7	93.8	93.9	94.0	94.1	94.2	94.3	94.4	94.5	94.6	94.7	94.8	94.9	95.0	95.1	95.2	95.3	95.4	95.5	95.6	95.7	95.8	95.9	96.0	96.1	96.2	96.3	96.4	96.5	96.6	96.7	96.8	96.9	97.0	97.1	97.2	97.3	97.4	97.5	97.6	97.7	97.8	97.9	98.0	98.1	98.2	98.3	98.4	98.5	98.6	98.7	98.8	98.9	99.0	99.1	99.2	99.3	99.4	99.5	99.6	99.7	99.8	99.9	100.0
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Reduced to 1/4 Scale  
Govt Photodup Office, Poona, 1915

(Signed) H. Clarke M. Inst. C. E.  
Executive Engineer  
Tansa Project

# TANSA PROJECT LONGITUDINAL SECTION OF LINE OF DUCT FROM 33.20 TO 48.50 MILES



Reduced to 4 Scale  
Govt Photodup. Office, Poona, 1885.

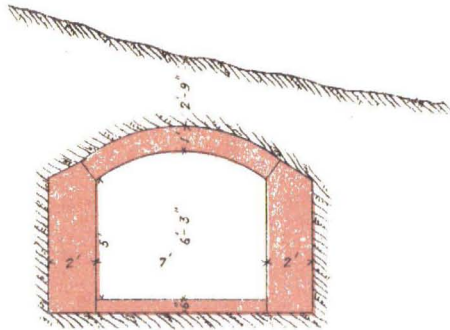
(Signed) H. Clarke M. Inst. C. E.  
Executive Engineer  
Tansa Project

# TANSA PROJECT

DRAWING N<sup>o</sup> 10

## CONDUIT.

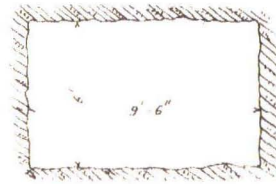
TRANSVERSE SECTION



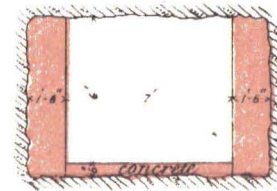
## TUNNEL.

TRANSVERSE SECTIONS.

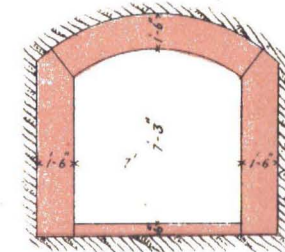
*Unlined.*



*Partially lined.*

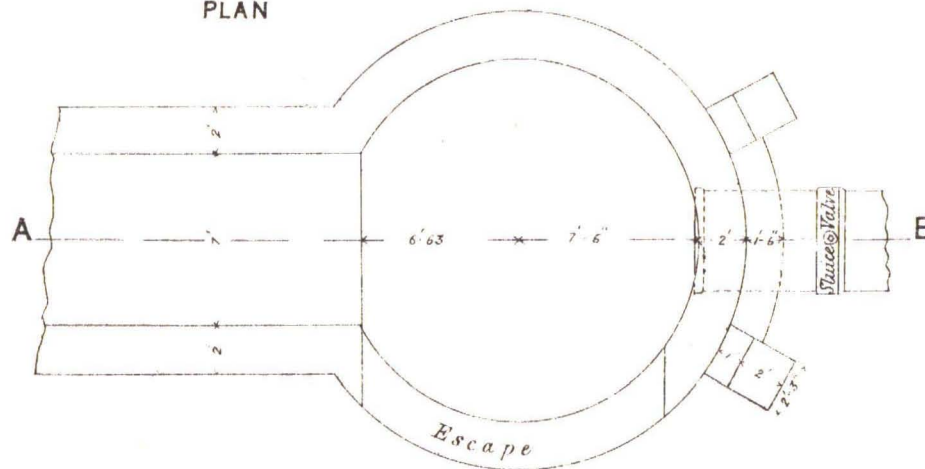


*Wholly lined.*

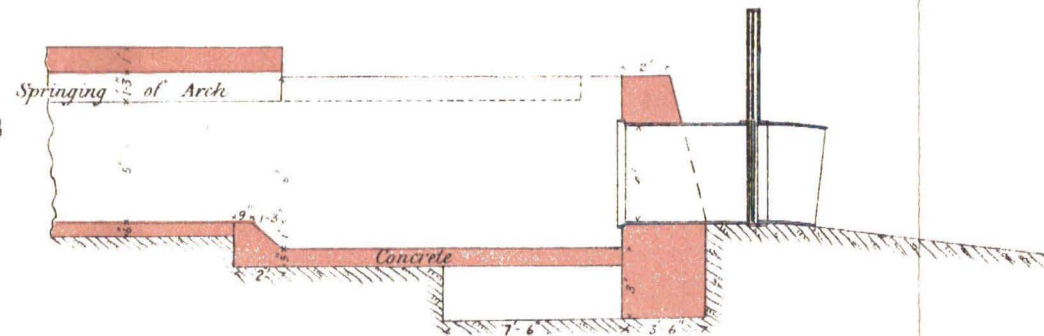


## SIPHON-HEAD.

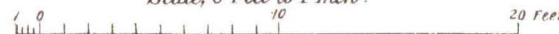
PLAN



SECTION ON LINE A. B.



Scale, 8 Feet to 1 Inch.



(Signed) *W. Clarke*, M. Inst. C. E.  
Executive Engineer  
Tansa Project