P.W.C. № 9974

the President, Municipal Commission,
Civil and Military Station, Bangalore,
on the subject, from which it will be
seen that the small quantity of manure
collected on the margin of the Tank
has been removed and that the use
of manure for the garden will be
discontinued.

I have the honour to be,

The Hon'ble Under Secretary

Sir,

Your most obedient Servant.

Under Secretary - B

for Assistant to the Resident.

B.N.№ 2894 W 4/27-10-87
G.O. 2292-3W-10-9-86

No 3400 W 4/13. 10 December 1887.

Communicated to the Supdg. Engineer, V circle with reference to his letter No. 2819 dated 12th Octr. 1887.

8.12.87

8/12/87.

S.E. V circle ✓ Dept. 14.12.87.

9-12-87 R.12-12-87

No. 3881/1667

SECRETARY TO GOVERNMENT 6 DEC 87 PUBLIC WORKS DEPARTMENT

L. WHITE KING, Esq. C.S.
ASSISTANT TO THE RESIDENT IN MYSORE.

To The Secretary to the Government of Madras, Public Works Department.

Dated, Bangalore, 5th December 1887.

Sir,

With reference to your letter No. 2894. W. dated 27th October 1887, bringing to notice the possible pollution of the water of the Ulsoor Tank by the gardening operations carried on by the Municipality on the foreshore of the Tank, I am directed to enclose for the information of the Government of Madras a copy of a letter from the

† No. 1035/1537 dated 16th Nov. 87.

of manure collected on the margin of the Tank, to which in vicinity no exception could possibly be taken, has been removed and the use of manure for the very limited garden will not be continued.

I have &c.
(Sd) E. Stewart
President.

Copy
Henry Cleaves
Registrar

E.1
PW 9974/87

No 1035/1537

Office of the Municipal Commission

Civil and Military Station

Bangalore 16th November 1887

From:

The President, Municipal Commission

Civil and Military Station

Bangalore.

To.

The Assistant to the Resident in Mysore

Bangalore.

Sir,

I have the honour to acknowledge the receipt of your letter No. 3681/6667 dated 11th November 1887, giving Cover to a copy of letter from the Government of Madras Public Works Department regarding the possible pollution of the water of the Ulsoor Lake, and in reply to inform you, that the small quantity of

No. 2172/70

Office of the Resident in Mysore

Bangalore 6th November 1869

From

Major J. H. Nevill

Agent to the Resident

in Mysore.

To

Colonel Shah Stewart R.E.

Secretary to the Govt. of Madras

Public Works Department.

Sir,

Vide Min. letter is printed at page 5 of Pro. 22 2292 W.R. 10-9-96.

× × ×

2. The Municipal Commissioners, having agreed to deepening the Lower Tank, and raising the waste weir at a cost of Rs. 10,000, and to the purchase of the Jeevanhally Tank, the work of excavation was begun early in August and was actively carried on till the heavy fall of rain in the latter part of September stopped it. In all some 34,000 cubic yards of earth have, at a cost of Rs. 5546-11-4 been removed from the bed of the Lower Tank to form an island and an embankment on the Eastern side, which

are

are now being laid out as ornamental grounds 1450 lineal yards of hedge have been planted, 8000 square yards of embankment have been sectioned and turfed; 2 culverts have been lengthened and some minor works have been completed. The constant rain of the last six weeks has so raised the level of the water in the Lower Tank that it is impossible at present to undertake work on the weir.

× × ×

I have &c.

(Signed) J. H. Newill

Agt. to the Resident.

(True Copy)

(Signed) G. Swinley Colonel

Agt. Dr. Mr. Genl. B.D.

(True Copy)

H. H. Robert Coll. R.E.

Supty: Engineer, V Circle.

E.2
P.W. 8172/87

No. C/4

Supty: Engineer's Office,
5th Circle-Madras
Bangalore 20th September 188

From
Colonel H. H. Hibart R.E.
Supty: Engineer. V Circle.

To
The Agt. Dr. Mr. General
Bangalore Division.

Sir,

I have the honor to draw your attention to the fact that the Municipality are forming a garden on the foreshore of the Ellaon Tank between the tank and Kensington Road. This seems to me highly undesirable as the formation of a garden entails the use of manure and when I visited the place this morning I observed a cart load of manure on the ground - apparently horse dung. This strip of land was as far as I remember purchased by the Madras Government some 12 years ago - for a sum of 2 or 300 Rupees with the idea of keeping it neat and clean - grass probably to be sown and no doubt a few trees to be planted - but it was never contemplated to have a garden. I shall be obliged if you will inform me if this garden has been formed with

with the permission of the Major General Commanding as I cannot help thinking that the promoters of this garden have gone far beyond the intention of the Military Authorities. I observe also that arrangements are being made to place a picottah (or something of the kind) on this ground - to enable a house owner (R. P. Campbell Esqr. I believe) to take water from the tank. This also it would be as well to prohibit.

I have written to my Office to obtain exact information about this piece of ground as well as about the piece of ground in front of the Dhobi's Wells - which is also Military ground and should be demarcated.

I have the honor &c.

(Signed) Henry M. Hibbert Lt. R.E.

Supdg. Engineer, V Circle.

No. 684

Agt. Dr. Mr. Genl. Offices
Bangalore Division.

From Bangalore 10 October 1887.

The Agt. Quarter Master Genl.
Bangalore Dv.

To

The Supdg. Engineer,
V Circle - Chepauk Madras.

Sir,

I have the honor, by order, to

to acknowledge the receipt of your No. C/4 dated 20th September 1887, and I regret the delay in replying to the same.

2. Regarding the formation of a garden on the foreshore of the Ulsoor Tank, between the Tank and Kensington Road, I have the honor to invite your attention to the accompanying copy of para 2 of letter No. 2172/70 dated 6th November 1886 from the Resident in Mysore to the Government of Madras, P.W.D. in which it was stated among other matters, that some 34,000 cubic yards of earth had, at the expense of the Municipality and at a cost of Rs. 5,546 been removed from the bed of the Lower tank to form an island, and an embankment on the Eastern side which were being laid out, as ornamental grounds, 1,450 lineal yards of hedge had been planted, 8,000 square yards of embankment had been sodded and turfed, 2 culverts had been lengthened and that some minor works had been completed.

3. The Government of Madras it will be observed, raised no objection to the laying out of the ground referred to, viz - the embankment -

whi[illegible]; "a

cohis is alluded to by you, as the foreshore of the Ulsoor Tank.

4. The manure used for the few flower beds, can hardly be prejudicial to the purity of the water in the Tank and to such a limited extent is the manure used, that the most particular person cannot take exception to its use in the case under reference.

5 In this connection I would request attention to P.G. No. 4325 dated September 6th 1884 in which, in para 2 of the Resident's letter No. 756/388 dated 30th June 1884, the Ulsoor Tank is referred to, as a property vested in the Municipal Commissions by the Municipal Regulations of 1883.

6. With reference to the placing of a Picottah on the East embankment of the Ulsoor Tank, I have the honor to observe that it seems far from objectionable as it will prevent people from having any excuse to enter the tank as they can fill their water barrels &c from the trough at the Road side.

I have the honor &c
(Signd) G. Sewell Colonel
Agt Dr Mr Genl B. Dn

(True Copies)

H. Vibart Colonel R.E.
Suptg: Engineer V Circle

E.1
P/8172/87

SUPERINTENDING ENGINEER'S OFFICE,

No. 2819. Camp Bangalore V Circle, Madras,
~~Depth~~, 12th October 1887.

From

Colonel H. M. Vibart R.E.

SUPERINTENDING ENGINEER, V CIRCLE,

To

THE Secretary to Government,
Public Works Department.

SIR,

Enclosures.

Last month I drew the attention of the Agt Dr Mr General Bangalore to the fact that the Municipality were forming a garden on the foreshore of the Ulsoor Tank between the Tank and Kensington Road. I stated that it seemed to me highly undesirable as the formation of a garden entails the use of manure and that when I visited the place there was a cart load of manure (apparently horse dung) on the ground. In reply the Agt Dr Mr Genl that on 6th Nov/85. the Agt to the Resident in Mysore wrote to the Secretary to Government Madras P. W. D. and informed him that it was intended to form an island and embankment on the Eastern side (of Ulsoor Tank) which are now being laid out as ornamental grounds" and that the

the Government of Madras made no objection to the laying out of the ground in question.

The Asst. Quarter Master General further observes that "the manure used for the few flower beds can hardly be prejudicial to the purity of the water in the tank and to such a limited extent is the manure used that the most particular person cannot take exception to its use in the case under reference".

There can I think be no objection to the formation of an "Ornamental ground" along side the Ulsoor tank - as I should understand this to be merely laying out the ground with gravel walks and grass with trees. But I think there is an objection to the use of manure so very close to the tank and it is impossible to produce good flower beds without the free use of manure. The flower beds at present in use are not very extensive but there seems to me to be nothing to prevent the Municipality extending the flower beds all along that side of the tank. I therefore think that the formation of flower beds in this part should

be

be prohibited. I forward the correspondence with the Asst. Qr. Mr. General and should be glad to know if the Municipality are to be allowed to continue the formation of a garden.

So much has been written regarding the necessity of keeping the Ulsoor Tank water pure that I cannot think it consistent allowing the formation of a garden (which must have manure) along the very margin of the Tank.

I have the honor to be

Sir

Your most Obedient Servant

Alexr. Rebert Lt. R.E.

Supty. Engineer. V Circle.

G.O. 2292 W 4/10-7-86

OWC No. 8172

No. 2819.

From

The Supt. & Engr. 5th Circle

To

The Secretary to Govt
P.W. Deptt.

No. 2894 W 4/27th Oct/87

Dated 12th October 1887.
Read " 14th " "
E.2.

New Municipal Garden on the foreshore of the Ulsoor Tank-Bangalore

Brings to notice that there is every likelihood of the tank being polluted by the manure to be used for the flower beds thereon, & states that such a thing as this cannot be permitted along the very margin of the tank & the necessity for preserving a pure water supply in it has already been much said.

circ 21-10-87 R. 25-10-87

P.B./W.P.

No. 2894 W 4/27th October/87

P. W. Department

To

The Resident in
Mysore.

Sir.

I am directed to forward copy of a letter No. 2819 dated 12th October 1887 from the Supg: Engineer V. Circle, on the subject of possible pollution of the water of the Ulsoor Tank at Bangalore by gardening operations on the foreshore carried on by the Municipality, and to suggest that the Municipality be advised to restrict planting to grass and trees, and to

P.T.T. 23/10

prohibit altogether the use of manure on the margin of the lake.

2. So much considera= =tion has been given of late years to the necessity of keeping the surroundings of the Ulsoor tank free from sources of pollution, in order to provide, as far as possible, pure water for the troops, that it seems inconsistent to run the risk of contaminating the water merely for ornamental purposes.

I have &c.

Gardening operations on margin of Ulsoor lake

No. 2834 W a/27. October/87

W.C.W. 21.10.87 Secy. 25/10/87 W. Received 27.10.87

Copy to the S.E. V. circle. Received 27.10.87

for information

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

Buildings and Roads.
Civil Works.

READ again—

G.O., dated 5th October 1883, Nos. 2794-95 W.
" " 13th June 1884, Nos. 1473-74 W.
" " 25th July 1884, No. 1814 W.

READ—also the following papers :—

G.O., dated 23rd February 1885, No. 427 W., Public Works.

Read—the following letter from Colonel H. L. PRENDERGAST, R.E., Superintending Engineer, V Circle, to the Chief Engineer, Public Works Department, dated Madras, 19th January 1885, No. 3900 :—

I have the honor to forward Captain Romilly's report on the supply of water for the European troops at Bangalore, as called for in G.O., No. 1473 W., dated the 13th June 1884.

Captain Romilly has taken up thoroughly the investigation of the different schemes, and gives the cost of them in an abstract statement in appendix Y. There are added, at foot of the table, the annual maintenance charges for the three projects A, B and C.

2. The object in view is to have really good water supplied to the barracks ; and, in my opinion, this object can only be attained by distillation. By this process the water obtained from any source available is supposed to become perfectly pure ; and it will be most convenient to make use of the Halsur tank water, with condensers at the rock, new cisterns at the rock for drinking water, to be conveyed by new mains to the barracks, and with arrangements for pumping water direct from the Dhobies' Wells to the service cisterns at the barracks, to be used for other purposes than drinking.

This scheme is described in paragraphs 23 to 35 of Captain Romilly's report.

The first cost of providing distilled water, Rs. 1,67,000, is a good deal less than that of pumping filtered water from Agaram tank, Rs. 2,90,000 ; but there will be a much higher annual expenditure, which, with interest and depreciation of stock, is estimated at Rs. 84,600.

3. The objections urged in the Military Department are entered in appendix R, and consist in condemning the use of the water in the Halsur tank, in deprecating the conveyance of ablution water through the same pipes as the drinking water, and in showing the danger of depending on a single condensing apparatus, with no source to fall back upon in case of accident.

These objections appear to me to be fully met by the proposals to have a separate main-pipe for the pure drinking water, to use the water of the Halsur tank only after condensation, and to have a double condensing apparatus, so that there will be no failure in the delivery of pure water, even if the machinery in use were to be disabled temporarily.

4. The engine now at work at the Dhobies' Wells is an expensive one in fuel. It is in good order, and is saleable. The rock engine is old and liable to break down.

Hence it is desirable to get rid of the two old engines, and to provide a pair of new engines, each of 12-horse power, to be placed at the Dhobies' Wells, and to pump the water to the cisterns at the barracks.

To obviate the risk of a failure of water in the wells, it is proposed that there should be filter beds of sufficient capacity to allow of the tank water being filtered and pumped up to the service cisterns at the barracks.

The present small pure water cistern is not large enough to allow of sufficient water being pumped up; and it is proposed to utilize this cistern as an additional filter to let out water by gravitation to a new pure water cistern at the wells.

5. The condensing station is intended to be upon the Halsur rock; and it is expected that the Engine house on the rock will, with slight alterations, hold the condensing machinery; a plan of the building has in the mean time been sent to London, and the Normandy Company have been asked if there is sufficient accommodation.

A condenser producing nominally 9,000 gallons, but working up to 12,000 gallons, will in six days provide water sufficient for eight days' consumption; and it is proposed that there should be two complete condensers so as to provide against an accident happening to one.

Captain Romilly shows in paragraph 31 that it will be advantageous not to pump the condensed water over a stand-pipe at the rock but to place cisterns on the rock for the condensed water to gravitate to stand-cocks at the barracks. A lower pair of cisterns will each hold a day's supply for the Royal Horse Artillery, the Royal Artillery and the Cavalry, while an upper pair of cisterns will have command sufficient to give each a day's supply to the Infantry barracks.

The main pipes from the cisterns at different levels will be kept distinct for the delivery of water to the stand-cocks at the Agaram and at the Parade barracks. As a further precaution for maintaining the purity of the water, the estimate provides for iron water-carts, to take the place of the leathern buckets that are now in ordinary use for carrying water about the barracks.

6. The scheme would be more complete if the improvements to the Halsur tank were combined with it in part of the project C. The condition of the tank would be much improved by completely diverting the town drainage, filtering the northern drainage, and bringing in a fresh supply of water from a better gathering ground.

The additional cost through would be as given in paragraph 53:—

	Rs.
New channel masonry works, compensation	26,130
Improvements to tank	33,730
Add for contingencies	2,990
Total ...	62,850

and as the condensing system is not affected by the natural quality of the water, the improvement of the Halsur tank will not be for the benefit of the British troops.

The advantages of a better supply of water would be felt chiefly by the civil population of Bangalore; but I fear the municipality would not consent to pay even a half share of the expenditure.

Order—dated 23rd February 1885, No. 427 W., Public Works.

The above papers will, in the first instance, be referred to the Sanitary Commissioner, Madras, for an expression of his opinions, and will then be forwarded for the remarks of His Excellency the Commander-in-Chief, who will be requested to return them to the Secretary to Government, Public Works Department, with a view to examination in detail and final orders by Government.

(True Extract.)

(Signed) J. SHAW-STEWART, Colonel, R.E.,
Secretary to Government, P.W.D.

From the Resident in Mysore, dated 14th March 1885, No. 2456/1280.

From Deputy Surgeon-General G. BIDIE, M.B., C.I.E., Sanitary Commissioner for Madras, to the Secretary to Government, Public Works Department, dated Madras, 15th April 1885, No. 414.

In returning the correspondence* regarding the Bangalore water-supply, referred under G.O., No. 427, of 23rd February 1885, I have the honor to submit the following remarks to the Right Honorable the Governor in Council.

* 1. Report by Captain F. J. Romilly, R.E.
2. Letter from the Superintending Engineer, V Circle, No. 3900, dated 19th January 1885.
3. Note by Under Secretary to Government, Public Works Department, dated 19th February 1885.

2. In dealing with this question it appears to me that, in restricting inquiries to the requirements of the troops, a somewhat narrow view has been taken of the necessities of the station. A large civil population has been allowed to settle down in the centre of the cantonment, and to outgrow the available water-supply and pollute its sources. These conditions are no doubt greatly to be regretted, but from a sanitary point of view they cannot be ignored. If the bazaar population be constantly exposed to epidemic and other disease from insanitary conditions, all our precautions to protect the health of the troops will be rendered more or less nugatory. I would therefore suggest that steps be taken to move the municipality of Bangalore to adopt some contemporaneous measure to secure for the inhabitants generally, independent of the troops, a sufficient supply of fairly good water. It appears to me that this might be obtained by adopting Colonel Mullins' scheme, with the additions proposed by Captain Romilly † for excluding the whole of the foul sewage of the town from the Halsur tank, and for bringing into it the drainage of a tract of open cultivated ground to the eastward of Bangalore. The supply thus obtained would not perhaps be unimpeachable, but it would be greatly superior to the existing one. The cost of these improvements is estimated at close on Rs. 30,000, which would not certainly be a heavy tax on a population of 81,810; and I have hopes that if the matter were placed fairly before the townspeople, they would not grudge so moderate an outlay for such an important purpose.

† See paragraph 37 of his report, and clause 2, paragraph 51, of Colonel Mullins' report.

3. Of the schemes suggested by Colonel Mullins and worked out by Captain Romilly for securing an improved water-supply for the troops, it appears to me that the proposal to use condensed water is, all things considered, the best.

4. The Agaram tank, which is mentioned as a possible source, receives the drainage of four villages, and although the sewage of two of these could be diverted, that of the remaining two could not be excluded. The proximity of native villages to the reservoir would also be objectionable, as it is almost impossible, under such circumstances, to prevent bathing, washing of clothing and cattle, and other objectionable practices. Captain Romilly puts the whole case very clearly when he says "there can be no doubt that the Agaram tank water is liable to dangerous contamination, and if adopted as the future reservoir for the troops, it is urged that the source of supply must not be accepted as, or expected to be, pure." Looking also at the chemical analyses of the water, they are not, so far as such results give warning of danger, of a satisfactory nature.

5. As regards the scheme for improving the Halsur tank and utilising the existing system with certain additions and modifications, there can be no doubt that, although calculated to effect a great improvement in the quality of the water, it is not such as can be recommended where the health of a large body of European troops is concerned, as they are much more sensitive to the effects of water of inferior quality than natives appear to be.

6. As stated by Colonel Mullins, "it is nearly certain that water of perfectly satisfactory quality could be obtained at Bangalore only by distillations." It is proposed, therefore, to use Normandy's condensing apparatus, and to have, in case of a break-down, two sets, each capable of producing 9,000 gallons in 24 hours. The water for distillation is, according to Captain Romilly's modification of the scheme, to

be drawn from the Halsur tank, and supplied to the troops for drinking and cooking purposes through a distinct series of cisterns, pipes and stand-cocks, at the rate of 3 gallons per head daily. Water for other purposes is to be drawn from the Dhobies' Wells, which yield a tolerably pure supply, and distributed through a separate system of pipes. These arrangements seem to meet the wants of the case. As pointed out by His Excellency the Commander-in-Chief, it is no doubt undesirable to have two qualities of water, the one potable and the other doubtful, supplied to barracks; but it is to be hoped that, by a careful arrangement of stand-cocks and other precautions, the anticipated risks may be nullified. I have therefore no hesitation in recommending the adoption of the scheme for the supply of water by Normandy's apparatus.

From Brigadier-General R. C. STEWART, Quartermaster-General, to the Secretary to Government, Public Works Department, dated Ootacamund, 2nd May 1885, No. 970 B.

In returning the documents received with your No. 10 E., of 17th April 1885, on the subject of the water-supply for Bangalore, which were forwarded for the remarks of the Commander-in-Chief, I am desired to say that, after full consideration of the three schemes which are adverted to in the above papers, Sir Frederick Roberts prefers project B, or that for retaining the present system, and providing for a separate service of water for drinking and culinary purposes by condensation.

2. The difficulty of inducing people to make invariable use of pure water when another and less wholesome supply is equally at hand, renders objectionable any system which comprises two sources, but the difficulty of securing water of sufficient quantity and of adequate purity at Bangalore is so great that His Excellency thinks it best to accept project B, provided that at the same time the conservation of the Halsur tank will be taken in hand by Government and the catchment area increased.

3. The cost of these improvements, as stated by Dr. Bidie, would be about Rs. 30,000, and taking into consideration the benefit that would accrue therefrom to the civil population of Bangalore, it would, in the Commander-in-Chief's opinion, be reasonable to expect the municipality to bear the cost of them, or at all events of a portion of them. Should the municipality not be prepared to accept the obligation, then it is hoped that Government will bear the whole expense, for unless these improvements be carried out, the water of the Halsur tank can never be satisfactory.

From A. H. T. MARTINDALE, Esq., Assistant to the Resident in Mysore, to the Secretary to the Government of Madras, Public Works Department, dated Bangalore, 23rd May 1885, No. 477/236.

In continuation of this office letter, No. 286, dated 13th May 1885. No. 2456/1280, dated 14th March 1885, I am directed to forward copy of letter, number and date as per margin, from the President, Municipal Commission, Civil and Military Station of Bangalore, asking to be furnished with the plans of the recently selected gathering grounds in connection with the late Captain Romilly's scheme for the improvement of the Halsur tank.

2. I am to request that the plans in question may be forwarded to this office if they are available.

From Colonel J. SHAW-STEWART, R.E., Secretary to the Government of Madras, Public Works Department, to the Resident in Mysore, dated 2nd June 1885, No. 173 E.

With reference to your letter, No. 477/236, of 23rd ultimo, I have the honor to forward, for communication to the President of the Bangalore Municipality, the plans prepared by Captain Romilly for adding to the gathering grounds of the Halsur tank and improving the quality of its supply.

2. At the same time I am directed to forward copies of letters from the Quartermaster-General and the Sanitary Commissioner for Madras, in which are recorded the opinions of His Excellency the Commander-in-Chief and of the Sanitary Commissioner on the alternative schemes for improving the water-supply to the British troops at Bangalore.

3. You will observe therefrom that, whilst supporting the project for the distillation of the drinking water to be drawn, as at present, from the Halsur tank for the use of the garrison, both the Military and Sanitary authorities strongly advocate the contemporaneous adoption of the measures proposed in Captain Romilly's project C for adding to the supply available for the civil population of the cantonment, excluding foul sewage from the tank, and improving its conservancy.

4. The estimates for these improvements amount to Rs. 59,860 (not to Rs. 30,000 only as stated by Dr. Bidie), and I am to inquire whether, in view of the decided benefits that will be conferred thereby on the general public of Bangalore, the municipality are prepared to contribute towards the cost of same, and if so, to what extent.

From Major J. H. NEWILL, Assistant to the Resident in Mysore, to the Secretary to the Government of Madras, Public Works Department, dated Bangalore, 6th November 1885, No. 2172/70.

With reference to correspondence ending with your No. 173 E., dated June 2nd, 1885, I have the honor, under instructions from the Officiating Resident, to forward a copy of further papers, as noted on the margin, relative to adding to the gathering grounds of the Halsur tanks and to improving the quality of the water-supply.

1. Note, dated 6th July 1885, on the Halsur tanks, by Captain C. H. M. Kensington, R.E.
2. Letter, No. 943/44, dated 15th July 1885, to the President, Municipal Commission, Civil and Military Station.
3. Letter, No. 838, dated 27th July 1885, from the President, Municipal Commission, Civil and Military Station.
4. Letter, No. 1193/53, dated 3rd August 1885, to the President, Municipal Commission, Civil and Military Station.
5. Demi-official letter, dated 27th August 1885, from Mr. McLaughlin.
6. Letter, No. 1468/70, dated 3rd September 1885, to the President, Municipal Commission.
7. Notification by the President, No. 12, dated 11th September 1885
8. Letter, No. 1173, dated 25th September 1885, from the President, Municipal Commission, with enclosures.

2. The municipal commissioners having agreed to deepening the Lower tank, and raising the waste weir at a cost of Rs. 10,000 and to the purchase of the Jevanhully tank, the work of excavation was begun early in August and was actively carried on till the heavy fall of rain in the latter part of September stopped it. In all some 34,000 cubic yards of earth have, at a cost of Rs. 5,546-11-4, been removed from the bed of the Lower tank to form an island and an embankment on the eastern side, which are now being laid out as ornamental grounds; 1,450 lineal yards of hedge have been planted; 8,000 square yards of embankment have been sectioned and turfed; two culverts have been lengthened, and some minor works have been completed. The constant rain of the last six weeks has so raised the level of the water in the Lower tank that it is impossible at present to undertake work on the weir. The necessary notification has been given for acquiring the Jevanhully tank. This, when it comes into the possession of the municipality, will constitute a valuable reservoir. The result of what has been done is to lessen, in the Lower tank, the area exposed to evaporation, and to increase the capacity. As the level in the Lower tank sinks, the Upper tank will be drawn upon to supply what is wanting, and so long as the water in the Jevanhully tank admits of so doing, the Upper tank will be similarly replenished from it.

3. With his letter, No. 3150, dated September 22nd, which forms an enclosure to No. 1173, dated September 25th, 1885, from the President of the Civil and Military Station to my address, Colonel Burton, the Executive Engineer of the Presidency

Division, who is also a municipal commissioner for Bangalore, and who has taken a great interest in the work of improving the Halsur tank, has forwarded estimates involving a total expenditure of Rs. 21,500. Of this sum, Rs. 5,546-11-4 had, as shown above, been spent up to the date of his letter from Municipal funds. In his letter, No. 838, dated July 27th, 1885, to my address, the President of the Civil and Military Station has communicated the expectation of the municipal commissioners that the Madras Government will bear its share in the undertaking. As the commissioners have contributed so generously, I trust that their action may now be liberally supported by His Excellency the Governor in Council, and I would express the hope that a similar sum of Rs. 10,000 may be put at our disposal to help in the completion of the work. Independently of that amount already subscribed by the commissioners, there will devolve on them the further cost of compensation for the Jevanhully tank and for raising the waste weir of the Lower Halsur tank. Hence the necessity for a large measure of assistance from outside.

4. The most important feature of Captain Romilly's scheme for improving the quality of the water in the Halsur tanks was to abandon the present catchment area on the west, which is mainly covered by the cantonment bazaar, and to substitute, as the gathering ground, a tract of high and sloping land to the east which belongs almost, if not entirely, to the Mysore Government. Mr. Girdlestone visited this locality some weeks ago, in company with Colonel LeMessurier, R.E., Colonel Burton, R.E., Major Bowen, R.E., Mr. McLaughlin, C.E., and Major Maltby. The last-named officer is the President of the Municipal Commission, Civil and Military Station of Bangalore. The general opinion was that the proposed area for catchment is larger, and that its soil is more holding in its nature than are the area and the soil of the reservoir constructed by Colonel Sankey on the Tumkur road for the use of Bangalore; that for the contour channels sharper gradients than those recommended by Captain Romilly are desirable so as to ensure the prompt and efficient passage into the Halsur tanks of even slight rainfall; that if the land were taken up its cleanliness would have to be secured, as in the case of the English War Officers' Fortification Act, by reserving to the municipal commissioners the right of clearing trees, of preventing the erection of new buildings or a change in existing levels, and of forbidding the construction of unauthorized water channels. Conservancy powers would also have to be obtained over villages now in the area. At present there is sewage forming on fields within the area. Were this practice deemed prejudicial (there was a difference of opinion on this subject amongst those who accompanied Mr. Girdlestone to the spot), the municipality's sale of sewage to this tract would need to be discontinued and disallowed.

5. There does not seem to the Officiating Resident any likelihood that the municipal commissioners would contribute towards the cost of the proposed new catchment area; and in the event of opposition, Mr. Girdlestone would not, under existing circumstances, feel justified in using his influence to overcome their objections. As at present advised, he himself is not prepared to acquiesce in the belief that the proposed scheme would result in water for the garrison much more pure than that now supplied. The municipal commissioners entertain grave doubts as to the value of contour channels for supplying reservoirs; and at any rate they have for the moment before their eyes the failure of Colonel Sankey's scheme on the Tumkur road, which depended to a large extent on this source of supply. They also urge that the water-supply, as it now exists, is acceptable to the townspeople and not unhealthy in its effects; and consequently that as their first care should be for the townspeople, they would not be justified in sharing an expenditure the necessity of which has not been proved to their satisfaction. From this it follows that if the Madras Government still regards this part of Captain Romilly's proposals as imperative, it will rest with itself to provide the funds required for its accomplishment. It seems desirable that if the scheme is undertaken, the supply from the western side should not be cut off till the success of the new undertaking has been fully established.

6. I am to take this opportunity of intimating that much attention has been paid of late to the question of purifying and maintaining pure in its passage to the Halsur tanks the water which runs thither from the western side. Within the gathering ground on the west there is much cultivated land. This it is practically impossible,

owing to the prohibitive cost of compensation, to throw out of cultivation. But scavenging is systematically carried out, and patrolling frequent in all places of public resort. It having been found that on the occasion of heavy rain in the cantonment bazaar the main drain overflowed into the main sewer, the dividing wall between them has been raised so as to prevent this evil. The nuisance caused by the pollution of ground in and about the tanneries and potteries has been stopped. New sites, beyond the limits of the catchment area, for small-pox and cholera camps, are being sought. The question of allowing the Hindu burial-ground to be still used has been referred for the opinions of the Officer Commanding the Division and of the chief Medical authorities in Bangalore. If their opinions are unfavorable, the Officiating Resident will use his influence to put an end to such use. For the protection of the Halsur tanks eight watchmen have been appointed at a cost to the municipality of Rs. 56 a month. Should there be any other practical safeguards which the Madras Government may wish to suggest in the interests of the troops, Mr. Girdlestone will gladly, on receiving details from you, give consideration to them.

From the Resident in Mysore, dated 17th November 1885, No. 2293/70.

From Colonel J. SHAW-STEWART, R.E., Secretary to the Government of Madras, Public Works Department, to the Resident in Mysore, dated 8th January 1886, No. 68 W.

In reply to your Assistant's letter, No. 2172-70, dated 6th November 1885, I am directed to state that, after full and careful consideration, and taking into account the recommendations made by Sir Frederick Roberts and the Sanitary Commissioner, the Government of Madras feel convinced that the most appropriate method of securing a pure water-supply for the troops and civil population of Bangalore is to adopt the proposals made by the late Captain Romilly as set forth in his project B, with the addition of the first seven of the estimates which compose project C.

2. The cost of project B is estimated at Rs. 1,67,000; and that portion of project C that it is proposed to carry out, at Rs. 59,860; or a total expenditure of Rs. 2,26,860. In this connection I am to say that the Government of Madras note that the municipal commissioners of Bangalore are unwilling to contribute any sum towards the cost of taking up a new catchment area to the east of the Halsur tank. But it is hoped that they will raise no objection to this much-needed improvement being carried out by Government. The two items to which the consent of the municipal commission is requisite are—

(1) Diversion of the town drainage, and
(7) New supply-channel and compensation,

and I am to solicit that the matter may be laid before the municipal commissioners as early as practicable, and that you will move the commissioners to accord their consent to the scheme.

3. In view of the heavy expenditure that will be incurred should it be finally decided to carry out the works above mentioned, the Government of Madras regret that they are unable to contribute towards the estimate of Rs. 21,500 for work in connection with the tank which the municipal commissioners have taken in hand; but the Government will be prepared to pay a moiety of the sum expended by the commission on works which will render any of the items from 1 to 7 of project C unnecessary.

4. Adverting to the concluding portion of paragraph 5 of your letter under reply, I am authorized to give the assurance that the Halsur tank supply from the western side shall not be cut off until the success of the new gathering ground to the east shall have been fully established.

5. The enclosures received with your letter are herewith returned, and in conclusion I am directed to solicit that the early consent of the Government of Mysore and of the municipal commissioners to the scheme for taking up a new catchment area to the east of the Halsur tank may be obtained and communicated, in view to the proposal being submitted for the final sanction of the Government of India.

G.O., dated 1st June 1886, No. 1386 W., Public Works.

Read—the following letter from Major E. A. FRASER, Assistant to the Resident in Mysore, to the Secretary to the Government of Madras, Public Works Department, dated Bangalore, 15th April 1886, No. 1022/705 :—

With reference to letter, No. 829 C., dated 1st March 1886, from your office, requesting an early reply to letter, No. 68 W., of the 8th January 1886, regarding the proposed improvements to the Bangalore water-supply, I am directed to forward, for information, a copy of the correspondence noted on the margin which has passed on the subject.

Letter, No. 2194, dated 9th March 1886, from the President, Municipal Commission, Civil and Military Station of Bangalore.
Letter, No. 902/705, dated 7th April 1886, to the Chief Secretary to the Dewan of Mysore.

ENCLOSURES.

From Major E. P. MALTBY, President, Municipal Commission, Civil and Military Station, Bangalore, to the Assistant to the Resident in Mysore, dated Bangalore, 9th March 1886, No. 2194.

I have the honor to acknowledge the receipt of your letter, No. 396/70, dated 23rd ultimo, forwarding copies of letter, No. 2172/70, dated 6th November 1885, from the Assistant to the Resident, to the Secretary to the Government of Madras, Public Works Department, and letter, No. 68 W., dated 8th January 1886, to the Resident in Mysore.

2. In reply, I have to state that as the Government of Madras is willing to bear all the expense of bringing water into the Halsur tank by a new channel on the east, and as that Government gives an assurance that the bazaar drainage which now enters the tank from the west "shall not be cut off until the success of the new gathering ground to the east shall have been fully established," the municipal commissioners now raise no objection to the proposed improvement to the Halsur tank.

3. The commissioners were afraid that the present supply (which, indifferent as it is, is still better than none) would be cut off *before* it was *proved* that water could be brought in in sufficient quantity from the east.

4. Having now the assurance of the Madras Government that such shall not be done, they will be very glad to see the work put in hand.

From J. H. NEWILL, Esq., Assistant to the Resident in Mysore, to the Chief Secretary to the Dewan of Mysore, dated Bangalore, 7th April 1886, No. 902/705.

I am directed to forward a copy of the correspondence noted on the margin regarding improvements to the Halsur tank, and to express the hope of the Officiating Resident that the Government of His Highness the Maharaja will give the subject its most careful consideration and favor him with an early reply.

No. 2172/70, dated 6th November 1885, to the Secretary to the Government of Madras, Public Works Department, with enclosures (to be returned).
No. 68 W., dated 8th January 1886, from the Secretary to the Government of Madras, Public Works Department.
No. 2194, dated 9th March 1886, from the President, Municipal Commission, Civil and Military Station of Bangalore.

Read—the following letter from Major E. A. FRASER, Assistant to the Resident in Mysore, to the Secretary to the Government of Madras, Public Works Department, dated Bangalore, 22nd May 1886, No. 1430/705 :—

In continuation of letter, No. 1022/705, dated 15th April 1886, from this office, regarding the proposed improvements to the Halsur tank, I am directed to forward a copy of letter, No. 1159/60, dated 28th idem, from the Chief Secretary to the Dewan of Mysore stating that every facility will be afforded by His Highness' Government in the matter of acquiring land for a new catchment area to the east of the tank.

2. I am to request that you will favor the Officiating Resident with an expression of your opinion on the considerations urged by the Durbar in paragraph 3 of its letter above quoted, with regard to certain rights proposed to be reserved to the municipal commissioners of the civil and military station for the purpose of securing the cleanliness of the Halsur tank.

ENCLOSURE.

From M.R.Ry. R. VIJAYENDRA RAO, Chief Secretary to the Dewan of Mysore, to the Assistant to the Resident in Mysore, dated Ootacamund, 28th April 1886, No. 1159/60.

I am directed to acknowledge the receipt of your letter, No. 902/705, of the 7th instant, on the subject of the Halsur tank improvements, and inviting the consideration of His Highness the Maharaja's Government thereto.

2. It would appear from the correspondence that the Government of Mysore has no direct concern with the project under reference, beyond that connected with the acquisition by the British Government of the land to be taken up for the proposed channel to the east of the Halsur tank, which channel will, for the greater part of its course, run through the territory of His Highness, and in regard to this I am desired by the Dewan to say that every facility will be afforded by His Highness' Government for the transfer of the land on reasonable terms.

3. I am to invite attention, however, to paragraph 4 of your letter, No. 2172/70, of 6th November 1885, to the Secretary to the Government of Madras, Public Works Department, where it is proposed to reserve to the cantonment municipal commissioners the rights of clearing trees over the catchment area drained by the channel, of preventing the erection of new buildings or "a change of existing levels," and of forbidding the construction of unauthorized water-channels. Further, conservancy powers over the villages in this area are to be vested in the commissioners and apparently the manuring of fields is to be prohibited. This proposal involving, as it does, the abrogation of immemorial occupancy rights may, the Dewan apprehends, complicate the question considerably ; and I am to request the favor of a reconsideration of the necessity for conferring on the cantonment municipality powers to this extent over lands outside their jurisdiction. His Highness' Government fully recognizes the desirability of improving the water-supply of the Bangalore cantonment, and will gladly facilitate the furtherance of any scheme to that effect, but they desire to point out that interference with the rights of land-holders outside the municipal limits should, if possible, be avoided. Extensive powers, such as those indicated above, would probably necessitate the throwing out of cultivation of a large area of land, and the payment of compensation far in excess of what was contemplated by the projectors of this contour channel.

Read—the following letter from Major E. A. FRASER, Assistant to the Resident in Mysore, to the Secretary to the Government of Madras, Public Works Department, dated Bangalore, 21st May 1886, No. 1418/3495 :—

I am directed to forward, for your information, a copy of the Officiating Resident's Minute on the water-supply of Bangalore.

ENCLOSURE.

Minute by the Officiating Resident on the Water-supply of Bangalore.

The object of various measures to which the attention of this Residency has been given during the past fourteen months has been to increase the water-supply of Bangalore and to improve the quality of the water.

2. To this end the bed of the Shoolay tank was deepened and the weir and the embankment which surrounds it were raised in the spring of 1885, the result being that an additional depth of two and a half feet was secured over the whole reservoir. The cost of the work was Rs. 7,200. There still remains the work of enlarging the catchment area of this tank and that at Hakitimanhalli, where more water is much required. The outlay on this account is estimated at Rs. 4,000, of which Rs. 1,000 have been entered in the present year's budget, and will be sanctioned, for a feeder on the side of Trinity Church.

3. During August and September 1885 about 35,000 cubic yards of earth were dug out from the bed of the Lower Halsur tank, on the northern and eastern sides, at a cost of about Rs. 5,600, and were formed into an island and an embankment on the eastern side, which are being laid out as ornamental grounds. In the conduct of all this work the help received from Colonel Burton, R.E.,

was very valuable. The total sum voted by the municipality of the civil and military station for the improvement of this tank is Rs 10,000. Since the end of last September the progress of excavation, and the raising of the waste weir, which was a part of the general scheme, have been stopped, owing to the high level of water in the reservoir caused by the autumnal rain. It is very desirable that both works should be taken in hand again whenever circumstances admit. Here, as elsewhere, it is of great importance to increase the capacity of the reservoir. For want of a higher waste weir much water ran off and was lost last October.

4. In connection with this particular supply, the municipal commissioners have exercised a wise forethought in acquiring the Jevanhully tank. The cost of this has amounted to Rs. 6,675. The tank will serve as a valuable feeder to the Upper Halsur tank.

5. The result of what has been done at Halsur is to lessen in the Lower tank the area exposed to evaporation, and to increase the capacity. As the level in the Lower tank sinks, the Upper tank is drawn upon at once to supply the deficiency, and so long as there is water in the Jevanhully tank, the Upper tank will similarly be replenished from it. The chief loss of water, in an extensive but comparatively shallow reservoir, such as the Lower Halsur tank, is due to evaporation, not to consumption. The device of preventing evaporation by means of aquatic foliage has not proved satisfactory in India. Hence the necessity for meeting the difficulty by restriction of area and corresponding excavation.

6. The Madras Government has a separate project under consideration, whereby, at a cost of about 2¼ lakhs of rupees, it would fill the Lower Halsur tank entirely from a new catchment area on the east side of the tank. The undertaking is prompted by the wish to afford the European soldiers, who are entirely dependent on the Halsur reservoir, purer water than it is believed can, with the best conditions, be secured under the present system. As the Madras Government is ready to bear all the expense, and as it has given an assurance that the rain drainage from the cantonment bazaar, &c., which now enters the tank from the west, shall not be cut off till the success of the new gathering ground to the east shall have been fully established, the municipal commissioners of the civil and military station have raised no objection to the proposal. They are averse to sharing the cost, not only because it would be difficult to find the necessary funds, but also because they do not feel justified in making such a marked change, so long as the water-supply, as at present it exists, is acceptable to the townspeople and, not unhealthy in its effects. The scheme is now before the Mysore Government, whose consent has been sought to the alienation of the land involved by it.

7. Much has been done of late to purify, and to maintain pure in its passage to the Halsur tanks, the water which runs thither from the western side. Within the gathering ground there is much cultivated land. This it is practically impossible, owing to the prohibitive cost of compensation, to throw out of cultivation. But scavengering is systematically carried out, and patrolling frequent in all places of public resort. For the protection of the tanks eight watchmen have been appointed at a cost to the municipality of Rs. 56 a month. It having been found that on the occasion of heavy rain in the cantonment bazaar the main drain overflowed into the main sewer, the dividing wall between them has been raised, so as to prevent this evil, and has satisfactorily withstood the test of the late sharp storms. The nuisance caused by the pollution of ground in and about the tanneries and potteries has been much diminished. New sites, beyond the limits of the catchment area, have been chosen for small-pox and cholera camps, with special regard to the accommodation of the homeless poor in time of scarcity or famine; for experience has proved that the inhabitants of the town are best treated for infectious and contagious diseases in their own houses. A new site has also been chosen for the Hindu burial-ground, which it is hoped that the Durbar will concede. In such case the present one will be closed with as little delay as possible.

8. The supply of water to Miller's tanks, which is the third of the three great systems on which the civil and military station depends, has been facilitated by the construction of a diversion sluice in Cunningham road to serve tank No. 3. The channel with which such diversion is connected is one of the principal feeders of the Sampangi tank, which lies for the most part outside the limits of assigned tract. Consequently, as the Durbar has direct interest in the matter, it has been suggested that it should be left to the Public Works Department Secretary of the Mysore Government and to the President of the Civil and Military Station to agree when the diversion sluice should be used, and that in case of difference, the Resident should settle the question. This arrangement I hope that the Durbar will acquiesce in.

9. Advantage would be gained, I believe, by deepening all three Miller's tanks, provided that the lower soil is tenacious enough to hold water, and provided that there is no risk of setting free malarious influences if the present bottom be disturbed. Such has not been the result of the excavations at Shoolay and Halsur. I also think favorably of a scheme advocated by Mr. J. W. Hayes, municipal commissioner, for the construction of another reservoir below, but in close vicinity to the Shoolay tank. The configuration of the ground is such that the undertaking is not likely to be very expensive. Mr. Hayes puts the cost at Rs. 15,000, irrespective of compensation for house-property. Population in this neighbourhood is numerous and apparently on the increase. Hence the desirability of intercepting and holding water which, as actually happened

last year, may otherwise run to waste. In the present year I am afraid there is no prospect of funds being available for this work. I am also strongly impressed with the necessity of taking water nearer to the houses of the inhabitants as soon as money can be spared. At present the distance to which poor persons have to go for water, specially those who live in the cantonment bazaar, is considerable. This improvement may perhaps be best effected by pumping from existing reservoirs through pipes into cisterns or open basins at convenient centres. In connection with it the establishment of drinking fountains and drinking troughs at places of general resort seems desirable.

10. Not long ago it was represented to me that the water level in the wells of the civil and military station has been steadily getting lower for some years past. The fall has been variously attributed to the increased growth of casuarinas, which have a great tendency to absorb moisture, to a diminution in the rainfall, and to other climatic influences. The subject is, I think, worthy of investigation. At present the information at disposal is too limited to warrant the assumption that the water level in general has sunk. Till this fact has been established it is premature to speculate on the causes which may be at work.

11. The construction of the low level sluice from Sankey's reservoir for the benefit of the city of Bangalore does not in my opinion imperil the interests of the civil and military station. Colonel Sankey's main object of continuously supplying the High Ground and neighbourhood with water having failed, and there being no present means or likelihood of achieving that object, it would be an act of selfishness to oppose the utilization of such water as can serve the city under circumstances when the high-level sluice cannot be worked. Apart from this consideration the city has a claim by reason of the catchment area of the Dharmabudi tank having been circumscribed by the formation of Sankey's reservoir. The distribution of the water can always be determined by the Resident and the Dewan in consultation. It was by mutual agreement that Miller's tanks were thus replenished last autumn in a season of exceptional drought. As no difficulty was then experienced, there is reason for anticipating as satisfactory results in cases of future necessity. There seems no likelihood of raising the level in Sankey's reservoir, except at inordinate expense, and with risk of taking from the supply of other tanks in the neighbourhood.

12. The importance of not allowing present sources of water-supply beyond the limits of the Assigned Tract to be interfered with for purposes of irrigation or otherwise has been recognised, and assurances have been given on the part of the Durbar that it will not allow such interference, and that practically now it stops such interference in all cases which are brought to its notice.

13. There has not been leisure, on the part either of myself or of the engineer officers who have favored me with their help and advice in the above-mentioned matters of more immediate importance, to go deeply into the larger consideration of making Bangalore independent of its present system of tanks and wells. Even the preliminary inquiries involved in such schemes as that of leading water from Nundidroog and of pumping from the Cauvery would necessitate the employment of specially qualified professional men at no slight expense. That the cost of either scheme would be very great is beyond doubt. Such cost could only be met by a water-rate on the population which would be unobjectionable, if it did not exceed the present cost of fetching water, but which otherwise might press on a community that believes municipal taxation to be already quite high enough. Geologists have hitherto declared against the practicability of Artesian boring. It may be that this process, when more perfected, may solve the difficulty. Such a measure would be less likely to be hampered by questions of compensation; it would be without the risk of intermediate interruption which is attendant on the other two schemes, and it might be comparatively inexpensive. The deep borings which are now being made at various points on the Kolar gold fields may show what volume of water is to be hoped for at specified levels under known conditions of intervening rock or other material, and may yield information on other important points. Meanwhile, I think that the municipalities of Bangalore will be wise in restricting themselves, as regards improvement, to the lines which they have been pursuing of late.

12th May 1886. (Signed) C. E. R. GIRDLESTONE.

Note by the Secretary to Government, Public Works Department.

In February 1885 the three projects prepared by the late Captain Romilly, R.E., for improving the water-supply of Bangalore were referred to the Sanitary Commissioner for an expression of his opinion, and, in his No. 414, dated 15th April 1885, Dr. Bidie approved project B, which provided for drawing the supply from Halsur tank and distilling the water by means of condensing engines. His Excellency the Commander-in-Chief also expressed his preference for project B, "provided that, at

the same time, the conservation of the Halsur tank will be taken in hand by Government and the catchment area increased."

In order to carry out the foregoing proviso it was found necessary to adopt the first seven items of project C, in addition to project B; and the Resident in Mysore was informed, in January 1886, that the Government of Madras were convinced that that was the most appropriate method of securing a pure water-supply for Bangalore.

Of the first seven items of project C, two required the previous assent of the Government of Mysore, which was accordingly solicited.

The items were—

(1) Diversion of the town drainage.
(2) New supply channel and compensation.

With regard to (1) it was proposed to divert the town drainage from the west of the Halsur tank, and to draw the supply in future from a new catchment area to the east of the tank.

The area of the proposed new catchment basin was 2·4 square miles, or 1536 acres; and the compensation provided for in the estimate was Rs. 2,680 for the contour channel, and Rs. 2,635 for 52·7 acres of land thrown out of cultivation under the Kadarampolem tank.

Further information regarding the items referred to will be found in paragraphs 41—43 of Captain Romilly's report, copy of which is attached.

In requesting the approval of the Bangalore Municipal Commissioners and the Government of Mysore to the two items above referred to, the Government of Madras gave the assurance that the supply from the catchment on the west should not be cut off until the success of the new gathering ground to the east had been fully established; and, on this assurance and on the understanding that the British Government paid all expenses, the Municipal Commissioners, in March last, stated that they had no objection to the proposed improvements.

In a communication, dated 28th April 1886, to the Resident in Mysore, the Government of Mysore state that every facility will be afforded for the transfer, on reasonable terms, of the land required for the new catchment area; but invite attention to a letter from the Resident, dated 6th November last, in which it was stated that, in the event of the new catchment area being taken up, its cleanliness would have to be secured, as in the case of the English War Officer's Fortification Act, by reserving to the Municipal Commissioners the right of clearing trees, of preventing the erection of new buildings or a change in existing levels, and of forbidding the construction of unauthorised water channels. The Resident further expressed his opinion that conservancy powers would have to be obtained over villages situated within the catchment area, and that, if it were deemed prejudicial, sewage forming on fields within the area should be stopped.

The Mysore Government now represent that the prohibition of manuring of fields would involve the abrogation of immemorial occupancy rights, and might, it is feared, complicate the whole question considerably; they request that the necessity for conferring on the cantonment municipality powers to the extent indicated above over lands outside their jurisdiction may be reconsidered; and add that, while the Mysore Government will gladly facilitate any scheme for improving the water-supply of Bangalore, interference with the rights of land-holders outside the municipal limits should, if possible, be avoided. Extensive powers, such as those indicated above, would probably necessitate the throwing out of cultivation of a large area of land, and the payment of compensation far in excess of what was originally contemplated.

The question now to be decided is whether the proposed new gathering ground, lying to the east of the Halsur tank, may be added to the drainage area of the tank without taking any special precautions for securing its thorough conservancy. The only alternative appears to be to acquire possession of the land which forms the proposed new gathering ground, and to throw it permanently out of cultivation; but it is to be observed that this alternative course would involve very heavy additional expenditure.

(Signed) J. SHAW-STEWART, Colonel, R.E.,
Secretary to Govt., P.W.D.

31st May 1886.

Order—dated 1st June 1886, No. 1386 W., Public Works.

These papers, with the note thereon which has been drawn up in this department, will, in the first instance, be referred to Surgeon-General Bidie, who, with advertence to his letter, dated 15th April 1885, No. 414 (written as Sanitary Commissioner), will be requested to favor the Government with his opinion on the point which has lately been raised.

2. The papers will then be forwarded to the Quartermaster-General,* who will be requested to obtain the opinion of His Excellency the Commander-in-Chief, and to return the papers to the Secretary to Government in the Public Works Department.

* *Vide* his No. 970 B., dated 2nd May 1885.

(True Extract.)

(Signed) J. SHAW-STEWART, Colonel, R.E.,
Secretary to Govt., P.W.D.

From G. BIDIE, Esq., M.B., C.I.E., Acting Surgeon-General with the Government of Madras, to the Chief Secretary to Government, dated Ootacamund, 23rd June 1886, No. 0/191.

In returning the papers referred to me under G.O., No. 924 C, of 8th June 1886, I have the honor to submit the following remarks on certain points connected with the proposals for the improvement of the water-supply of Bangalore.

2. The chief point on which my opinion is invited is, "whether the proposed new gathering ground, lying to the east of the Halsur tank, may be added to the drainage area of the tank without taking any special precautions for securing its thorough conservancy."

3. From a sanitary point of view it is no doubt desirable that the gathering ground should be thoroughly conserved, but as that end could only be attained by throwing the whole of the land out of cultivation, I am not prepared to advocate such a measure, inasmuch as the water prior to delivery to the troops is to be purified by storage in a reservoir and distillation.

4. I have not inspected the proposed new gathering ground, which is said to embrace an area of 2·4 square miles; but from Colonel Mullins' report (paragraph 34) learn that the soil is of a "light sandy character," for the most part under dry cultivation, and extensively manured with more or less filthy material collected from the barracks, the station, and the bazaars. Such land will undoubtedly contaminate the surface wash more or less, the amount of impurity depending to a considerable extent on the weight of the showers and the season at which they fall. A heavy shower, occurring shortly after tillage and the application of manure, would carry off a considerable amount of organic matter; but on the crops attaining some size, the surface water would be comparatively clean, as growing vegetation rapidly disposes of nitrogenous matter in the soil, and any of it on the surface not got rid of in this way would speedily be converted into nitrates (inorganic matter).

5. As a precautionary measure, however, I would suggest that arrangements be made for the exclusion from the tank of foul water resulting from heavy showers falling immediately after the manuring of the gathering grounds.

6. If this be done, the only other precautions that seem necessary are—

(*a*) The prohibition of any extension of the present cultivated land within the gathering grounds.

(*b*) The institution of some arrangement with the Mysore Government for the surface conservancy of the villages that exist on the protected area, and for the prevention of the erection of any more buildings except in substitution of those already existing.

(*c*) That offensive trades—such as tanning—be forbidden on the gathering ground.

7. As already stated, I make these suggestions clearly on the understanding that the water is to be purified prior to use by a Normandy's condensing apparatus; and have only to add, that the supply obtained from the proposed new gathering ground ought to be much purer than that now deposited in the Halsur tank from the densely populated and filthy town of Bangalore.

No. 318 D.

Forwarded, with advertence to G.O., No. 1386 W., dated 1st June 1886, to the Quartermaster-General, for favor of His Excellency the Commander-in-Chief's opinion.

2. Copy of a minute, dated 12th May 1886, on the water-supply of Bangalore, by Mr. Girdlestone, is enclosed for information.

OOTACAMUND,
30th June 1886.

(Signed) J. SHAW-STEWART, Colonel, R.E.,
Secretary to Govt., P.W.D.

From Colonel E. FAUNCE, Officiating Quartermaster-General, to the Secretary to Government, Public Works Department, dated Ootacamund, 24th August 1886, No. 2797 B.

In returning the papers received with G.O., No. 318 D., dated 30th June 1886, relative to the improvement of the water-supply at Bangalore, I have the honor, by order, to state that, although the Commander-in-Chief would prefer the alternative measure of thoroughly conserving the new gathering ground to the east of the Halsur tank, by throwing the whole of the land permanently out of cultivation (similar arrangements being made as regards the old gathering ground of the north feeder) yet, as the cost of these measures would apparently be prohibitive, and great difficulty would arise in acquiring the necessary land, His Excellency accepts the scheme as proposed, viz., that the town drainage having been diverted, a new gathering ground lying to the east of the tank be added to the drainage area of the Halsur tank, the precautionary measures in connection with the entire gathering grounds suggested by Dr. Bidie (in paragraphs 5 and 6 of his letter, No. O/191, dated 23rd June 1886) being fully adopted.

2. I am to request that, if convenient, a printed copy of the correspondence now returned may be forwarded for record in this office.

ORDER—dated 10th September 1886, No. 2292 W., Public Works.

Frequent outbreaks of enteric fever among the troops at Bangalore having led to strong representations respecting the quality of the water and the sufficiency of the water-supply available for the use of the troops and of the cantonment bazaar at that station, this Government, after careful consideration of the subject, arrived, in October 1883, * at the conclusion that the best means of providing the troops and town with wholesome water would be to extend and complete the scheme known as the Ooparhalli project, which had been originated, in 1868, by Major-General Sankey, R.E., C.B., when Chief Engineer of Mysore.

* G.O., No. 2794 W., dated 5th October 1883.

2. With that object, Colonel J. Mullins, R.E., was placed on special duty to investigate the subject; and, on the 31st March 1884, that officer submitted a report in which the whole subject of the water-supply of Bangalore was exhaustively treated. The results of Colonel Mullins' inquiries were summed up by the Chief Engineer in his note printed with proceedings, No. 1473 W., dated 13th June 1884, as follows:—

(1) The Ooparhalli project is incapable of supplying the station or troops.
(2) The Halsur tanks are not capable of being made a satisfactory source of supply for the troops.

(3) Wells may be sunk which would yield a sufficient supply for the troops for drinking and cooking purposes, but the quality of the water must remain doubtful.
(4) The Agaram tank offers a new source of supply of suitable water, having an ample and sufficiently clear catchment basin.
(5) Water of unexceptional quality is probably obtainable at Bangalore only by distillation.

3. In their order, No. 1473 W., dated 13th June 1884, the Government recorded their opinion that the Agaram tank scheme offered the most promising solution of the question of the water-supply to the Bangalore garrison, and directed the late Captain Romilly, R.E., to elaborate the scheme, and to prepare the requisite plans and estimates. In the following month,* orders were issued to Captain Romilly to include in his investigations the alternative scheme suggested by Colonel Mullins for condensing a supply of water from the dhobies' wells, sufficient to meet the requirements of the troops for drinking and cooking purposes, leaving the water required for other purposes to be pumped from the Halsur tank. Captain Romilly was further ordered to investigate the question of taking in an area of additional gathering ground to the eastward of the Halsur tank, and to include in his estimate for the Agaram tank scheme all compensation for land rendered necessary thereby.

* G.O., No. 1814 W., dated 25th July 1884.

4. With his letter, No. 3900, dated 19th January 1885, the Superintending Engineer, V Circle, submitted Captain Romilly's report, accompanied by three alternative estimates. The first, A, provided for the supply of water to the barracks from the Agaram tank, and amounted to Rs. 2,90,000; the annual cost of maintenance being Rs. 44,385. The second, B, provided for drawing the supply from the Halsur tank and distilling the water by means of condensing engines, and amounted to Rs. 1,67,000; the annual cost of maintenance being Rs. 84,600. The third, C, provided for certain improvements to the existing source of supply, and the augmentation of the supply by taking up a new gathering ground. The cost was Rs. 1,33,000, and the annual maintenance charges, Rs. 27,000

5. This report having been referred to the Sanitary Commissioner, and to His Excellency the Commander-in-Chief, for opinion, the former officer condemned project A, and concurred in Captain Romilly's views that the Agaram tank-water was liable to dangerous contamination; and, if adopted as the future reservoir for the troops, the source of supply could not be accepted as pure. Dr. Bidie approved project B as the only means of insuring a supply of pure water for the use of the troops. His Excellency the Commander-in-Chief also expressed his preference for project B, "provided that, at the same time, the conservation of the Halsur tank will be taken in hand by Government, and the catchment area increased." His Excellency was of opinion that, as the civil population of Mysore would benefit by the improvements, the municipality should bear a portion of the cost; but he expressed a hope that, if the municipality were not prepared to do so, the Government would carry out the improvements and bear the whole expense.

6. In June 1885, the Resident in Mysore was addressed on the subject. The plans and estimates prepared by Captain Romilly were forwarded with the remark that, whilst supporting the project for the distillation of the drinking-water drawn from the tank for the use of the garrison, both the military and sanitary authorities strongly advocated the contemporaneous adoption of Captain Romilly's proposals for adding to the supply available for the civil population; for excluding foul sewage from the tank; and for improving its conservancy. These improvements comprised the first seven items of Captain Romilly's project C, estimated to cost Rs. 59,860; and the Resident was asked whether the Bangalore municipality were prepared to contribute towards the cost, and, if so, to what extent.

7. In his reply, dated 15th November 1885, the Resident intimated that the municipality had already incurred considerable expense on works undertaken by themselves in improving the Halsur tank; and, with respect to Captain Romilly's proposal to

substitute a tract of high and sloping ground to the east of the tank for the existing catchment area on the west, Mr. Girdlestone did not think the Commissioners would bear any portion of the outlay involved, inasmuch as the necessity for the change had not been demonstrated to their satisfaction. The Resident intimated clearly that, if the Madras Government still considered the change imperative, it would rest with this Government to provide funds to the full amount required for its accomplishment. On an assurance from this Government that the supply from the catchment on the west shall not be cut off, until the success of the new gathering ground to the east has been fully established, the municipality have given their assent to the proposal to divert the town drainage from the tank. The Government of His Highness the Maharaja also have intimated their willingness to afford every facility for the transfer, on reasonable terms, of the land required for the new catchment area. While doing this, the Mysore Government pointed out that complications would arise, and the cost of compensation would be greatly enhanced, if attempts were made to thoroughly conserve the new gathering ground, and throw it permanently out of cultivation. With reference to this point, the Government have received the opinion of Surgeon-General Bidie (who, as Sanitary Commissioner, previously reported on the water-supply question) that, if certain precautionary measures be taken, the prohibition of cultivation in the new catchment area need not be insisted upon; and His Excellency the Commander-in-Chief, in view of the great outlay which would be involved if this Government determined to acquire the whole of the gathering ground, has accepted the position.

8. His Excellency the Governor in Council considers that the question has now arrived at a stage when the Government of India may be addressed. That Government will accordingly be asked to sanction Captain Romilly's project B, with the addition of the first seven items of project C, involving a total estimated outlay from Imperial funds of Rs. 2,26,860.

9. The measures suggested by the Surgeon-General, in paragraphs 5 and 6 of his letter of 23rd June 1886, will receive consideration hereafter, should the Government of India sanction the proposals now to be submitted.

10. The following letter will be addressed to the Government of India:—

(Here enter No. 2293 W., dated 10th September 1886.

(True Extract.)

(Signed) J. O. HASTED, Colonel, R.E.,
Secretary to Govt., P.W.D.

To the Military Department.
" Superintending Engineer, V Circle.
" Examiner, Public Works Accounts.
" Public Department.

LETTER—to the Secretary to the Government of India, ~~Public Works~~ Military Department, dated Fort St. George, 10th September 1886, No. 2293 W.

I am directed to forward, for the consideration of the Government of India, copies of the proceedings of this Government marginally noted, relative to the proposals for improving the water-supply of the troops at Bangalore.

No. 2794 W., dated 5th October 1883.
" 2795 W., " 5th "
" 1473 W., " 13th June 1884."
" 1474 W., " 13th " "
" 1814 W., " 25th July "
" 2292 W., " 10th Sept. 1886.
with Captain Romilly's report annexed.

2. The history of the question and its present position are stated in the last quoted proceedings of this date; and it will be seen that the sanction of the Government of India is required to a total estimated outlay, from Imperial Military Funds, of Rs. 2,26,860.

3. It will further be seen from the correspondence, that the question of improving the water-supply of Bangalore has been the subject of exhaustive inquiry by this Government, who are convinced that the only feasible means of giving the garrison a

pure water-supply, at a reasonable cost, is by adopting Captain Romilly's project B, estimated to cost Rs. 1,67,000, with the addition of the first seven items of project C, estimated to cost Rs. 59,860. The annual cost of maintenance of project B is estimated at Rs. 84,600.

4. The Army Sanitary Commission in England have frequently noticed the high rate of mortality from enteric fever among the troops at Bangalore, and have urged a consideration of the question of improving the water-supply; and I am to forward, for the information of the Government of India, copies of the two last reports of that body, printed with the proceedings of this Government, in the Military Department, marginally noted.

No. 4290, dated 5th August 1885.
" 4761 " 9th " "

4. I am therefore to express the hope of His Excellency the Governor in Council that the Government of India will take this subject into early consideration, and sanction the proposed expenditure of Rs. 2,26,860. Also, that the Government of India will be pleased to make a substantial grant for inclusion in the budget for 1887-88, in view to the early commencement of the work.

(Signed) J. O. HASTED, Colonel, R.E.,
Secretary to Govt., P.W.D.

Exd. E. Fernandez.
Spare Copies

BUILDINGS AND ROADS.

Mily. ~~CIVIL~~ WORKS.

Govt. of {1886} Madras.

PUBLIC WORKS.

Dated September, 10th.

Recd. *Encl.*

G.O., 10th Sept. 1886, Nos. 2292, 2293 W.

SEPTEMBER.

Bangalore Water-Supply

Proposals for improving the — for troops, submitted for the sanction of the Government of India.

into the tank to the main bund a little to the north of the present surplus weir, which latter would be lowered and a new weir built in the new bund; this tank receives drainage from foul ground at its north-west corner, and this also would need to be diverted into the western feeder above the culvert just referred to.

Moreover, the water-supply of the upper tank is far from pure. There is a large population on this part of the gathering ground, and there are tanneries and a large native cemetery, which are quite sufficient to account for the quality of the supply.

34. It has been ascertained that a considerable area of fresh ground could be drained into the lower tank by running a supply channel at a gradient of 2 feet per mile to the eastward.

The position and general circumstances of this area are shown on the general plan,* and on a larger scale and in more detail on plan No. 9. This ground measures 3·10 square miles, and the soil is generally of the light sandy character which is common to the neighbourhood. The water-supply from it would be of a better character than that now received by the tank, but it certainly would not be even approximately pure, for, though the land is for the most part under dry cultivation, it is extensively manured with all the various more or less filthy material which is conveyed from the barracks, the station, and the bazaar by the conservancy carts. There is further the additional objection that the construction of such a channel would interfere with, and diminish the supply of, a great many small tanks, some of which belong to the Mysore Government, while others are privately owned.

* No. 1.

The settlement of compensation would be difficult and troublesome, because there are not only the tanks of which the supply would be directly diminished to a demonstrable extent, but many others which get water from the surplus of the former, and no reliable estimate could be formed of the extent to which the supply of these lower tanks would be affected On the whole then, promising though the plan of bringing in a supply from the open country to the eastward appeared in the first instance, it is considered that the circumstances are too unfavorable as regards quality of the supply to warrant relief being sought in this direction.

To secure the drainage from the 3·10 square miles above mentioned, a channel 9½ miles in length would be needed, but a fresh area of 2·174 square miles could be secured by stopping the channel at 5 miles, and, as this would more than compensate for the 1·68, *plus* 0·22, equal to 1·90 square miles of the present catchment, which would be diverted from the tank, and as the shorter channel would interfere with but few existing tanks, it would be the better arrangement.

	Rs.
The cost of diverting the western and north-west feeders of the tank would be about	18,850
The supply channel 9½ miles in length for the catchment of 3·10 square miles would cost about	11,120
The channel 5 miles long for the catchment of 2·174 square miles would cost about	6,460

So that the larger scheme would require an expenditure of Rs. 29,970 and the smaller of Rs. 25,310, exclusive of compensation for water diversion. Approximate abstract estimates and specifications are given in Appendices Nos. 16 to 17-C. In either case it is proposed to raise the full tank level 1 foot, and so increase the storage by 5·113 millions of cubic feet.

35. The Halsur tank, prior to the formation of the upper tank, held, when full ... ... millions of cubic feet. 38·293

At present the capacities of the two tanks are—

Upper tank	millions of cubic feet.	11·240	
Lower do.	do.	37·633	
		———	48·873
		Increase ...	10·580

A table of capacities has been drawn up and will be found in Appendix No. 10. Statements of particulars of water-supply have been worked out from the registers for the years 1880 to 1883 inclusive, Appendices Nos. 11 to 14, and a summary is given in Appendix No. 15. From the latter it will be seen that the year 1880 was one of exceptionally heavy rainfall, and the tanks received no less than 165·372 millions of cubic feet, but in neither of the other years was the yield of the basin equal to the capacity of the tanks. The average receipts of these three years were indeed only just one-half of that capacity.

36. It has been alleged that the falling off in the supply of the Halsur tank has resulted from the diversion of part of the drainage by the catchment channels of the new (Ooparhalli) reservoir, but the area of drainage so diverted is only one-twelfth † of a square mile, and would

† 53 acres (*vide* paragraph 23).

account for only 1·32 millions of cubic feet in the last three years or on the average 0·44 millions per annum, or 1·8 per cent.

Compared with the period prior to 1864 the supply has no doubt suffered material reduction by the construction of the main sewer, but the idea of the prejudicial effect of the Bangalore water-supply project works doubtless originated in the contrast between the abundant supply of 1880, when the waste weir discharged surplus on no less than 88 days between the 14th August and the 7th December, and the short supply of subsequent years. The real cause is explained by the rainfall register, and a reference to the statistics of the Halsur water works, Appendix No. 20, will show that the water level in the tank on the 31st December was much the same in 1878, the first year in which the new reservoir held water, as in 1877, and that in 1879 and 1880 it was at a higher level than in any year after 1872.

37. It will be noticed that the rainfall registered at the Halsur rock is about 18¼ per cent. less than that registered at the Bowring civil hospital, which is distant but little more than a mile. This is due chiefly to the gauge at the rock being on the top of the rock, or indeed some feet higher than the latter.

1,900 yards.

An examination of the monthly abstract of the registers shows that, on the other hand, in February the rainfall gauged at the rock has always been higher than that at the hospital, but for the other 44 months this was the case in only 6 months.

Appendix No. 19.

It is further noticeable that the rainfall register at the Bowring hospital is not always a guide to the rainfall over the catchment of the Ooparhalli reservoir, distant about three miles, for 1880 was only an average year in the latter locality, the rainfall being 39·56 inches against 51·69 at the hospital, and again in 1881 the figures are 21·63 and 27·44 respectively. In 1882 and 1883 the two sets of registers agree very nearly.

38. The yield of the Halsur catchment basin for the four years averaged 0·174 and 0·146 of the rainfall registered at the rock and hospital respectively. The proportion at the Ooparhalli reservoir averaged 0·12 for the same period. Omitting 1880, the proportions for the Halsur catchment are 0·085 and 0·071, and for the Ooparhalli reservoir 0·127.

39. *Wells.*—These, as a means of procuring water, are in very general use, and, seeing how small a proportion of the rainfall runs off the ground, it might be expected that a fairly abundant supply would be met with below the surface. The ordinary surface soil is very sandy, and below this, at varying depths, a subsoil composed of gneissic rock in a more or less advanced state of disintegration and decomposition is met with; this overlies gneiss in either the massive or detached state. In many places the rock comes to the surface, but, more generally it is at a considerable, and sometimes at a very considerable, depth therefrom. Many houses possess wells which are said to yield water of excellent quality, but there is no certainty that two wells, though only a short distance apart, will contain water of at all similar character. The water of the wells in that part of the station which has for a long time been thickly populated is generally confessedly bad, as is to be expected, but besides these there are many wells the water of which is unfit for domestic use because it is impregnated with salts, which render it brackish or bitter.

There is at Bangalore ample space on fairly clean ground for a sufficient number of wells to produce collectively a much greater quantity of water than is required, but while it is certain that a very considerable proportion of such wells would contain brackish water, there would be no means of determining beforehand where wells of good water would be obtainable. Borings would afford *primâ facie* evidence of the character of the soil at the spot, and the water drawn therefrom could be tested, but even then it would not be demonstrable that the water taken from a large well on the same spot would be of the same quality, for directly the quantity taken out become considerable, the area drawn from would be extended proportionately, and new conditions would be met with.

There is no generally-distributed water-bearing stratum, containing good and pure water, into which wells can be sunk, and a supply of this character obtained with certainty.

40. To the south of the South Station hospital there is a small water course on the banks of which some wells were sunk in the famine years 1876-77. One of these wells, No. 2, at 760 yards from the hospital and conveniently situated as regards the Field Artillery and European Cavalry barracks has been tested, and partial (qualitative) analysis made under the direction of the Deputy Surgeon-General is fairly favorable.

Plan 15.

Vide first entry in Appendix No. 26-F.

If an abundant supply of such water could be obtained, this source might be considered satisfactory, but the experiment made in March with an engine and pump lent for the purpose by the Secretary to the Mysore Government, Public Works Department, shows that at a time when the yield of a well is certainly not at its minimum, the inflow averaged during 138½ hours only 5·37 cubic feet, or 33·56 gallons an hour. On the average of four years the hourly consumption of water by the troops has been 2,349 gallons.

Appendix No. 21.

It would therefore require 70 such wells to supply the total quantity required, and probably not less than 40 larger wells, distributed so as to drain the greater part of the basin of the

watercourse, which has an area of 258 acres, would suffice, while there would be always the possibility of the failure of the supply towards the end of the dry season. With a bund across the valley above the road, it is probable that sufficient water would be obtainable for cooking and drinking purposes for the Cavalry Regiment, the two Field Batteries, and the hospitals, as this part of the supply might be taken to be one-sixth of the whole, or say 400 gallons an hour, which quantity might be obtained from, say, six connected wells of 20 feet diameter each, and the supply could be lifted by a pump worked by coolies or bullocks, which would be less expensive than a steam engine, as the cost would not exceed Rs. 1,000 per annum.

41. Similar arrgements might be made for the supply of the Horse Artillery and the European Infantry at a cost of about Rs. 1,500 per annum, but for other purposes two-thirds of the present supply would still have to be pumped up from the Halsur water works, and the cost of these two-thirds would be but little less than the Rs. 10,400 expended at present on the whole supply of the troops.

The register of the pumping operations at No. 2 well will be found in Appendix No. 22.

42. Some of the data—*e.g.*, the number and length of the connections with the several buildings—for an approximate estimate of the cost of the arrangements above indicated would require more time for their collection than is now available, but the following summary will give a tolerably good idea of the probable outlay required. The way in which the calculation has been made will be found in Appendix No. 23.

	Rs.
Seven wells	4,550
Pump with gear	1,200
Pipes and laying	8,354
Trench for connecting pipes	3,000
Unwatering during construction	3,000
Taps and fittings	2,000
Contingencies	1,896
Total ...	24,000

About an equal amount would be required to supply the Horse Artillery and the European Infantry Regiment with water from wells, or, say, Rs. 50,000 altogether. The current charges being estimated at Rs. 1,000, *plus* 1,500 annually, this, capitalized at twenty-five years' purchase, would represent Rs. 62,500; so the entire cost of supplying well water for drinking and cooking purposes only to the European troops would be about Rs. 1,12,500.

43. None of the heretofore considered sources of supply being likely to be acceptable and also adequate, attention has been given to others which it seemed possible might be better suited to meet the requirements. Necessarily there could be no adequate supply obtainable without pumping, and all that could be hoped for was sufficient water at a level not very much below that of the station and at a moderate distance. The Hoskote tank, which is much the largest in the neighbourhood, was visited. It has a catchment basin of 540 square miles, and is the terminal of a very large group of tanks, of which at present only one sub-series has been surveyed, so the statistical information is incomplete. Notwithstanding the large number of tanks above it, the supply is said to be good. In 1876 there was some water, but not enough for cultivation; in 1877 the tank got a good supply. About twenty years ago (probably 1866) the tank was entirely without water. In 1875 the supply was so great that it was feared the tank would breach.

The extent of irrigation is about 2,000 acres and the revenue about Rs. 5,000; the assessment has been reduced since 1877. The season of cultivation is from December to August or September. Only one crop is cultivated, and this is commenced from December to April, the harvest being from June to September. The tank is from 12 to 13 miles from the barracks, and it is about 104 feet lower than the Halsur tank. There is a small hill, 2 miles west of the 14th milestone, which would be a convenient site for a stand-pipe as it is 190 feet above the tank level. The appearance of the water in January, when the tank was nearly if not quite full, was not prepossessing, and the native opinion of it is unfavorable, the expression used being that they would not give it to a horse to drink, and they say that to bathe in it is apt to produce fever. The inhabitants of the town use the water of a small tank to which lies immediately east of the large tank and north of the town, and its water is altogether different in appearance. Under these circumstances, it seemed unnecessary to carry the investigations further. The information above given was obtained from the native accountant of the amani tanks.

44. About three miles south-east of the Race-course, or Cavalry and Field Artillery barracks, there is the Agaram tank, which on the whole affords the best prospect of being a suitable source for the supply of the troops. It has a catchment basin of 32·10 square miles, of which, however, a considerable part is rendered non-effective or only partially effective, by the upper tanks in the same basin. It receives no drainage from the pettah or cantonment. It is

said to be generally well supplied, though in 1876 it was, in common with nearly every tank in the country, for a time dry. This season, though the rainfall was below the average, the tank was full up to the 19th January, or 4½ weeks after the last considerable rainfall. On the 6th March the water had fallen 0·96 of a foot, so that, inclusive of the water drawn off for cultivation, the water surface had fallen less than one quarter of an inch a-day.

The position of the tank with regard to the barracks and that of its catchment basin will be seen on referring to plan 1, sheets 1 and 2, and the survey of the tank is given in plan 13.

The area of the waterspread at full tank level is 131 acres, or 5·706 millions of square feet. The sill of the lowest sluice is at 7·16 feet below full tank level, and the area of waterspread at this sill level is computed to be about 1·017 millions of square feet. The capacity between sluice sill and full tank level is about 24·068 millions of cubic feet, and it has been ascertained that, were the full tank level raised three feet, 20·601 millions of cubic feet would be added to the contents. There are 280·17 acres of land classed as wet under the tank, and of these 129·10 acres are usually cultivated and yield a revenue of Rs. 617-8-0.

The full tank level is 58·25 feet below that of the Halsur tank, and the water would have to be pumped at least so much higher in order to secure as much command as at present.

45. Samples of the water have been analysed by the Chemical Examiner with the result shown in Appendix No. 26. It will be seen that the water has obtained only the qualified character "usable," but that is the highest character given in any of the analyses of Bangalore water, and it seems to be more than doubtful whether anything more favorable is likely to be found.

The Agaram water is slightly clouded, but it is good wholesome looking water and very different indeed from that which even at the best of times is to be found in the Halsur tank. It will be noticed that the analysis differs somewhat in the case of the two samples, though the water was all taken from the tank at one time and at one place.

46. It was at first intended to get rid of all matter capable of removal by filtration from the water by sinking a large well in a convenient spot near the north-west corner of the tank, and allowing no water to enter the well except through several feet of soil. The analysis by the Chemical Examiner, however, of the water of one well to the north-west of the tank, and the partial analysis at Bangalore of the water of four wells but a short distance from its waterspread on the west side, which, and more especially Nos. 3 and 4, were chosen to serve as an index to the probable quality of the soil through which a supply well would be sunk, render it more than probable that such an arrangement might materially injure the quality of the water. The fixed hardness, for instance, is 6·2 degrees in the best, No. 4, of these four wells against 1·4 to 1·75 degrees for the tank water, while in other respects the well water is considerably less pure than that in the tank, though the former looks clearer.

Appendix No. 26-E.
Do. No. 26-F

It would be desirable, if possible, to avoid the expense and complication of artificial filtration, and so in any case it would be desirable to have an experimental well sunk in the bed of the tank to test, through the water therefrom drawn, the character of the soil through which the water has filtered, and its effect upon the potable qualities of the supply. Samples of water have been taken from two wells or pools in rear of the western end of the bund, and their analyses will be found in Appendix No. 26-G. The results are satisfactory as the turbidity of the water is no doubt due to the wash of the water on the soil, the pools or wells being used for irrigation.

47. On plan 14 are shown the relative levels of the tank and the several service cisterns attached to the barracks, hospitals, &c. Also the proposed height of the stand-pipe, which is intended to be rather more than 15 feet above the water surface, when full, of the highest cistern to be filled.

48. Appendix No. 24 contains specifications and approximate estimates for the work to be done, and a short summary of the latter is subjoined. It appears to be essential to increase the capacity of the tank if the water be drawn direct from the latter, and in the estimate for this arrangement such increase has, it will be seen, been provided for. The average consumption of water by the troops has been 3·292 millions of cubic feet per annum, or less than one-seventh of the contents of the tank, and probably not more than one-twentieth of the quantity received; the estimated maximum consumption also has been taken as 5·256 millions of cubic feet in the year, or perhaps one-twelfth of the supply coming into the tank. Were, however, a corresponding extent of land, viz., about 25 acres, thrown out of cultivation and compensation on that account paid, there would still be much risk of the storage proving insufficient at times. With an addition to the storage capacity of nearly four times the maximum off-take, there is every probability of there being always in the tank an ample reserve to meet the contingency of an unusual interval between successive receipts from rainfall. It is indeed worth consideration whether it would not be the better plan, even if water be drawn from a well within or below the tank, to enlarge the tank, as by so doing all question of injury to landholders under the tank would be avoided, and that is a matter of importance.

Particulars.	With: Water drawn direct from tank.	With: Water drawn from supply well in or below tank.
	RS.	RS.
Engines and pumps	36,500	36,500
Stand-pipes including masonry	3,930	3,500
Delivery mains	1,18,000	1,18,000
Suction pipe from supply well	...	2,570
Supply well	...	900
Suction pipe from tank	4,600	...
Do. from pure-water well	560	...
Two filters	15,000	...
Enlarging tank	13,000	...
Ground for pumping station	250	250
Engine-house and chimney	12,500	12,500
Quarters for Engineer, &c.	3,000	3,000
Enclosure walls	4,000	4,000
	2,11,340	1,81,220
Contingencies ...	8,660	6,780
Total ...	2,20,000	1,88,000

49. Inquiry has been made as to whether any of the pumping plant at the present water works would be suitable and available for transfer to the Agaram water works. The engine at the rock is an old one, but with new boilers it would be serviceable for some years to come. The engine at the Dhobies' wells is comparatively new, and it ought to be capable of a much higher duty than has so far been obtained from it. At present it is costly as regards fuel consumed as compared with work done, but it seems probable that this is in a considerable measure due to the use of a small delivery pipe.

However, the chief difficulty would lie in the necessity for continuing the present water supply arrangements until other and better arrangements have been carried out and are perfectly ready to be substituted. The troops cannot be left without water for two or three weeks or perhaps longer, and so the engines and pumps must be kept where they are and others be provided for the new works. It may be taken as certain, however, that will it in the long run be the more economical and satisfactory plan to get complete machinery, suited in all respects to the work to be done, from a firm which understands the special requirements of such works. Water works need to be well carried out in all respects, and all the parts should be in harmony. The old plant will fetch something considerable when done with though much less than its value. The pipes now in use ought to fetch their full value, or some of them might with advantage be used for extending the distribution arrangements to the lines occupied by the officers of the regiments supplied.

50. It is nearly certain that water of perfectly satisfactory quality could be obtained at Bangalore only by distillation, and it seemed desirable, therefore, to complete the water-supply investigations by ascertaining the cost of the necessary apparatus and the expense of producing potable water in this way. General Hyde of the India Office has obligingly furnished the requisite information. In Appendix No. 25 will be found a statement giving the results of the working of the new and old Government condensers at Aden, as well as those of two private owners. The new condensers were made by the Normandy Company and are considered to be the best and most economical known. Also two letters from the Normandy Company to General Hyde and estimates for three sets of apparatus. It will be seen that the cost of two sets of apparatus to produce together 12,000 gallons in 24 hours would be ... £ 4,362

One set to produce 9,000 gallons ... ... „ 3,052

One set to produce 12,000 „ ... ... „ 4,046

These prices are free on board in London, and the corresponding prices at Bangalore would probably be Rs. 65,430, 45,780, and 60,690.

	GALS.
The smaller or 6,000-gallon size has, in an experimental trial at Aden, produced in 24 hours ...	7,082
The larger or 9,000-gallon size has, in an experimental trial at Aden, produced in 24 hours ...	12,110

But the average yield is shown by the statement to be about four-fifths of the above. Coal is the fuel used at Aden, and one pound of coal is equivalent to four pounds of wood, the fuel available at Bangalore.

The yield is 16 lb. of condensed water for 1 lb. of coal, and therefore 4 lb. of water would be obtained for 1 lb. of wood-fuel.

The Company's estimate of outturn is higher than the above and varies slightly according to the size of the apparatus, the yield being 18·0, 18·8, and 19·8 lb. of water to 1 lb. of coal for the three sizes respectively.

The Aden experience may, it is considered, be accepted as a safe guide.

No better water than that of the Dhobies' wells could be obtained for distillation. Assuming that 9,000 gallons a day would meet the requirements of the troops if the use of the condensed water were restricted to drinking and cooking purposes, one set of apparatus at a cost of Rs. 45,780 would suffice if kept constantly at work, but as at any rate it would be advisable to stop the machinery on Sundays, it would be desirable to have a 12,000-gallon set which would produce in six days enough water for eight days' consumption, and its cost would be Rs. 60,690. The weight of 12,000 gallons is 120,000 lb., and the wood-fuel required would be 30,000 lb. The present price of wood is 1 rupee for 268½ lb., therefore the daily cost of fuel would be Rs. 112 nearly, and the annual cost $52 \times 6 \times 112 =$ ... ... Rs. 34,344

Small stores, &c.	„	256
Working expenses		34,600

The apparatus includes pumps capable of delivering the water where required. It is stated that the attendance of one man will suffice to work the apparatus, and therefore the existing establishment at the Dhobies' wells would suffice; and, as the engine and pumps there would not be required, the buildings would be available for the condensers.

The only other outlay would be for pipes, cisterns at the barracks, &c., say 25,000, and the total annual outlay may be thus estimated:—

	Rs.
15 per cent. interest and depreciation on the cost of the condensers...	9,104
10 per cent. do. on rest of outlay	2,500
Working expenses	34,600
Total ...	46,204

or about 15·40 rupees annually per head. The present cost, about Rs. 10,400 a year, for the working expenses of the Halsur water works would remain unaffected, as water for other purposes would have to be pumped up by the Halsur rock water works.

51. The results of the investigations that have been made are briefly these:—

(1) The Bangalore water-supply project was designed and has been, with the exception of the greater part of the distribution works, carried out to supply the population generally with good water.

The (Ooparhalli) reservoir is inadequately supplied. It has never been full or nearly so for nearly five months in the year; on the average of six years the water level therein has been below the sill of the off-take sluice. The cause of this failure is the very small extent of the gathering ground, 2½ square miles, which is not more than about one-third of the area necessary to enable the reservoir to perform the duty for which the works were constructed.

Paragraph 27.

Paragraph 28.

There is but an insignificant extent* of additional ground, the drainage of which could be brought into the tank within a distance of eight or nine miles, and, owing to the low level of the intervening country, the cost of bringing in the water therefrom would be out of all proportion to its quantity and value.

* A little over one square mile.

Paragraph 30.

The Bangalore water-supply project is therefore incapable of supplying the station or the troops, and its utility will necessarily be confined to the improvement of the supply of a part of the pettah or native town and to occasionally supplementing the supply of Miller's tanks, which are of much importance to the inhabitants of the cantonment bazaar. The high ground at Nundidroog is the nearest and indeed only locality in which there is any considerable extent of ground on a sufficiently high level to command Bangalore, and even there the

Paragraph 31.

area between 9 and 12 square miles is much less than would be desirable. It is not yet certain that a suitable site for a reservoir in that neighbourhood can be found, but, if there be such a site, the cost of supplying Bangalore generally including the garrison would be between Rs. 24,87,000 and Rs. 28,80,000, depending upon the thickness of the cast-iron mains. These amounts represent, together with an allowance for working expenses, annual charges of from Rupees 1·698 to 1·960 per head of a population of 150,000 and of from Rs. 1·960 to 2·262 per head of the present population of 130,000.

(2) The Halsur tanks, the present source of supply for the troops, are supplied from, for the most part, a densely populated gathering ground, and the quality of the water is therefore unsuitable for drinking and cooking purposes. It would be possible to exclude the whole of the foul drainage from the lower and larger of the tanks, and to compensate for this exclusion by bringing in the drainage of open cultivated country to the eastward. This new gathering ground, however, though comparatively clean, is manured with the dirt and refuse of the cantonment bazaar, barracks, &c., and is therefore not capable of yielding anything like pure water. It is, moreover, not practicable to get rid of the foul supply of the upper tank, which receives drainage not only from ground carrying a considerable population, but from that occupied by tanneries, a large native cemetery, &c.

The Halsur tanks therefore are not capable of being made a really satisfactory source of water-supply for the troops.

The cost of such improvements as are feasible would be from Rs. 25,310 to Rs. 29,970, the former for a new catchment of 2·174, and the latter for one of 3·10 square miles.

(3) The proportion of the annual rainfall which does not run off the surface of the ground, but which is absorbed thereby, is in favor of wells as a source of water-supply, and there is still a large extent of open and fairly clean ground in the neighbourhood of the barracks occupied by the troops, in which wells could be sunk to obtain the water-supply required for drinking and cooking purposes.

Paragraph 39.

The nature of the sub-soil composed of gneissic rock in a more or less advanced state of decomposition makes it difficult to find subsoil water of suitable quality, and there is great uncertainty as to the quality of the water which wells sunk in any given locality would yield.

Separate sets of wells would, moreover, be needed to supply—

1*st.* The European Cavalry.
The two Field Batteries.
The South Station Hospital.
2*nd.* The Horse Artillery.
3*rd.* The European Infantry Regiment.
The North Station Hospital.

The water-supply of one well, No. 2, about 760 yards south of the South Station hospital has been tested as regards both quantity and quality. The latter is satisfactory, and the former indicates that, for drinking and cooking purposes only, six supply wells, each 20 feet in diameter, would be required for the first section above mentioned of the garrison.

The total cost of supplying the troops from wells is estimated at Rs. 1,12,500, representing the following annual expenditure:—

Paragraph 42.

	Rs.
Interest and depreciation on cost of works at 10 per cent. ...	5,000
Working expenses	2,500
Total ...	7,500

which would be in addition to present charges on this account.

The difficulty of forecasting the quality of the water and the uncertainty as to the maintenance of that quality if found suitable in the first instance render it unadvisable to resort to wells as a source of supply if any better arrangement can be made.

(4) A new source of supply for the troops has been found in the Agaram tank, a reservoir situated about three miles to the south of the South Station hospital, and having a catchment basin of 32·10 square miles, of which, however, a considerable part is rendered non-effective by a number of tanks in the upper part of the valley. The tank is well supplied; it receives none of the drainage

Paragraph 44.

of Bangalore, and the quality of the water, which has been analysed by the Chemical Examiner, is described as "usable," the highest character given to any water, from the neighbourhood of Bangalore, which has been examined. The surplus weir is 56·62 feet below that of the Halsur (lower) tank, and water would have to be pumped up to a level sufficiently higher than at present to cover this difference and the head due to the greater distance. The water could either be drawn direct from the tank, filtered, and then pumped into the existing service cisterns, or it could be drawn from a supply well in or below the tank, in which case artificial filtration might not be needed.

Paragraph 45.

The tank at present has a capacity of 24·068 millions of cubic feet, and, by raising the weir 3 feet, an additional storage capacity of 20·601 millions would be secured, making the total 44·669 millions of cubic feet. The estimated outlay required is Rs. 2,20,000 if water be taken direct from the tank, and Rs. 1,88,000 if it be drawn from a supply well within the influence of the tank. These amounts would represent an annual expenditure as follows:—

	No. 1. Rs.	No. 2. Rs.
Interest and depreciation on cost of engines, pumps and boilers, &c., at 15 per cent. ...	5,475	5,475
Interest and depreciation on other outlay at 10 per cent.	18,350	15,150
Total ...	23,825	20,625

or from Rs. 7·94 to 6·87 per head.

The present working expenses for pumping, &c., amounting to about Rs. 10,400 per annum, would suffice for the new pumping station; and the engines and pumps at the Halsur rock and Dhobies' wells could, after the new arrangements had been completed, be disposed of.

Troops and families, 3,000.

(5) Water of unexceptionable quality is probably obtainable at Bangalore only by distillation.

It has been ascertained that the best known apparatus for this purpose is the Normandy Company's condenser, which is that recently introduced for the Government water-suppply at Aden.

Paragraph 50.

Taking 9,000 gallons, or 3 gallons a head, as the quantity essential for the use of the troops for drinking and cooking purposes, the annual expenditure on this account would be about Rs. 46,204, or Rs. 15·40 per head.

The working expenses of the present water works would be unaffected, as all the rest of the supply would have to be obtained from the Halsur tanks.

The Dhobies' well water would be the best for distillation, and the buildings there would be suitable for the condensing apparatus.

The Normandy condenser produces pure, cold, palatable, and well aërated water.

52. The thanks of the undersigned are due to Captain Kensington, R.E., the Secretary to the Mysore Government, Public Works Department; to Lieutenant-Colonel Burton, R.E., Executive Engineer, Presidency Division; and to Mr. J. Smith, the Engineer of the Halsur Water Works, for much valuable assistance given in carrying out the investigations referred to in this report; as also to Dr. T. Tarrant, Deputy Surgeon-General, Bangalore Division, for the very useful information afforded, at short notice, as to the quality of samples of water taken from several wells, and to the President of the Madras Municipal Commission for particulars of the consumption of water, cost of distribution and maintenance, and of pipes and fittings, &c.

BANGALORE,
31st March 1884.

(Signed) J. MULLINS, Colonel, R.E.,
Chief Engineer, on Special duty.

APPENDIX No. 15.

Halsur Tank.

SUMMARY of Particulars of Water-supply from 1880 to 1883 inclusive.

Years.	Gauge readings.	Contents, millions of cubic feet.	Volume expended. Total, millions of cubic feet.	Volume expended. Used for troops, millions of cubic feet.	Volume expended. Lost, millions of cubic feet.	Volume received, millions of cubic feet.	Rainfall, inches.	Area of catchment basin, square miles.	Proportion of rainfall received.	Percentage of rainfall received.
1880	0·52	35·023	165·123	3·379	161·744	165·372	43·98	4·64	0·349	34·90
	0·47	35·272								
1881	0·49	35·172	29·852	3·300	26·552	19·395	23·28	Do.	0·077	7·70
	2·64	24·715								
1882	2·64	24·715	26·689	3·049	23·640	26·784	31·13	Do.	0·080	8·00
	2·62	24·810								
1883	2·62	24·810	27·844	3·437	24·407	27·181	28·75	Do.	0·087	8·70
	2·76	24·147								
	..	..	..	..	..	238·732	127·14	..	0·174	17·40
							Rainfall, Bowring Civil Hospital, inches.			
1880	..	..	..	..	..	..	51·69	..	0·297	29·70
1881	..	..	..	..	..	..	27·44	..	0·065	6·50
1882	..	..	..	..	..	..	37·02	..	0·067	6·70
1883	..	..	..	..	..	..	34·80	..	0·072	7·20
	..	..	..	..	..	238·732	150·95	..	0·146	14·60
Years 1881, 1882, and 1883, Halsur rock rain register ..	..	..	..	..	..	73·360	83·16	..	0·0851	8·51
Do. do. Bowring Civil Hospital rain register	..	..	..	..	..	Do.	99·26	..	0·0713	7·13

N.B.—A square mile = 3,097,600 square yards = 27·8784 millions of square feet; 4·64 square miles = 129·356 millions of square feet.

APPENDIX No. 16.

APPROXIMATE Abstract Estimate for diverting Drainage of Western Feeder from Halsur Tank.

Quantity.	Description.	Unit.	Rate.	Amount.	Work Totals.
		RS. C. PT.	RS. A. P.	RS. A. P.	RS. A. P.
	Bund from culvert at mouth of western feeder to main bund of Halsur tank. 10,95,465				
	Diverting drainage puddle wall 1,21,770				
	Diverting drainage revetment 1,20,540				
789,195	Diverting drainage gravel backing 63,960				
	3,06,270	1,000	3 7 6	2,738 0 0	
121,770	Puddle wall	1,000	4 11 0	571 0 0	
1205·40	Revetment (formed of sized stones)	100	9 8 0	11,451 0 0	
639·60	Gravel backing	100	2 0 0	1,279 0 0	
					16,039 0 0
	New Waste Weir—Crest, 90 feet.				
24·42	Concrete	100	12 8 0	305 0 0	
100·50	Rubble masonry	100	14 1 0	1,417 0 0	
24·44	Rough-stone apron	100	9 8 0	232 0 0	
	Excavation and filling	..	..	39 0 0	
					1,993 0 0
	Lowering old waste weir 4 feet	..	..	..	300 0 0
	Diverting North-west Drain into western feeder.				
42·126	Earthwork forming channel	1,000	2 14 3	122 0 0	
	A culvert under cross road	..	..	300 0 0	
					422 0 0
					18,754 0 0
	Contingencies	..	..	..	96 0 0
					18,850 0 0

N.B.—The rates were obtained from the office of the Executive Engineer, Presidency Division.

ESTIMATE FORM.

Abstract.

Quantity.	Description of Work.	Rate.	Per	Amount.	Total.
	Detailed data for 100 cubic feet of Concrete of the following proportions.	Rs. A. P.	C. ft.	Rs. A. P.	Rs. A. P.
50	Broken stones ¾″ to 1″ cube	6 0 4	100	3 0 2	
8½	Screened and washed gravel	3 0 0	..	0 4 0	
16⅔	Slaked lime	0 4 3	C. ft.	4 6 10	
16⅔	Soorkee	0 1 9	..	1 13 2	
25	Sand	1 13 9	100	0 7 5	
4	Men coolies	0 3 0	Each.	0 12 0	
12	Women coolies	0 1 8	Do.	1 4 0	
	Contingencies	..	..	0 8 5	
	Total for 100 cubic feet ..	..	..	..	12 8 0
	Do. 1 cubic foot ..	..	..	..	0 2 0
	Grand Total of Estimate ..	..	..	..	..

NOTES.

Reference to Madras P.W.D. Code.

Paragraphs 1074, 1075, 1086, 1087, 1091 to 1094, 1108, 1111 to 1114, 1130 and 1145 to 1147.

1. Abstract of estimates should be prepared under such sub-heads as are to be separately shown in the accounts (register of works, work vouchers, &c.) of the work. For repairs of buildings and roads, the classification of the budget estimate should be strictly followed, one estimate only being framed for each budget entry, and if a further estimate is required, it should be supplemental to the first; by this means, as the work abstracts follow the estimates, the register of works, the schedule of expenditure and the books of the Central office will show by one entry the entire outlay on repairs to each work for the whole year, which is not the case when several estimates are sanctioned for the repairs of one work in the course of the year.

2. Quantities are to be entered as so many units.

3. All rates are to be quoted in rupees, annas and pies.

4. Annas and pies are to be excluded from the abstract estimates, the cost of each item being brought to the nearest rupee. Totals of estimate need not be brought to round numbers.

Specification for the Diversion of the Western Feeder of the Halsur Lower Tank.

1. A bund 2,460 feet in length, as shown on the survey, from which the table of waterspread and capacity was prepared, to be run from near the left wing of the 5-vent culvert at the lower end of the feeder, in a curve to near the point marked M, and thence nearly parallel to the road, at a minimum distance of 90 feet between the rear top edge of the bund and the top edge of the road, up to 50 from the site of the new weir whence the bund will curve to the eastward to connect with the weir wing.

Plan No. 11.

2. The ground to be cleared of all vegetation, and a trench 6 feet wide and 3 feet deep to be excavated and filled with puddle formed of well-tempered clayey soil taken from the bed of the tank before the formation of the bund is commenced.

3. The top width of the bund to be 8 feet, the interior slope 1½ to 1, and the exterior slope 2 to 1. The top of the bund will be 3½ feet above full tank level.

4. A puddle wall to be carried up simultaneously with the bund, and to terminate at 1½ feet below the top of the latter with a width of 2 feet. The faces to have a batter of 1 in 6.

5. The interior slope to be revetted to ½ a foot above full tank level with stones 1½ feet long laid at right angles to the slope on 1 foot of gravel backing. This height of revetment has been deemed sufficient because at the time of the year (March) when the easterly winds are strong, the water level will be from 3 to 3½ feet below the top of the revetment. The rear slope to be similarly revetted to the level 2927·97. The revetments to be carried up simultaneously with the earthwork.

6. All earthwork to be well watered and rammed.

7. The general arrangement of the channel between the bund and the road is shown on the section.

8. The present waste weir of the tank to be lowered 4 feet or to 2925·97. This is supposed to be as low a level as can be secured without reconstructing the bridge, but it would be advantageous to lower it still further if found to be feasible.

9. A new waste weir with a crest 90 feet long and 1 foot above the present full tank level, *i.e.*, at 2930·97 instead of 2929·97, to be constructed a few feet from the present main bund in the line of the new bund, as shown on the survey.

Plan No. 12.

It is calculated that the new weir will with a depth of 1⅓ feet passing over discharge 654 cubic feet a second, whereas the present weir with a nominal length of 90 feet but actual only 76½ feet and with a wide irregular crest does not discharge more than 422 cubic feet. Consequently maximum water level will not be more than 18 inches above the new crest level, and it probably will very rarely exceed 1 foot.

$$D = 90 \times 3{\cdot}56d\sqrt{d.}$$

$$D = 76\tfrac{1}{2} \times 3d\sqrt{d.}$$

10. The drainage channel which now enters the tank at its north-west corner to be diverted along the west of the road forming the western boundary of the tank, and to be dropped into the channel now called the western feeder.

The diversion channel to be 4½ feet wide at bottom with side slopes of ½ to 1.

Its length will be 2,340 feet.

APPENDIX No. 17.

Approximate Estimate for constructing a Channel 5 Miles in length to bring into the Halsur Lower Tank the Drainage of 2·174 Square Miles to the Eastward.

Length.	Area of Cross Section.	Thousands of Cubic. Feet.
5,280	48	253,440
5,280	$\frac{48+28}{2}$	200,640
5,280	$\frac{28+21}{2}$	129,360
5,280	$\frac{21+13}{2}$	89,760
5,280	$\frac{13+10}{2}$	60,720
		733,920

Quantities.	Description.	Unit.	Rate.	Amount.	Totals of Works.
			Rs. A. P.	Rs.	Rs.
733·920	Cutting channel and forming left bank ..	1,000 cubic feet ..	2 14 3	2,121	
	Rock cutting	Do. ..	..	500	
					2,621
300	Waste weirs	Running foot ..	5 0 0	1,500	
					1,500
	Tail weir	.. ..	..	330	
					330
	Culvert for cross road, Knoxpett ..	..	..	200	
	Do. for main road, Binnamangalam ..	..	..	300	
	Four other culverts for village tracks ..	..	120 0 0	480	
					980
					5,431
	Contingencies	..	..	..	29
					5,460
20	Compensation for land	Acres	50 0 0	..	1,000
					6,460
	Compensation for diversion of water ..	..	..	..	?

APPENDIX No. 17 A.

Approximate Estimate for constructing a Channel, 9½ Miles in Length, to bring into the Halsur Lower Tank the Drainage of 3·10 Square Miles to the Eastward.

Length.	Area of Cross Section.	Thousands of Cubic Feet.
5,280	48	253·440
5,280	$\frac{48 + 40}{2}$	232·320
5,280	$\frac{40 + 36}{2}$	200·640
5,280	$\frac{36 + 30}{2}$	174.240
5,280	$\frac{30 + 26}{2}$	147·240
5,280	$\frac{26 + 22}{2}$	147·840
5,280	$\frac{22 + 18}{2}$	126·720
5,280	$\frac{18 + 14}{2}$	105·600
5,280	$\frac{14 + 10}{2}$	84·480
2,640	$\frac{10 + 8}{2}$	63·360
		23·760
	Total ...	1412·400

Quantities.	Description.	Unit.	Rate.	Amount.	Total of Works.
			Rs. A. P.	Rs.	Rs.
1412·400	Cutting channel and forming left bank ..	1,000 cubic feet ..	2 14 3	3,083	
	Rock cutting 6th and 7th mile	..	..	800	
	Rock cutting elsewhere	..	..	700	
					4,583
500	Waste weirs	Running foot ..	5 0 0	2,500	
					2,500
	Tail weir	..	..	330	
					330
	Culvert for cross road, Knoxpett	..	..	225	
	Do. for main road, Binnamangalam ..	..	..	335	
	Do. do. near 5th mile stone ..	..	..	220	
	Nine other culverts for village tracks ..	..	125 0 0	1,125	
					1,905
					9,318
	Contingencies	..	..	..	52
					9,370
35	Compensation for land	..	50 0 0	..	1,750
					11,120
	Compensation for diversion of water ..	..	..	..	?

APPENDIX No. 17 B.

Dimension, &c., of Channels for additional Catchment to eastward of Halsur Lower Tank.

(1) Channel for Catchment of 3·10 square miles.

Miles from Lower End.	Side Slopes.	Depth of Water.	Bottom Width.	Area of Waterway.	$\sqrt{r}$.	C.$\sqrt{S}$.	$\sqrt{\ }$. Feet per Second.	Discharge Cubic Feet per Second.	Area of Catchment approximate.	Discharge, in Inches, draining off per Day.
		ft.	ft.	sq. ft.					sq. mls.	
1	½ to 1	3	12	40·50	1·47	1·236	1·817	83·59	3·10	1
2	do.	3	12	40·50	1·47	1·236	1·817	83·59	3·10	do.
3	do.	2½	11	30·62	1·36	1·176	1·60	49·00	1·80	do.
4	do.	2½	8	23·12	1·30	1·139	1·48	34·22	1·44	do.
5	do.	2¼	8	20·53	1·25	1·106	1·38	28·33	1·00	do.
6	do.	2	8	18·00	1·20	1·074	1·29	23·22	0·84	do.
7	do.	2	6	14·00	1·16	1·049	1·22	17·08	0·67	do.
8	do.	2	4½	11·00	1·10	1·005	1·11	12·21	0·45	do.
9	do.	1¾	4	8·53	1·04	0·960	1·00	8·53	0·30	do.
9½	do.	1½	3	5·62	0·94	0·887	0·83	4·66	0·15	do.

(2) Channel for Catchment of 2·174 square miles.

1	½ to 1	2½	12	33·12	1·37	1·180	1·62	53·66	2·17	1
2	do.	2½	12	33·12	1·37	1·180	1·62	53·66	2·17	do.
3	do.	2	8	18·00	1·20	1·074	1·29	23·22	0·85	do.
4	do.	2	5	12·00	1·13	1·026	1·16	13·92	0·50	do.
5	do.	1½	4	7·12	0·98	0·916	0·897	6·39	0·23	do.

APPENDIX No. 23.

Specification and Approximate Estimate for the Supply of the European Cavalry Regiment, two Batteries of Field Artillery, and South Station Hospital with Water for Drinking and Cooking from Wells in the Small Valley to the south of the Hospital.

1. *Wells.*—The wells to be seven in number and 20 feet in diameter.

The sump well to be in the centre and to be placed at or close to the present well No. 2, with its bottom at 2886·00.

Vide plan 12.

The remaining six wells to be arranged as a hexagon, at a distance of 500 feet from the sump well, centre to centre, and consequently 500 feet apart. Their bottoms to be at 2888·00. It is estimated that these wells will collect the water from 72 acres, or from a circle with a radius of 1,000 feet. The six wells to be connected with the sump well by 6-inch cast iron pipes laid with their ends at the external wells at 2890·00 and at the sump well at 2888·00. All the wells to be steined with stone in mortar from 1 foot above ground level to 5 feet below that level, and below this with dry stone. The space at the back of the masonry steining to be filled in with red soil, like that used for compound walls, well puddled and carefully trodden in, so as to prevent any surface drainage getting into the wells.

The steining from the level 2902·00 or 10 feet below the top to be stepped in 4 inches for each course (of 8 inches) so as to reduce the top diameter of the wells to 10 feet, a width convenient for beam-stones.

The platform of the sump well to be at 2912·00, the beam-stones for the pump at 2909·33, and the rose of the suction pipe at 2890·00, the lowest level to which the water is to be drawn off being 2891·00, or 18·33 feet below the valve of the pump.

2. The water-supply required being taken at 400 gallons per hour, or 9,600 gallons a day and the pumping time at ten hours, the pump should be capable of raising 960 gallons an hour

J. Taylor and Sons' treble barrel 3½-inch pumps with frame, Fig. $\frac{204}{2}$, price £31, are estimated to raise 940 gallons an hour to a height of 100 feet with four men.

The greatest lift required is from 2891·00 to about 2988·00* or 97 feet.

* Floor of cistern of female hospital 2984·75.

Two sets of coolies, or eight men, taking turn and turn would be needed. The cost of this arrangement including suction pipe and fixing, freight and carriage may be taken to be Rs. 600. With bullock gear treble 5-inch pumps would be better, and the cost would be about Rs. 1,200. This latter will be entered in the estimate, as the work would be hard for coolies.

3. For laying the pipes connecting the outer wells with the sump well, a deep trench, 3 feet wide, will have to be cut and properly shored. The quantity of soil to be removed will be $6 \times 500 \times 3 \times 23 = 207{,}000$ cubic feet, costing about 1,500 rupees. The rest of the item of 3,000 rupees allowed is for planks and bars for shoring.

4. Pumping will be necessary in connection with the well sinking and the laying of the connecting pipes, and as it is difficult to estimate the time required, Rs. 3,000 will be allowed.

Approximate estimate—

			Rs.
7 wells at Rs. 650		=	4,550
6 × 510 = 3,060 feet of 6-inch C. I. pipes, $\frac{3}{8}$ inch, metal, at 23·4lb. per foot, 71,604lb. or	32 tons.		
4,500 feet of 3-inch C. I. pipe, $\frac{3}{8}$ inch, at 12·4lb. per foot, 55,800lb. or	24 tons.		
1,000 feet of 2-inch C. I. pipe, $\frac{3}{8}$ inch, at 8·7lb. per foot, 8,700lb. or	4 tons.		
	60 tons.		
60 tons of C. I. pipe, at Rs. 95		=	5,700
2,000 feet of 1½-inch wrought iron pipe, at Rs. 0-8-6		=	1,063
Laying 1,020 yards of 6-inch pipe, at Rs. 0-10-0 ...	637-8-0		
Do. 1,500 yards of 3-inch pipe, at Rs. 0-7-6 ...	703-2-0		
Do. 1,000 yards of 2-inch pipe, at Rs. 0-4-0 ...	250-0-0		
			1,591
Pump with gear			1,200
Trench for connecting pipes			3,000
Unwatering during construction			3,000
Taps and fittings			2,000
Contingencies			1,896
Total ...			24,000

APPENDIX No. 24.

Specification and Approximate Estimates for the supply of the Troops from Agaram Tank.

1. *Data for Supply.*—The ordinary supply, on the average of four years, has been 56,376 gallons per day, the greatest 71,040 gallons. It is probable that 60,000 gallons would be sufficient, which are equivalent to 9,600 cubic feet, but to allow of a possible extension of the distribution, it is proposed to provide for a maximum quantity of 14,400 cubic feet a day.

It is desirable that this supply should be capable of delivery into the cisterns in 8 hours and the quantity per minute will then be 30 cubic feet.

The Agaram tank is about 3 miles from the old Racecourse barracks and nearly 4½ miles from the cistern which supplies the European Infantry barracks.

This latter cistern is also at the highest level at which water has to be delivered, viz., 2999·62. The present full tank level of the Agaram tank is 2873·35.

To obtain the required head for discharge through the pipes, the water must be lifted or forced over a stand-pipe, the bend (centre) of which is intended to be at 3015·00.

2. There are two alternative ways of obtaining water from the Agaram tank :—

(i) from a supply well sunk in the bed of the tank, in which case clear water would be obtained and artificial filters would not be needed ;

(ii) from the tank direct, and in that case filtration prior to pumping would be requisite. It would for this arrangement be necessary also to increase the capacity of the tank.

It is doubtful whether the quality of the water would not suffer from filtration through the soil into a supply well sunk in the tank bed, seeing that water taken from wells, not many yards from and above the tank, has been found to be inferior to that of the tank itself, though it remains to be determined whether a well sunk in the tank, or perhaps below the tank, would give similar results.

The maximum height to which water would have to be raised under this arrangement would be 161 feet.

With the alternative arrangement the maximum height is estimated at 151 feet.

3. *Engines and Pumps.*—The quantity of water being 30 cubic feet a minute, and the maximum lift 161 feet, the nominal engine horse-power required is $\frac{30 \times 62 \times 161}{33{,}000}$ = just over 9-horse power.

It is intended therefore to provide two engines each of 12-horse power nominal, and these should be of the compound condensing type ; there should be three boilers, each capable of supplying, with wood fuel, full steam to one engine. The three boilers to be fixed side by side and to be connected by means of the usual steam domes and pipes with valves, so that any one or two adjacent boilers may be used at a time.

Fuel being dear, the present price being Rs. 8·34 per ton equivalent to Rs. 33·36 a ton for coal, it is essential that, in designing the engines and boilers, economy of consumption should be specially studied.

Pumps.—These should be of the ordinary plunger kind, and there should be a set for each engine. Each set to consist of three barrels about 8 inches in diameter and from 20 to 24 inches stroke. The delivery with the former stroke would require 17·20 strokes a minute nearly, and with the latter 14·33 strokes a minute.

The other requirements will be noticed in connection with the alternative arrangements.

An air vessel of ample capacity to be provided to equalize the pressure and flow. The amount entered for engines and pumps is based on the cost of the machinery at Dhobies' wells, which is said to have been £1,138 in England.

4. *Stand-pipes.*—These to be three in number, and with 10 inches internal diameter, one up pipe and one down pipe connected by a bend at the top, and one waste pipe connected with a vertical pipe from the summit of the bend ; such connection to be at 4 feet above the centre of the bend and 4 feet below the open top of the pipe.

Vide plan 14.

The length of the pipes above the masonry platform will differ by about 7 feet in the two arrangements for the supply, but in either case the pipes are intended to be set up with a batter of 1 in 12, and to be strutted and braced at intervals of 2, or at most 3, lengths of pipe, *i.e.*, probably at every 18 or 27 feet, so as to make the whole structure quite rigid and able to withstand the severe gales at times experienced.

The pipes should rest on a base plate of suitable form, and they, as well as the connecting pipes below, should be securely bolted thereto.

The metal is supposed to be $\frac{3}{4}$ inch thick, and a special rate is allowed to cover the subsidiary parts.

490 × 79 = 38,710lb. = 18 tons.

6 sets of struts and braces.

		Rs.
Bed plates—		
18 tons at Rs. 120	=	2,160
Erecting		340
Total ...		2,500
Masonry foundation if water drawn from tank direct		1,430
Do. do. if drawn from supply well in tank		1,000

5. *Delivery Mains.*—The main from the foot of the stand-pipe to a short distance from the Racecourse cistern, Cavalry barracks, a distance of about 18,000 feet, will be of 10 inches diameter and $\frac{3}{4}$ of an inch thick.

Flanged pipes are provided for. The working head, exclusive of the margin for bends, which will however be very slight, is arranged to give a gradient of 0·60 of a foot in a thousand feet.

By Nevilles' formula—

$$V = 140\sqrt{r.s.} - 11\sqrt[3]{r.s.}$$

$$R = \frac{10}{4 \times 12} = \cdot2083 \quad S = \cdot0006$$

$$\therefore V = 140 \times \cdot01118 - 11 \times \cdot05 = 1\cdot56 - \cdot55 = 1\cdot01$$

A = ·5454 and D = ·55 cubic feet a second = 33 cubic feet a minute.

By Jackson's tables the discharge would be 29·64 cubic feet a minute.

The proportional discharge into the Racecourse cistern will be 18·60 cubic feet a minute, and the gradient to this cistern being high, viz., 1·94 feet in a thousand, a 7-inch pipe will be ample. The length of this branch will be about 500 feet.

The discharge of the other branch will, for 1,500 feet to the head of the Horse Artillery cistern branch pipe, be 11·40 cubic feet a minute, and for the rest of the distance, about 5,000 feet, to the E.I.B. cistern, 9 cubic feet a minute ; a 7-inch pipe has been allowed for all through. For the R.H.A. pipe 3 inches will be a suitable diameter. Its length will be about 1,200 feet—

18,000 feet of 10-inch pipe, $\frac{3}{4}$ inch thick, × 79 = 1,422,000 lb. = 635 tons.
7,000 feet of 7-inch pipe, $\frac{3}{4}$ inch thick, × 46·7 = 326,900 lb. = 146 „
1,200 feet of 3-inch pipe, $\frac{3}{4}$ inch thick, × 12·4 = 14,880 lb. = 6½ „

		Rs.
787½ tons of C. I. pipe, at Rs. 120		94,500
Laying 6,000 yards, at Rs. 1-2-0		6,750
„ 2,333 yards, at „ 0-10-0		1,452
Contingencies		5,298
		1,08,000

6. The cisterns and subsidiary distribution are intended to be left as at present.

7. *Arrangements at Agaram Tank and Pumping Station.*—First—With a supply well in or below the tank. In this case the only special works required would be a well in the bed of the tank at the deepest part of the small bay near the waste weir bridge, and a pipe therefrom to the engine at the pumping station.

The well would be 30 feet in diameter at top with its bottom at 2850·00, and its top at 2880·00, the excavated soil being arranged round that part of the steining which would be above tank bed level, so as to prevent any surface water passing into the well. The steining to be constructed in masonry down to 5 feet below bed or ground level,* and below that in dry stone.

* About 2868·63.

The steining above bed level may be arched as shown in the section, or it may be stepped in 6 inches for each course, and then covered in at top with slab stones.

Plan No. 14.

The well will be 30 feet in diameter for 3 feet below bed level, 27 feet for the next 7 feet, and 25 feet for the last 7 feet. The contents of the well, from estimated L.W.L. 2855·63 to bed level, are 7485·64 cubic feet, or rather more than half the supply required in the 24 hours.

The calculated required inflow of water is $\frac{14{,}400 - 7{,}485}{8 \text{ hours}} = 864\frac{1}{2}$ c. ft. per hour.

The surface for inflow is—

1st—The area of the bottom of the well		452·39 sqr. ft.
2nd—The sides, where lined with dry stone, 1404·29 square feet which may be taken as $\frac{1}{8}$th unobstructed ...		175·54
		627·93

so that 1·4 cubic foot per square foot per hour will be needed.

	Rs.
The probable cost of the well will be 9·300 earth-work, at Rs. 15-10-0 per 1,000 cubic feet	148
17·82 dry stone steining at Rs. 12-8-0 per 100 cubic feet	223
17·17 steining stone in mortar, at Rs. 18-12-0 „ ...	322
Slab stones	50
Sundries	37
	780
Contingencies	120
Total ...	900

Suction pipe, 12 inches diameter, $\frac{3}{4}$ inch thick, about 500 feet.

	Rs.
500×93·2=46,850 lb.=say 21 tons of C. I. pipe at Rs. 95 per ton =	1,995
Laying 167 yards at Rs. 1-4-0 per yard ... ... =	210
Trench to pumping station, for laying pipe, average depth about 12 feet, 500×4×12 = 24,000 cubic feet, at Rs. 10 per thousand ...	240
Sundries	125
Total ...	2,570

The suction pipe would have a connection, with a suitable valve, with each set of pumps.

Secondly—If water be drawn off direct from the tank. The special works are—

(1.) A suction pipe from the tank to the pumps;
(2.) A pair of filters with a pure water well attached and a suction pipe therefrom to the pumps;
(3.) An increase to the capacity of the tank.

(1.)—The suction pipe, which would be connected with each set of pumps to be 12 inches in diameter, and to be run out into the deep part of the tank, so as to be able to draw off water to about the 2866·63 level, or 6·72 feet below present full tank level. The length will be about 960 feet.

	Rs.
960 feet × 93·7 = 89,952 lb. = 40 tons.	
40 tons C. I. pipe at 95 ... ... =	3,800
Laying 320 yards at Rs. 1-4-0 ... ... =	400
Trench for pipe, average depth 6 feet, 960×4 × 6 = 23,040 cubic feet at Rs. 7 per thousand ... ... =	161
Sundries ... ... =	239
	4,600

Another suction pipe will be required from the pure water well: it will be 10 inches in diameter, 150 × 79 = 11,850 lb. = 5 tons.

	Rs.
5 tons of C. I. pipe at Rs. 95 ... ... =	475
Laying 50 yards at Rs. 1-2-0 per yard ... ... =	56
Sundries ... ... =	29
	560

(2.)—The quantity of water to be filtered being 30 cubic feet a minute, or 1,800 cubic feet hour, and the usual allowance being 2 square feet of filter bed for every cubic foot per hour, 3,600 square feet will be the area of each filter, or say 90 by 40 feet. The filters will be placed side by side, with a pure water well in connection with both. Depth of filters 10 feet and of well 13 feet; diameter of well 15 feet. Probable cost of the whole Rs. 15,000.

(3.)—The present capacity of the tank above the sill of the lowest sluice is 24·068 millions of cubic feet. It is proposed to raise the full tank level 3 feet, which will increase the capacity by 20·601 millions, or to 44·609 millions of cubic feet altogether. The present height of the bund varies considerably. There is only one waste weir, 119 feet in length, of which about 115 feet are effective, and this is not sufficient for the area of the catchment basin, 32·10 square miles. There was formerly a bywash at the other (east) end of the tank, but this was closed some time ago. The lowest estimate of the maximum discharge would be 2,646 cubic feet a second, viz.:—

$$D = 350 \sqrt[3]{32^2} = 3{,}528 \text{ cubic feet a second,}$$

with the time extended one-third by the action of the upper tanks.

The difference between full tank level and M.W L. should be limited to 3 feet and the proper length of weir will then be 157 feet, say 160 feet, or 45 feet, additional are required.

The revetment being out of section from settlements, will be rebuilt with a gravel and small stone backing, and the addition to the bund will be made, as is always desirable, on the inside, so far as may be practicable with due regard to securing a good alignment for the road

The top of the bund will be 6·28 feet above full tank level, and the clear width of roadway 15 feet; a width of 18 feet has been allowed at road level, so as to admit of side ridging, which adds to the security of the traffic and tends to maintain the edges of the bank in good order.

There being a great length of bund at the east end with but very little water-spread, it will be cheaper and better to make a cross bund to the high ground immediately west of the village of Agara, and the connection of this bund with the main bund will be at about 2,920 feet on the longitudinal section, the zero of which is at the 7th furlong of the 6th mile. For this new bund a top width of 6 feet and slopes of 1½ to 1 inside and 2 to 1 outside have been allowed, and revetment 1⅓ feet thick up to 2 feet below the top, which is the height to which the revetment generally will be carried up.

The new weir will be built towards the south end of this cross bund. The estimate for it has been made out on the supposition that the crest will be at 3 feet above ground level, but it is probable that a good site may be found on a higher level, in which case the cost will be proportionately reduced.

There is a small irrigation sluice to the eastward of the position of the cross bund, and it is proposed to put a 6-inch pipe in or under the crest wall of the new weir to supply the lands under that sluice. The discharge of water through the pipe can be regulated by a wooden plug.

The surplus from the new weir will have to be passed across the road at the old outfall by lowering the road to about 1·28 feet about present full tank level with ramps of 1 in 25 at either end.

If the low level road be 200 feet in length, the maximum depth of water passing over will not exceed one foot, and if the lower side be well revetted with 3 or 4 feet of rough stone apron at the toe of the revetment, no other protection will be required. Moreover, if a cut, 9 feet wide, be made on the south side of the road to the two-vent culvert, which is on a low level, no water will pass over the road in ordinary seasons. Rs. 500 have been allowed for these alterations: sufficient stone will be obtainable from the present bund to the east of the cross bund.

8. The levels of the Agaram tank, as plotted, require an addition of 1·63 feet as noted on plans 13, 15 and 16. The levels were ordered to be taken from the floor at the south end of the Cavalry part of the South Station Hospital, and they were actually started from an offset 0·96 feet above the floor. It has also been found that the levels on Lieutenant Romilly's section are not quite correct. His levels make the floor of the hospital 30·38 above datum which is 11·50 feet below Halsur tank waste weir, or the floor is 18·88 above the weir.

Vide section at end of paper on Halsur water-works, No. CCCLII., in No. 41, July 1881, of Roorkee Professional Papers.

The zero of the tank gauge is 11·95 feet below the bench mark on the offset on the south face of the rock engine-house, and the difference between that bench mark and the floor of the Cavalry hospital is 7·60 feet, so the latter is 19·55 feet above Halsur full tank level, or a difference of 0·67 feet.

The reduced level (Karwar mean sea level) of the zero of the Halsur lower tank gauge is 2929·97, so the floor of the Cavalry hospital is 2949·52, and the bench mark on the offset 2950·48.

In levelling to the Agaram tank the valve, 18·88 + 2929·97 = 2948·85 was used for this bench mark; hence the connection of 1·63 feet requiring to be added to the plotted levels above referred to. The levels entered on plan 14 have been corrected as regards the Agaram tank, but the levels of the several parts of the garrison distribution have been left as given in Lieutenant Romilly's section, as no connected series of check levels of the cisterns have been taken, and the stand-pipe has been designed so as to secure ample head.

9. The following is an abstract approximate estimate of the cost of enlarging the Agaram tank:—

Quantities.	Description.	Unit.	Rate.	Amount.	Work Totals.
			RS. A. P.	RS.	RS.
476·857	Earthwork to bund and forming cross bund	1,000 C.ft.	3 7 6	1,654	
					1,654
506·02	Rebuilding old revetment	100 C.ft.	1 8 0	760	
337·35	Gravel backing to do.	do.	2 0 0	675	
					1,435
363·44	New revetment	do.	9 8 0	3,453	
242·29	Gravel backing to revetment	do.	2 0 0	485	
					3,938
	Alterations to waste weir and 11-vent culvert	..	..	840	
	Alterations to west sluice	..	..	350	
					1,190
	New waste weir, 45 feet crest with sluice pipe	..	..	..	
46·25	Rubble masonry	100 C.ft.	14 1 0	650	
12·24	Rough stone apron	do.	9 8 0	116	
5	Feet sluice pipe 6 inches in diameter and ½ inch thick with elbow at tank end	..	..	10	
	Sundries	..	..	37	
					813
	Lowering road to pass surplus from new weir, with cut on south side of road to 2-vent culvert	..	..	500	
					500
53·3	Land compensation for additional water-spread	Acres.	60 0 0	3,198	
					3,198
	Contingencies	..	..	..	272
	Total ..	..	..	..	13,000

The additional capacity being in round numbers 20½ millions of cubic feet, the cost of storage would be per million cubic feet Rs. 634, which seems reasonable, as the rebuilding of the old revetment and the new waste weir are works appertaining to the security of the present tank, and without these two items the cost per million would be under Rs. 525.

10. The ground selected for the pumping station measures 4·54 acres, and provision has been made for enclosing the whole with a wall of stone in mud pointed with mortar, and coped with stone in mortar. The wall to be 6 feet in height. The item, Rs. 4,000, is a considerable one, but it seems to be important to exclude all but employés, as otherwise perfect cleanliness cannot be ensured.

Vide plan 13.

11. Subjoined is a general abstract of the alternative arrangements for the supply of the troops from this source. As the present establishment at the Halsur rock water works would suffice for the Agaram works, and as the working expenses generally would be much the same, no provision has been made on this account.

Particulars.	Water drawn direct from Tank. Amount. RS.	Water drawn from Supply Wells in or below Tank. Amount. RS.
Engines and pumps	36,500	36,500
Stand pipes	2,500	2,500
Masonry foundation pipes	1,430	1,000
Delivery mains	1,18,000	1,18,000
Suction pipe from supply well	...	2,500
Supply well	...	900
Suction pipe from tank	4,600	...
Do. do. from pure water well	560	...
Two filters	15,000	...

Particulars.	Water drawn direct from Tank. Amount. RS.	Water drawn from Supply Wells in or below Tank. Amount. RS.
Enlarging tank	13,000	..
Ground for pumping station	250	250
Engine-house and chimney	12,500	12,500
Quarters for Engineer, &c.	3,000	3,000
Enclosure walls	4,000	4,000
	2,11,340	1,81,220
Contingencies	8,660	6,780
Total	2,20,000	1,88,000

CONDENSER LIST No. 1.

PURE COLD FRESH WATER FROM SEA WATER WITH GREAT ECONOMY OF COAL.

For Yachts, Ships, or on Land.

Four-thousand and five-hundred gallons, or 20 tons for 1 ton of coal. (Results guaranteed abroad if required).

Normandy's Improved Patent Fresh Water Distilling Machinery.

This machinery converts sea, or other impure, water into *pure, cold, fresh water*, equal in appearance and taste to the best river or spring water, and fit for immediate use as it leaves the machinery, which will also force it to any distance, and to a height of 40 yards or metres, or more if desired.

It is well known that an *insufficient* or *impure* water-supply *is a constant source of danger from a sanitary point of view.* There are many places where such a state of things exists, and where the introduction of this machinery would at once provide a *cheap, pure, and abundant water-supply.* Over 1,030 machines have been supplied, and some of the land stations and ships supplied are given on the last page.

The process may be briefly stated as follows:—

Water distilled by the ordinary process, viz., by a boiler for generating steam, and a worm for condensing steam into water, is open to these objections:

1. *The entire heat of the condensed steam is lost.*

2. The water formed by the condensed steam contains organic impurities, which give it a disagreeable flavour.

3. This water is destitute of air, which it has lost in the process of boiling, and it is hence flat and vapid to the taste, besides being somewhat heavy if drunk in quantity.

These objections may be, to a certain extent, removed by exposing the water to air for a long time. *But on board ship, and in doubtful places, the water may absorb air which is not pure.*

Normandy's improved apparatus removes all these objections, by using over again the heat liberated by one or more successive condensations of steam, thus increasing the amount of distilled water to from 1¾ to 2¼ times the water evaporated by the boiler. The distilled water is aërated in the process of condensation and is cooled down to the temperature of ordinary water in the outer air, and the taint of organic matter is completely removed from the distilled water by passing it through a filter of prepared animal charcoal, from which it flows out cold, pure, well aërated, and equal in taste and appearance to the best river water as usually supplied to towns.

RESULT of the Trial of Normandy's Improved Patent Distilling Machinery, erected at Flushing for the Dutch Government, January and February 1877.

This machinery was supplied as suitable for producing 6,000 gallons of pure fresh water, per 24 hours, from sea water.

By the direction of Mr. Van Diesen, Chief Engineer of the Waterstaat, in the Province of Zealand, Holland, this machinery was carefully tested by being worked under the inspection of officials appointed for the purpose, the result being that *in* 19 *hours' work* this machinery produced 28,500 litres of fresh water, and consumed 1,545 kilos. of coal. This is equal to 6,270 gallons (or 28 tons) of fresh water, produced with 1½ tons of coal in 19 *hours' work.*

The fresh water produced, as it flowed from the machinery, *was bright-looking, clear, cold and agreeable, without any peculiar taste, and, in fact, equal in appearance and taste to the best river or spring water.*

It will be seen, therefore, that this machinery, when worked *for* 19 *hours*, produced 33 *per cent. more water than it was told to produce* in that time, and yielded 4,100 *gallons (or* 18·3 *tons) per* 1 *ton of coal;* it would have produced more had the machinery been less overworked, as similar machines at Aden and elsewhere have yielded over 20 tons or 4,500 gallons of water per ton of coal.

In the above trial, the productive power and consumption of coal were ascertained as follows:—The machinery having been fairly started, *the coals were removed from the furnaces* and the working was continued, under inspection, with *weighed coalls.* After 19 *hours'* working, *the unconsumed coals were removed from the furnaces and weighed,* and their weight was deducted from the quantity of weighed coals put into the furnances, the difference being taken as the weight consumed. The fresh water produced from the sea water was collected in an iron tank and carefully measured.

REPORTS *on the quality of the fresh Water produced by Normandy's Improved Patent Machinery for producing from sea-water pure, cold, and agreeable fresh water for drinking purposes.*

Alicante, 11th September 1879.

OPINION of DON JOSE SOLER Y. SANCHEZ, Licentiate in Pharmacy, Doctor in Sciences, late Professor of Chemistry to the Faculty of Sciences of University of Madrid, Professor of Chemistry and Physics to the Institute of Alicante, &c., &c.

I hereby certify that having analysed in my laboratory a sample of pure fresh water in order to see if the same was drinkable, and which sample was delivered to me by the Presidente Alcalde (Mayor) of the most illustrious Municipality of Alicante, the said sample being drawn according to his declaration from Mr. Normandy's Distilling Engine.

This sample of fresh water was received in the presence of the Notary, Mr Nereo Albert, in two glass bottles duly sealed and stamped with the letters J.C.B., the result being as follows:—

1st—Its hyrotimetrical degree is 5°.
2nd—A litre of water contains 0·085 grammes of mineral substance.
3rd—Does not contain any organic matter.
4th—Contains 17·64 cc. of air per litre of waters.
5th—Does not prevent soap from dissolving.
6th—Is clear, without colour, limpid, and transparent.

Therefore, by its character and condition, it is to be considered *a most eminently drinkable water.*

Dr. J. SOLER Y. SANCHEZ.

REPORT of Dr. NOAD, F.R.S., Professor of Chemistry at St.George's Hospital, London.

I find the water to be *absolutely free from organic matter,* which all river and well waters contain, more or less, and which is acknowledged to be a predisposing cause of disease. It is also bright, colourless, well aërated and agreeable, and it contains an exceedingly small percentage of saline matter, which is the case with all waters derived from the best natural sources.

From a sanitary point of view, I consider this water to be quite equal, and, in its absolute freedom from organic matter, superior to that obtained from the purest natural sources; it is therefore well suited for alimentary purposes.

REPORT of Dr. LETHEBY, M.B., M.A., Professor of Chemistry in the Medical College of the London Hospital, and Medical Officer of Health for the City of London.

The sample was colourless and well aërated and it was agreeable to the palate. It contained a very small proportion of saline matter, which I regard as an advantage, as it approximates the quality of the water to that derived from the best natural sources. For dietetical purposes, the proper aëration of the water is essential. *The water was absolutely free from organic matter,* and it is very soft.

I am of opinion, from these results, that the water is very wholesome and is well adapted for all domestic purposes.

LIST of Particulars of Normandy's Improved Patent Distilling Machinery for converting Sea water into pure, cold, Fresh-water, equal in appearance and taste to the best River or Spring Water, and fit for immediate use as it flows from the machinery, which will also force it to any distance and to a height of 40 yards (or metres) or more, if desired.

[See Reports and result of Government trial at Flushing, on other side.]

(Results guaranteed abroad if required.)

Quantity of Cold, Fresh-water produced from Sea-water in 24 hours. Under favorable circumstances the production will be about 30 per cent. more.		QUANTITY OF FRESH-WATER PRODUCED BY ONE TON (OR 1000 KILOS.) OF COAL. UNDER FAVORABLE CIRCUMSTANCES THE QUANTITY WILL BE ABOUT 10 PER CENT. MORE.					
		Single Distilling Arrangement.		Double Distilling Arrangement.		Treble Distilling Arrangement.	
Gallons.	Tons or Cub. Metres.	Gallons.	Tons or Cub. Metres.	Gallons.	Tons or Cub. Meters.	Gallons.	Tons or Cub. Meters.
These include as described Note A on next page.							
1,000	4·5	1,560	7·0	..	..	..	..
1,125	5·0	1,560	7·0	..	..	..	..
1,250	5·6	1,560	7·0	..	..	..	..
1,500	6·7	1,600	7·2	2,660	11·9	..	..
1,750	7·8	1,600	7·2	..	..	..	..
2,000	9·0	1,700	7·6	2,700	12·2	3,400	15·3
2,250	10·0	1,740	7·7	..	..	..	..
2,500	11·2	1,740	7·7	2,700	12·2	3,500	15·7
3,000	13·4	1,790	8·0	2,950	13·2	3,500	15·7
3,500	15·6	1,830	8·2	..	..	..	..
4,000	17·9	1,830	8·2	3,000	13·8	3,650	16·3
4,500	20·1	1,880	8·4	..	..	..	..
5,000	22·3	1,950	8·8	3,100	14·0	3,900	17·7
6,000	27·0	1,950	8·8	3,200	14·3	4,000	18·0
7,000	31·2	..	..	3,200	14·3	4,000	18·0
8,000	35·7	..	..	3,300	14·8	4,100	18·4
9,000	40·2	..	..	3,400	15·4	4,200	18·8
10,000	44·6	..	..	3,400	15·4	4,300	19·3
11,000	49·1	..	..	3,400	15·4	4,400	19·6
12,000	53·6	..	..	3,470	15·5	4,500	19·8
13,000	58·0	..	..	..	..	4,500	20·0
14,000	62·5	..	..	..	..	4,500	20·0
15,000	67·0	..	..	..	..	4,500	20·0
These include as described Note B on next page.							
100	0·5	1,000	4·5	1,680	7·5	..	..
150	0·7	1,000	4·5	1,680	7·5	..	..
225	1·0	1,000	4·5	1,680	7·5	..	..
300	1·4	1,230	5·5	1,680	7·5	..	..
400	1·8	1,230	5·5	1,900	8·5	..	..
500	2·2	1,230	5·5	2,120	9·5	..	..
625	2·8	1,230	5·5	..	..	..	..
750	3·3	1,230	5·5	2,120	9·5	..	..
875	4·0	1,230	5·5	..	..	..	..
1,000	4·5	1,230	5·5	2,120	9·5	2,800	12·5
1,125	5·0	1,340	6·0	..	..	..	..
1,250	5·6	1,340	6·0	2,240	10·0	2,800	12·5
1,500	6·7	1,340	6·0	2,350	10·5	2,910	13·0
1,750	7·8	1,450	6·5	..	..	..	..
2,000	9·0	1,450	6·5	2,350	10·5	3,020	13·5
2,250	10·0	1,450	6·5	..	..	..	..
2,500	11·2	1,450	6·5	2,350	10·5	3,130	14·0
3,000	13·4	1,560	7·0	2,350	10·5	3,130	14·0
3,500	15·6	1,560	7·0	..	..	..	..
4,000	17·9	..	..	2,460	11·0	3,130	14·0
5,000	22·3	..	..	2,680	12·0	3,250	14·5
6,000	27·0	..	..	2,680	12·0	3,360	15·0
7,000	31 2	..	..	..	..	3,360	15·0

See Condenser List, No. 2, for particulars of Normandy's Improved Patent Double Distilling Condensers (without boilers) for steamships, yachts, and torpedo boats, for working with greasy steam from main boilers supplying the engines, so as to produce good, cold, fresh-water for drinking, and also hot fresh-water, to keep up the full supply of fresh water in these boilers, to prevent scale accumulating therein.

See Condenser List, No. 3, for particulars of Single Distilling Condensers (without boilers) for producing from sea-water good, cold, fresh-water for drinking, when worked with clean steam from boilers fed with sea-water, but with less economy of fuel.

Estimate for complete sets of Normandy's Improved Patent Distilling Machinery for producing good, cold, drinking water from Sea-water, and for forcing the Fresh-water to a great height or distance, with letter, dated 21st February 1884, to General Hyde.

The drinking water as it flows from under-mentioned machinery is clear, cold, bright-looking and agreeable, without any peculiar taste, and equal in quality, taste and appearance, to the best river-water as usually supplied for drinking in towns. (See the reports on other side.)

Full instructions for putting together and working will be supplied with the machinery, and, if desired, special arrangements will be made for the machinery to be supplied and erected abroad, and also worked for an agreed time, the consumption of coal and the quantity and quality of the fresh-water produced being guaranteed.

Note A.—Under favorable circumstances, this machinery will produce from 20 *to* 30 *per cent. more water* per 24 hours than is stated below, and the quantity of fresh-water produced by 1 ton of coal will be increased *by* 10 *to* 15 *per cent.* (*See results of Flushing trial on other side.*) For long continued working, however, the best results will be obtained by working so as not to produce much more than the quantity specified below, as the production per 25 hours.

Each *complete set of machinery* includes one of Normandy's Improved Patent Condenser with filter, suitable steam boiler and steam pumps for supplying sea-water to the condenser and boiler, and for *forcing the fresh-water produced to a great height or distance.* Also *all connecting parts and pipes in between above, the whole being arranged to a suitable plan, ready for putting together on a level surface abroad.* It also includes iron chimneys for the boilers, complete with guy chains, 40 yards of suction pipe from sea to machinery, 20 yards of waste sea-water pipe, and 20 yards of fresh-water delivery pipe. Also a quantity of useful stores and tools, such as spare fire bars, stoking and cleaning tools, spanners for tightening up, oil cans, gauge glasses and sundry useful stores, so that the whole may be readily set to work and kept in order without delay or difficulty. The surface on which the machinery stands should not be more than 8 yards (or 7 metres) above the sea-level.

The condenser tubes are of solid brass, tinned inside and outside. The pumps are of strong and simple construction, and easily adjustable to compensate for wear. The water is drawn and forced by plungers moving through stuffing boxes, easily packed and kept tight by an *external* gland, thus avoiding the troublesome and difficultly repaired leaks, which so frequently stop other kinds of pumps. They *work at a moderate speed,* so as to avoid the excessive wear and knocking about of the valves and other parts, always resulting from quick speed. They have fly-wheels, and have all valves, bearings, plungers and working parts in contact with water, made of *brass or copper, wrought-iron crank shafts, and steel piston-rods.* The *boilers* have furance plates of *Low Moor or Bowling iron,* and have dampers, Bourdon's pressure gauges, safety valves, *and all necessary fittings.* They are proved to double the working pressure, and the working pressure is from $\frac{1}{6}$ to $\frac{1}{8}$ of the bursting pressure.

Note B.—If delivered in less than the maximum times stated below, then 4 per cent. extra on prices for every 10 per cent. less time.

Number of Estimate.	1	2	3	4	5	6	7	8
Number of complete and independent apparatus included in each estimate	2	1	1					
Type of the apparatus included in each estimate (single, double, or treble distilling)	Treble.	do.	do.					
Type of boilers included in each estimate	Lancashire.	do.	do.					
Fresh Water produced per 24 hours (See Note A above.)								
Gallons	12,000	9,000	12,000					
Tons, or cubic metres (1 *cubic metre equals* 1,000 *litres or kilogs*)	53·6	4·02	53·6					
Economy of Coal and Wood (See Note A above.)								
Wood or coals consumed for producing the quantities of water stated above as the production per 24 hours (weight in tons or 1,000 kilogrammes)	Coal 3 Wood 12	Coal 2·15 Wood 8·6	Coal 2·67 Wood 4·9					
Tons of water (or cubic metres) yielded per 1 ton or 1,000 kilogrammes) of coal	Coal 18 Wood 4·5	Coal 18·8 Wood 4·7	Coal 19·8 Wood 4·9					

(*Continued.*)

Number of Estimate.	1	2	3	4	5	6	7	8
Time required from receipt of order for delivering the machinery in London.								
Days for delivering all the independent apparatus included in above estimates	45 *to* 120	40 *to* 100	45 *to* 120	*to*	*to*	*to*	*to*	*to*
or else (See Note B above.)								
,, ,, first ,, ,, ,, ,,	*to*	*to*	*to*	*to*	*to*	*to*	*to*	*to*
,, ,, second ,, ,, ,, ,,	*to*	*to*	*to*	*to*	*to*	*to*	*to*	*to*
,, ,, third ,, ,, ,, ,,	*to*	*to*	*to*	*to*	*to*	*to*	*to*	*to*
,, ,, fourth ,, ,, ,, ,,	*to*	*to*	*to*	*to*	*to*	*to*	*to*	*to*
Prices, delivered packed and free on board in London.								
Prices for all the complete apparatus in each estimate as described above £	4,362	3,052	4,046					
Extras if required.								
Iron roofs, supported on iron columns to contain the above machinery £								
Tanks of galvanized iron to contain the quantities of fresh-water stated above as the production per 24 hours £								

REPORTS on Normandy's Improved Patent Machinery for producing from Sea-water, pure, cold, and agreeable Fresh-water for drinking purposes.

RESULT of the trial of Normandy's Improved Patent Distilling Machinery erected at Flushing for the Dutch Government, January and February 1877.

This machinery was supplied as suitable for producing 6,000 gallons, or 27 cubic metres, of good, cold, drinking water, per 24 hours, from sea-water.

By the direction of Mr. Van Diesen, Chief Engineer of the Waterstaat, in the province of Zealand, Holland, this machinery was carefully tested by being worked under the inspection of officials appointed for the purpose, the result being, that *in* 19 *hours' work* this machinery produced 28,500 litres of fresh-water, and consumed 1,545 kilogrammes of coal. This is equal to 6,270 gallons (or 28 tons) of fresh-water, produced with 1½ tons of coal in 19 *hours' work.*

The fresh-water produced, as it flowed from the machinery, *was bright-looking, clear, cold and agreeable, without any peculiar taste, and, in fact, equal in appearance and taste to the best river or spring water.*

It will be seen, therefore, that this machinery, when worked *for* 19 *hours,* produced 33 *per cent. more water than it was sold to produce* in that time, and yielded 4,100 *gallons* (*or* 18·3 *tons*) *per* 1 *ton of coal* (equal to 18·3 cubic metres per 1,000 kilogrammes of coal); the economy of coal would have been still greater had the machinery been less overworked, as similar machinery at *Aden and Alicante* has yielded over 20 *tons* of water per 1 ton of coal (or 20 cubic metres per 1,000 kilogrammes of coal).

In the above trial, the productive power and consumption of coal were ascertained as follows:—The machinery having been fairly started, *the coals were removed from the furnaces,* and the working was continued, under inspection, with *weighed coals.* After 19 *hours'* working, *the unconsumed coals were removed from the furnaces and weighed,* and their weight was deducted from the quantity of weighed coals put into the furnaces, the difference being taken as the weight consumed. The fresh-water produced from the sea-water was collected in an iron tank and carefully measured. The results were as above stated.

OPINION of DON JOSE SOLER Y SANCHEZ, Licentiate in Pharmacy, Doctor in Sciences, late Professor of Chemistry to the Faculty of Sciences of University of Madrid, Professor of Chemistry and Physics to the Institute of Alicante &c., &c.

Alicante, 11th September 1879.

I hereby certify that, having analysed in my laboratory a sample of pure fresh-water in order to see if the same was drinkable, and which sample was delivered to me by the Presidente Alcalde (Mayor) of the most illustrious Municipality of Alicante, the said sample being drawn, according to his declaration, from Mr. Normandy's Distilling Engine.

This sample of fresh-water was received in the presence of the Notary, Mr. Nereo Albert, in two glass bottles duly sealed and stamped with the letters J.C.B., the result being as follows:—

1st.—Its hyrotimetrical degree is 5°.
2nd.—A litre of water contains 0·085 grammes of mineral substance.
3rd.—Does not contain any organic matter.

4th.—Contains 17·64 cc. of air per litre of water.
5th.—Does not prevent soap from dissolving.
6th.—Is clear, without colour, limpid, and transparent.

Therefore, by its character and condition, it is to be considered *a most eminently drinkable water*.

And in order that the interested party make use of this certificate as he may think fit, at his own request I grant the present document attaching my signature thereto.

REPORT of DR. NOAD, Ph.D., F.R.S., Professor of Chemistry at St. George's Hospital, London.

I find the water to be *absolutely free from organic matter*, which all river and well waters contain more or less, and which is acknowledged to be a predisposing cause of disease. It is also bright, colourless, well aerated and agreeable, and it contains an exceedingly small percentage of saline matter, which is the case with all waters derived from the best natural sources.

From a sanitary point of view, I consider this water to be quite equal, and, in its absolute freedom from organic matter, superior to that obtained from the purest natural sources; it is therefore well suited for alimentary purposes.

REPORT of DR. LETHEBY, M.B., M.A., Professor of Chemistry in the Medical College of the London Hospital, and Medical Officer of Health for the City of London.

The sample was colourless and well aerated, and it was agreeable to the palate. It contained a very small proportion of saline matter, which I regard an advantage, as it approximates the quality of the water to that derived from the best natural sources. For dietetical purposes, the proper aeration of the water is essential. *The water was absolutely free from organic matter*, and it is very soft.

I am of opinion, from these results, that the water is very wholesome and is well adapted for all domestic purposes.

Krasnovodsk, 1st October 1880.

I, the undersigned, Doctor of Medicine, Doctor-in-chief of theTrans-Caspian Expedition, certify that the water of the Caspian Sea rendered potable by NORMANDY'S DISTILLING APPARATUS has been submitted to me, by being taken as it flowed from the apparatus, and that after an examination of fifteen days I found it to have the following qualities:—

The water was *perfectly pure, free from all organic matters, contained a sufficient quantity of air*, was without any taste of machinery, or of any other unpleasant flavor. I personally used it and found it suited me well. I consider it *perfectly suitable for alimentation and for all domestic purposes*.

In consideration of which I have delivered the present certificate.

DR. OSCAR HEYFELDER,
Councillor of State.

All sizes supplied, producing from 100 to 15,000 gallons of water per 24 hours, and yielding up to 20 tons, or 4,480 gallons of water per 1 ton of coal consumed.

Notes and Remarks.

The price of the treble distilling arrangement exceeds that of the double, and that of the double exceeds that of the single distilling arrangement, but this *extra first cost is soon repaid by the great saving of coal.*

Applications for prices and further particulars should state size, kind of arrangement preferred, and whether required to convert sea-water into cold fresh-water for drinking, for a land station, or on board ship, or whether to produce hot or cold fresh-water for feeding locomotive boilers, or other manufacturing purposes, such as for saltpetre refining, dying works, brightening colours for calico printing, &c.

This machinery will force the fresh-water produced to *any distance* and to a height of 40 yard (or metres) or more if desired, and it may be placed at any convenient distance from the sea; but the surface on which it stands should not be more than 8 yards (or 7·2 metres) above the sea-level, which would necessitate special arrangements according to circumstances.

The attendance of *one man* will suffice to work one or more sets of this machinery, provided that the total quantity of fresh-water produced per 24 hours does not exceed 8,000 gallons if-single distilling, 15,000 gallons if double distilling, or 20,000 gallons if treble distilling.

Full instructions for putting together and working will be supplied with the machinery, and, if desired, special arrangements may be made for the machinery to be supplied and erected abroad, *and also worked for an agreed time, the consumption of coal, and the quantity and quality of the fresh-water produced being guaranteed.*

Note A.—Each of these *complete sets of machinery* includes one of Normandy's Improved Patent Condensers with filter, suitable Cornish or Lancashire (double flue Cornish) steam boiler and steam pumps for supplying sea-water to the condenser and boiler, and for *forcing the fresh-water produced to any distance, and to a height of* 40 *yards* (*or metres*) *or more if desired.* Also *all connecting parts and pipes in between above, the whole being arranged to a suitable plan, ready for putting together on a level surface abroad.* It also includes iron chimneys for the boilers, complete with guy chains, 40 yards of suction pipe from sea to machinery, 20 yards of waste sea-water pipe, and 40 yards of fresh-water delivery pipe. Also a quantity of useful stores and tools, such as spare fire bars, stoking and cleaning tools, spanners for tightening up, oil cans, gauge glasses and sundry useful stores, so that the whole may be readily set to work, and kept in order without delay or difficulty. The surface on which the machinery stands should not be more than 8 yards (or 7·2 metres) above the sea-level.

The condenser tubes are of solid brass, tinned inside and outside. The pumps are of strong and simple construction, and easily adjustable to compensate for wear. The water is drawn and forced by plungers moving through stuffing boxes, easily packed and kept tight by an *external* gland, thus avoiding the troublesome and difficultly repaired leaks, which so frequently stop other kinds of pumps. They *work at a moderate speed*, so as to avoid the excessive wear and knocking about of the valves and other parts, always resulting from quick speed. They have fly-wheels, and have all valves, bearings, plungers and working parts in contact with water, made of *brass or copper, wrought-iron crank shafts, and steel piston-rods.* The *boilers* have furnace plates of *Low Moor or Bowling iron*, and have dampers, Bourdon's pressure gauges, safety valves, fusible safety plugs in crowns of furnaces, *and all necessary fittings.* They are proved to double the working pressure, and the working pressure is from $\frac{1}{6}$ to $\frac{1}{8}$ of the bursting pressure.

Note B.—Each of these complete sets of machinery includes the same as described under Note A, but the boilers included take up less room, and do not require setting in brickwork, being of the vertical, or return flue, type, and of simple construction so as to avoid difficulty in cleaning and working; they are, however, not so economical of coal, and boilers as described in Note A are generally preferable, especially for the larger sizes, as they are the most economical of coal, and easiest to clean, and keep in good working order, and are easily fixed in brickwork, concrete, cement, stone, &c.

Note C.—Tanks for containing the fresh-water produced are supplied as extras. They are best made of galvanized iron, fitted with drawing-off cocks complete. It is convenient to have tanks large enough to contain at least the production per 24 hours, as per list on opposite page. For convenience of shipping, large sizes are made of flat or curved pieces, easily bolted together abroad.

Extra length of sea-water suction pipe, waste sea-water pipe, and fresh-water delivery pipe, including bends and joints to suit various positions, are supplied at per yard as required.

Iron roofs supported on iron columns for containing this machinery for land stations are also supplied as extras if required.

Some of the Land Stations supplied with various kinds of Normandy's Patent Distilling Machinery.

Aden, Red Sea.	Gibraltar.	Ismalia (Egyptian War).
Flushing, Holland.	Alicante.	Island of Ascension.
Abyssinian Expedition.	Peru.	Krasnovodsk, Caspian Sea.
Malta	Chili.	Galapagos Islands.
Cape Coast Castle.	Australia.	China Hospital Ships.
West Coast of South America.	Brighton.	Heligoland.
Iquique.	Packam and Co., Croydon.	Fort Moultrie.
St. Vincent, Cape Verds.	Red Sea Light-houses.	Pure Water Co., London.

Some of the above produce 20 tons or 4,500 gallons of good, cold, drinking water from sea-water per 1 ton of coal.

Some of the Ships supplied with Normandy's Patent Distilling Machinery.

British Government.

H.M.S. Nelson	H.M.S. Rifleman	H.M.S. Forester
,, Victor Emanuel	,, Frolic	,, Northampton
,, Flying Fish	,, Dee	,, Foxhound
,, Iron Duke	,, Goshawk	,, Foreward
,, Lord Warden	,, Swinger	,, Emerald
,, Lord Clyde	,, Ready	,, Medina
,, Czarewitch	,, Serapis	,, Medway
,, Crocodile	,, Jumna	,, Sabrina
,, Euphrates	,, Undine	,, Spey

British Government—(*Continued*).

H.M.S. Audacious	H.M.S. Amphion	H.M.S. Tay
„ Vanguard	„ Caroline	„ Tees
„ Swiftsure	„ Imperiuse	„ Osprey
„ Encounter	„ Malabar	„ Condor
„ Invincible	„ Hydra	„ Flamingo
„ Magicienne	„ Briton	„ Temeraire
„ Assistance	„ Rupert	„ Turquoise
„ Curaçoa	„ Sultan	„ Ruby
„ Cleopatra	„ Volage	„ Pelican
„ Conquest	„ Active	„ Penguin
„ Inflexible	„ Hecate	„ Wild Swan
„ Diamond	„ Hotspur	„ Dolphin
„ Moorhen	„ Musquito	„ Wanderer
„ Sheldrake	„ Don	„ Sphinx
„ Superb	„ Esk	„ Calliope
„ Comus	„ Champion	„ Doterel
„ Belle Isle	„ Heroine	„ Mallard
„ Triton	„ Hyacinth	„ Shannon
„ Himalaya	„ Lark	„ Euryalus
„ Sapphire	„ Thetis	„ Garnet
„ Pioneer	„ Barrosa	„ Orion
„ Rover	„ Odin	„ Colossus
„ Fury	„ Gorgon	„ Conqueror
„ Lily	„ Druid	„ Sea Horse
„ Arab	„ Merlin	„ Cordelia
„ Investigator	„ Thalia	„ Canada
„ Hecla	„ Glatton	„ Rambler
„ Hymalaya	„ Triumph	„ Ranger
„ Express	„ Magdala	„ Niger
„ Contest	„ Foam	„ Algerine
„ Cygnet	„ Coquette	„ Kingfisher
„ Daring	„ Cyclops	„ Constance
„ Sappho	„ Decoy	„ Grappler
„ Pegasus	„ Tourmaline	„ Banterer
„ Dragon	„ Slaney	„ Wrangler
„ Albatross	„ Trent	„ Wasp
„ Modeste	„ Harrier	„ Espoir
„ Amethyst	„ Raleigh	„ Redwing
„ Shah	„ Ready	„ Bullfrog
„ Fantome	„ Pylades	„ Cockchafer
„ Egeria	„ Tweed	„ Swift
„ Dromedary	„ Iris	„ Linnet
„ Boadicea	„ Griffin	„ Flying Fish
„ Bacchante	„ Falcon	„ Agamemnon
„ Raleigh	„ Firebrand	„ Phœnix
„ Cormorant	„ Firefly	„ Miranda
„ Gannet	„ Carrysfoot	„ Satellite
„ Leander	„ Neptune	„ Wyvern
„ Arethusa	„ Starling	„ Edinburgh
„ Phæton	„ Stork	„ Majestic
„ Ariel	„ Raven	„ Rodney
„ Zephyr	„ Humber	„ Warspite
„ Kestrel	„ Firm	„ Collingwood

German Government.

H.M.S. König Wilhelm	H.M.S. Medusa	H.M.S. Deutschland
„ Krön Prinz	„ Vinetta	„ Leipzig
„ Kaiser	„ Albatros	„ Sedan
„ Ariaden	„ Nymphe	

Chilian, Danish, Brazilian, Portuguese, Argentine, Turkish, Spanish and Japan Governments.

H.M.S. Foo-so	H.M.S. Almirante Cochrane	H.M.S. Florencia
„ Kongo	„ Almirante Brown	„ Ingolf
„ Hiyei	„ Riachuelo	„ Miramar
„ Feyen	„ Mindelho	„ Lotus
„ Independencia	„ Moyini Zaffar	„ Gravina
„ Rainha de Portugal	„ Nictherhoy	„ Velasco

Royal Mail Steam Packet Company.

S.S. Moselle	S.S. Shannon	S.S. La Plata
„ Atrato	„ Esk	„ Tasmanian
„ Neva	„ Rhone	„ Oneida
„ Tagus	„ Seine	„ Elbe
„ Nile	„ Douro	
„ Boyne	„ Eden	

Allan Line of Royal Mail Steamers.

S.S. St. Andrew	S.S. Polynesian	S.S. Scandinavian
„ St. George	„ Pomeranian	„ Sweden
„ St. David	„ Norway	„ Sardinian
„ Germany	„ Nestorian	„ Nova Scotian
„ Peruvian	„ Circassian	„ Assyrian
„ Moravian	„ Prussian	„ Austrian

Messrs. R. and H. Green.

S.S. Sultan	Roxburg Castle	Agamemnon
„ Viceroy	Carlisle Castle	Windsor Castle
„ Shannon	New Castle	Renown
„ Melbourne	Clarence	Nile
Malabar	Alnwick Castle	

Belonging to various Governments and Shipowners.

S.S. Torrington	S.S. Samarang	Wellesley
„ Hampton	„ Zuid Holland	Kent
„ Harrington	„ Aurania	Ellenborough
„ Wyberton		Harkaway
„ Durham		Atalanta
„ Macassar	Indus	Aliquis
„ Bothnia	Beaumaris Castle	Canning
„ Synthia	Light Brigade	Samarang
„ Kingston	Eastern Empire	Norman Morrison
„ Spartan	Southern Ocean	Gresham
„ Madeira	City of Melbourne	Howrah
„ Nachimof	Marchesa	Mermaid
„ Serendib	Southern Cross	Maori
„ Dacia	Flying Cloud	Peeress
„ Russia	Hugoumont	Lincoln
„ Pavonia	Young Australia.	Zenobia
„ Padang	Lightning	Canterbury
„ Royal Dane	Prince of Wales	Gosforth
„ Gelderland	Blue Jacket	Avon
„ Nepaul	Sir Robert Sale	Clive
„ Kate Fawcet	Lansborough	Siam
„ Servia	Montmorency	Zelandia
„ Lena	Himalaya	Wansfell
„ Kent	Burlington	Philosopher
„ Friesland	Caroline Coventry	Thames
„ Dreuthe	Java	Poonah
„ Royal Welsh	Maryborough	Clara
„ Black Watch	Matilda Atheling	Arcot
„ Cephalonia	Clairellen	Dunbar Castle
„ Overyssel	Wambojeeg	Theresa

All sizes supplied and guaranteed to produce from sea-water from 100 to 15,000 gallons of best, cold, drinking water per 24 hours, and yielding up to 20 tons, or 4,500 gallons, of water per 1 ton of coal consumed, with the larger sizes.

See Condenser List No. 2 for particulars of Normandy's Improved Patent Double Distilling Condensers for steamships, yachts, and torpedo boats, for working with greasy steam from main boilers supplying the engines so as to produce good, cold, drinking water, and also hot fresh-water for keeping up the full supply of fresh-water in these boilers and prevent scale accumulating therein.

See Condenser List No. 3 for particulars of Single Distilling Condensers for producing good, cold, drinking water from sea-water; when worked with clean steam from boilers fed only with sea-water, these condensers are less economical of coal.

From A. NORMANDY, Esq., for Normandy's Patent Marine Aerated Fresh Water Company (limited), to General HYDE, India Office, Westminster, S. W., dated Custom House Station, Victoria Dock, London, 21st February 1884.

With reference to Colonel J. Mullins' letter to you, dated Bangalore, 17th January 1884, which you were good enough to show me, respecting the water-supply at Bangalore, I beg to observe as follows :—

Filtration will not make very foul water reasonably wholesome, and though filters may at first somewhat improve the quality of such impure water, they very soon lose this power and get out of order.

Such impure water as Colonel Mullins describes may, however, be converted into good and agreeable drinking water by distillation with apparatus such as we have supplied for Aden and other places, and which are very economical of fuel.

Ordinary distillation converts salt water into fresh water, but such fresh water is heavy and unwholesome, as well as unpleasant to drink, owing to want of proper aeration, and to its being tainted by an extremely small quantity of a very offensive oil.

If 25 gallons of ordinary distilled water be very slowly evaporated at considerably below the boiling point, at the end of several weeks the little platinum dish last used will be found covered with a film of a most offensive oil, and, if this film of oil is redissolved in 25 gallons of good drinking water, it will give it the unpleasant taste noticeable in the distilled water from which it was extracted as above.

The above film of oil results from as follows :—

The impure water to be distilled is evaporated in boilers, and the organic matter in such water coming in contact with the heated surfaces of the boiler is decomposed, thus creating a minute quantity of volatile oil, which mixes with the steam and is condensed therewith.

In our apparatus the distilled water, after being properly aerated, is passed through a large mass of prepared animal charcoal, which, without being acted upon itself, has the property of inducing some of oxygen dissolved in the water to oxydize the above-named offensive oil, so as to in effect burn it, the product of such oxydation being a minute quantity of water and carbonic acid gas, and the consequence is that the distilled water ultimately produced is purified from the above oil and rendered *quite tasteless* and agreeable to drink as well as wholesome.

The reason why distilled water on boardship is often not palatable is that the condensers are worked with *greasy* steam, which is good for driving the engines, but unsuitable for condensing into drinking water ; but it is sometimes collected separately for washing with our improved steamers ; such steam is sometimes so greasy that I have known pipes in our condensers more or less obstructed with a black fatty substance, and the filter rendered impervious to water from the same cause. Sometimes this greasy steam yields an oil more or less volatile, and catches fire in the filter if a light is introduced.

With reference to the existing boilers, they are not large enough for distilling, and, even if they were, they would not be suitable for obtaining good results as to quality of water and economy of fuel.

We should recommend working the proposed distilling machinery night and day, as they do at Aden, partly because it economises fuel, but principally because it saves 50 per cent. of the price of the distilling machinery, as less powerful machinery is then sufficient.

There would be no difficulty in arranging for our boilers to burn wood instead of coal.

We therefore beg to submit the following estimates for consideration :—

No. 1 *Estimate.*—Two complete sets of Normandy's improved patent treble distilling machinery as supplied for Aden, producing together 12,000 gallons of good, cold, drinking water per 24 hours, with a consumption of 3 tons of coal, or 12 tons of wood (assuming 4 of wood equal 1 of coal as in Colonel Mullins' letter) ; price packed and delivered in London, £4,362.

No. 2 *Estimate.*—One complete set as above to produce 9,000 gallons per 24 hours, with 2·15 tons of coal or 8·6 tons of wood ; price packed and delivered in London, £3,052.

No. 3 *Estimate.*—One complete set as above to produce 12,000 gallons per 24 hours, with 2·67 tons of coal or 10·7 tons of wood ; price packed and delivered in London, £4,046.

In above estimates each complete set of apparatus includes distilling condenser and filter, steam boiler with iron chimneys, steam pumps for circulating water, and for forcing the distilled water produce wherever desired, and all connecting parts in between so that the whole may be readily erected abroad, also suction and delivery pipes and spare stores, all as described at length in annexed printed estimate from dated this day.

P.S.—In case some other size or kind of our apparatus should be preferred, we send herewith our No. 1 condenser list, giving particulars of all the sizes and kinds we make.

You will observe we only estimate for *treble* distilling arrangements, as the saving in fuel they effect soon repays their extra first cost as compared with the single and double distilling arrangements also described in our No. 1 condenser list herewith.

From A. NORMANDY, Esq., for Normandy's Patent Marine Aërated Fresh Water Company (Limited), to General HYDE, India Office, Westminster, S.W., dated Custom House Station, Victoria Dock, London, 1st March 1884.

In reply to your letter of the 29th ultimo, as the prepared animal charcoal is not acted upon itself, but acts as explained in paragraph 7 of our letter of the 21st ultimo, it does not require renewing for very many years.

2. What does occur is as follows :—When the machinery is first started, more or less rusty water is produced for a few minutes ; this should be run off so as not to pass into the filter. A little rust, however, always finds its way in, and in the course of about a year may accumulate in the upper half-inch thick layer of charcoal ; this should then be scraped off and thrown away, and the rest of the charcoal should be removed from the filter to lighten it (it is apt to become dense by the constant flow of water through it) ; it is then simply replaced in the filter.

From the Commissary-General, to the Inspector-General of Railway Stores, India Office, Westminster, S.W., dated Bombay, 28th August 1883, No. E. 25-5554.

With reference to your letter of 3rd instant, I have the honor to inform you that the two new condensers were tried at Aden in June last with the following results :—

The 6,000 gallons condenser was worked for 24 hours, and the water produced during that period was 7,082 gallons with the expenditure of 1½ tons of coal, which gives an outturn of 21 lb. of water to every pound of coal consumed.

The 9,000 gallons condenser was worked for 24 hours, and the water produced during that period was 12,110 gallons with the expenditure of 2 tons 11 cwts. of coal, which also gives 21 lb. 3 oz. of water to every pound of coal consumed.

2. I beg to append a copy of the statement showing the results of the working of these new condensers contrasted with those hitherto in use and those of private companies, from which it will be observed that the result is very satisfactory.

CONTRASTED STATEMENT of Water produced by the new and present condensers belonging to Government and those of Private Companies at Aden.

Particulars.	New Condensers.	Present Condensers on Flat Hyderabad.	Messrs Luke, Thomas, and Co.'s Condensers.	Aden Water Company's Condensers.	Remarks.
Average outturn of water per 1 lb. of coal consumed ... ... lb.	16	9	8	12	The outturn of water produced by the new condensers on the first trial was found to be 21 lb. of water per lb. of coal consumed, but this cannot be taken as an average of their outturn in future when worked continually; so the average outturn is taken at 16 lb. of water per lb. of coal consumed.
Taking the daily consumption of coal for each condenser at 2 tons 18 cwts. or 6,496 lb., will produce ... ... lb.	103,936	58,464	51,968	77,952	
At 10 lb. per gallon ... ... lb.	10,393	5,846	5,196	7,795	
Difference in production of new and old condensers	...	4,547	5,197	2,598	
Profit to Government in using new condensers per day ... ... gallons.	...	4,547	5,197	2,598	
Profit to Government in using new condensers per month, taking 26 working days ... gallons.	...	118,222	135,122	67,548	
Cost at Rs. 1-12-0 per 100 gallons.	...	2,068-14-2	2,364-10-2	1,182-1-5	

N.B.—Thus it will be seen that the profit to Government per month in using the new condensers as compared with the present condensers on Flat Hyderabad is Rs. 2,068-14-2 as compared with Messrs. Luke, Thomas, and Company's condensers, Rs. 2,364-10-2, and with the Aden Water Company, Rs. 1,182-1-5.

COMMISSARIAT OFFICE, ADEN,
31st July 1883.

Lieut.-Col.,
Acting Commissary-General.

APPENDIX X.

PROJECT (GENERAL).

Statement of the Sanctioned Establishment of the Halsur Water-works.

Those marked * require accommodation on the premises.

Name.	Office.	Race.
1. Mr. J. Smith *	Engineer in charge ...	European.
2. Mr. J. Ottman *	Assistant do. ...	Eurasian.
3. Mr. M. Shinnock *	Stoker	European.
4. A. Sivaurajoo Moodelliar ...	Writer	Native.
5. Gooroo Chetty	Messenger	Do.
6. Doorgoo *	Engine-driver	Do.
7. Abdul Aziz *	Watchman	Do.
8. Muhammad Khan... ...	Do.	Do.
9. Ibram Saib	Do.	Do.
1. Coopoosawmy	Peon	Native.
2. Venkatram	Sweeper	Do.
3. Jones	Do.	Do.
4. Yellapah	Do.	Do.
5. Nagapah	Do.	Do.

APPENDIX Y.

Abstract of Cost of different items of the several schemes proposed.

Items.	Description.	Project A.	Project B.	Project C.	BB.	CC.	DD.	Remarks.
		Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	
1	New engines, pumps, &c.	30,900	15,600	7,800	...	...	7,800	ABC, cost of projects as estimated.
2	New boilers	...	...	4,360	...	...	4,360	
3	New condensers	...	...	...	80,180	...	...	BB, cost of schemes for condensing water, supposing the present system to remain as at present and only the details necessary for condensing added.
4	New stand-pipe	6,390	...	...	...	...	...	
5	New mains and stand-cocks	1,18,240	15,440	1,073	15,440	...	1,073	
6	Connections at pumping stations ...	1,900	...	...	...	...	...	
7	Do. between wells and rock ...	...	...	...	...	...	7,170	
8	New filters	19,410	...	16,550	...	...	16,300	
9	New pure-water cistern	7,350	...	4,630	...	...	4,630	CC, cost of scheme, supposing the present system unaltered and only arrangements carried out for diverting the town drainage and supplying the Halsur tank from the new catchment.
10	Repairs to present filter	...	...	1,570	...	...	1,570	
11	Alterations to pure-water basin ...	...	...	...	...	...	...	
12	Improvements to Agaram tank ...	17,010	...	9,210	...	9,210	9,210	
13	Do. to Halsur tank	...	...	...	8,000	...	...	
14	Settling beds	16,290	...	2,170	...	...	2,170	DD, scheme for improving the present system and increasing the supply in the tank without diverting town drainage.
15	Engine-house	9,260	...	...	...	...	...	
16	Alterations to present engine-house ...	...	...	18,910	...	...	18,910	
17	Accommodation for establishment ...	14,740	...	5,580	...	...	5,580	
18	Iron roofs for cisterns	18,910	...	24,520	...	24,590	24,465	
19	Additional wells	...	...	20,815	...	20,450	...	
20	Diversion of town drainage	...	...	...	9,880	...	...	
21	New feeder and masonry works	...	...	5,315	...	5,315	5,315	
22	Water-carts	...	...					
23	Tower and cisterns	...	2,000					
24	Compensation	15,082	9,880					
	Total ...	2,75,482	1,61,996	1,29,673	1,13,500	59,565	1,08,553	
	Unforeseen Contingencies ...	14,518	6,010	3,327	2,500	435	1,447	
	Grand Total ...	2,90,000	1,67,000	1,33,000	1,16,000	60,000	1,10,000	
	Annual Maintenance Charges ...	44,385	84,600	27,000	...	...	...	

APPENDIX Z.

Water pronounced bad not necessarily injurious.

The following analysis of certain water pronounced bad by the Chemical Examiner, Madras, after analysis, was referred to the Sanitary Commissioner for opinion as to whether the water was necessarily injurious to health:—

		Water from proposed reformatory site.
Total solids	Grms. per litre.	0·25
Volatile solids	Do.	0·15
Chlorine	Do.	0·014
Total hardness	Clark's scale.	3°·15
Permanent hardness	Do.	2°·1
Free ammonia	Ml. grms. per litre.	0·18
Albumenoid ammonia	Do. do.	0·80
Nitric acid	Do. as ammonia.	0·60
Apparent quality of the water as inferred from the results obtained on examination		Bad.

Remarks.—Scanty deposit composed of vegetable debris.

Subjoined is the Sanitary Commissioner's reply:—

From Deputy Surgeon-General M. C. FURNELL, M.D., F.R.C.S., Sanitary Commissioner for Madras, to the Chief Secretary to Government, dated 31st January 1884, No. 96.

I have the honor, with reference to the query contained in memorandum, No. 179, of the 25th January 1884, Judicial Department, to answer succinctly no; I do not think the water is necessarily injurious to health.

It is necessary, however, that I give reasons for my answer. I examined the locality with Mr. Symonds as reported in letter No. 1501, and it seemed to me the place was in every respect a most eligible site for a reformatory.

The water is reported by Mr. Symonds to be the same as is drunk by the Chief Justice (I have ascertained this to be a fact.—M.C.F.), Mr. Justice Kernan, and others living in the Adyar, and was drunk by Mr. Symond's family for some time. As no sickness or deterioration of health has occurred amongst these persons, it follows, I think, the water is not "necessarily injurious to health."

No chemist can authoritatively pronounce that a water is unwholesome; all he can do is, having fixed upon a standard of purity, to say that waters submitted to him for analysis depart in certain respects from that ideal standard.

We constantly see in India communities using water, and with impunity for years, so dirty that the marvel is any human being can drink it. No evil seems to result, until presently that something is added which causes an epidemic of cholera. But the chemist cannot tell us by analysis the difference between the water before and after the outbreak.

The subject has lately been thrashed out in a most interesting paper, and debate thereon reported in the minutes of proceedings of the Institution of Civil Engineers, Volume LXVIII (June 1882), in which the leading Analytical Chemists and Physicists took part. In this paper and debate we find these most startling assertions, *e.g.*:

"Mr. Ekin (Analytical Chemist) quite agreed with the author and Dr. Thudichum as to the little value to be attached to the determination of organic matter in water, because he had over and over again examined water that had undoubtedly given rise to typhoid fever and found that it contained a very small amount of organic matter, and he had gone into districts where there could be no sort of contamination and examined the springs, rivers, and brooks in which he had frequently found a large amount of organic matter that by no test could be distinguished from the organic matter in sewage."

Mr. Folkard (Analytical Chemist):

"The existence of an infectious property in water cannot be proved by chemical analysis. The various processes of water analysis had one and all been shown on chemical grounds to be worthless, and he had endeavoured to prove that they were worthless (as far as the power of indicating wholesomeness was concerned) by reasoning which required no technical knowledge to follow it. Eminent water analysts had brought forth apparently conclusive evidence of the worthlessness of all processes of water analysis except their own, and he was convinced that each one of those chemists was right."

Professor Tyndall "agreed with Dr. Thudichum that chemical analysis would afford but little information as to the deadliest things that might be in water." Many other eminent men expressed much the same opinion.

The outcome of it all is that, if water has been drunk with impunity by people without any injury to health, it would be folly to condemn it because chemists demonstrate it contains so many hundredths or thousandths of a grain of organic matter per litre. On the other hand, if two waters were for choice, one would naturally take the one chemists pronounced most pure.

In this analysis of the water of the proposed reformatory site, it must be owned that the amount of organic matter is very high. I visited the place again this morning (January 30th) to see if anything in the surroundings could account for this, and I found in the well itself a quantity of organic matter sufficient to condemn any water. There were pieces of broken sugar-cane and plantation stalk, old straw, some leaves, &c., floating and decaying on the top. The house is not inhabited, and the well is evidently uncared for. If it were cleaned out and allowed to fill again, it would most probably yield a better water.

General Specifications to accompany the Projects for Water-supply for the Troops at Bangalore.

The various descriptions of work that will have to be undertaken are detailed below. They must be carried in accordance with the standard specifications of the Madras Department of Public Works except where the Executive Engineer in charge of the work considers deviations necessary or advisable, and in such cases the alterations in the standard specifications must be stated in writing.

The sections and paragraphs of the standard specifications referring to the different descriptions of work are noted opposite the work to which they refer :—

Description of Work.	Reference to Standard Specification.
Carriage	III 1—4.
Earth-work	V 1—34.
Limes, mortars, cements	VIII
Concrete	IX 1—12.
Pisé-work	X 2.
Brick-work	XII i, 1—30—ii, 1—3—iii, 1—2.
Stone masonry	XIII i, 1—13—vi, 1—5—ix, 1—3—xi, 1.
Plaster-work	XIV i, 1—12—ii, 1—3.
Foundations	XV 1—13.
Well-sinking	XVI i, 1—8, 11—16.
Roofing	XVII i, 1—3—ii, 1—4—iii, 1—2—iv, 1—3—ix, 1—5.
Flooring	XVIII i, 2 and 3—XIII, ix, 2.
Metal-work	XIX.
Painters' work	XX.
Drainage of buildings	XXIII.
Wood-work	XXIV.
Lightning conductors	Appendix A.

The various details of the projects are to be carried out in the following manner :—

PROJECT A.

The general arrangements of the different works are shown on sheets No.

The earth for the embankments for the settling beds, raising the existing bund, and forming the protective bunds is to be taken from the tank-bed, care being taken that no excavations are made within 8 yards of the portion of the cutting line of the toe of any embankment in its completed section, except where foundations have to be cut for sluices. The raising of the existing weir must not be commenced until the new weir and new embankments are completed.

The Engine-house and Chimney are to be constructed of well-burnt brick-in-chunam, pointed outside and plastered inside. Flooring to be stone-flagging on concrete, the roof an ordinary tiled roof carried on teakwood queen-posts, and trusses fitted in the usual manner.

The chimney must be placed so that its foundations have a clear interval of 1 yard between their outer edge and those of the main building, and the connecting flue must not be bonded into the chimney shaft. The lightning conductor for the chimney is to be attached to it by wooden bricks built in at about 6 feet intervals, and the "earth" is to be formed by a sound attachment with the cast-iron main to the barracks. The connection to be made by laying the conductor along the main for a length of 4 feet, binding them together with iron wire and forming a metallic connection with molten zinc. The whole connection to be then tarred and covered with tarred rope to prevent galvanic action.

All necessary details are given on plan No. 11.

Boilers.—If horizontal boilers are used, the walls on which they rest must be only 3″ to 5″ thick, so as to leave as little space as possible for water lodging and corroding the iron. For the same reason there must be no central support. The brick-work in the interior of the flues and next the boiler must be set in fire-clay as lime rapidly corrodes the iron. An inclination of ½″ in 10″ of length must be given towards the blow-off cock, so that the boiler can be thoroughly drained.

Proper doors must be left for cleaning the flues, and the upper part of the boilers must be covered with sand to prevent loss of heat by radiation. The flue area should be about 4¾ square feet for a 25-horse power boiler, and the fire-grate to allow of wood fuel being used should be 32 square feet. Thickness of fire-bars ½″ distance apart ½″, and the height of the dead-plate above the floor of the stoke-hole should be 2′ 8″.

The boilers must be delivered complete with the following mountings:—Furnace front, door, fire-bars, bearers, dead-plate, damper, damper frame and weight, fusible plug, one safety valve with lever and weight, one pressure gauge, one set of water-gauge mountings, two gun-metal try cocks, one blow-off cock, one feed check valve, and one steam stop valve. Before delivery they should be guaranteed to have been submitted to a test pressure of 120 lb. to the square inch.

If vertical boilers are used, they will merely be set up on a bed of concrete 1 foot thick covered with stone slabs 6″ thick. They should be of the new patent multitubular type, and be guaranteed before delivery to have been tested to 120 lb. pressure per square inch.

Engines and Pumps.—The engines to be compound condensing horizontal direct acting steam engines of 25-horse-power or 16-horse power as may be decided on, fitted with automatic expansion gear and supplied with condenser, feed pump, and foundation bolts and plates complete. They are to be set in a bed of brick-in-chunam floored with flag stones dressed and 6″ thick.

The pumps are to be treble-barrelled iron pumps with cast-iron air vessel and plungers.

The Filters.—The walls to be of brick-in-chunam carefully built of close joints and plastered inside with surki mortar.

The flooring to be two courses of brick on edge over concrete and laid with an inclination towards the draw-off culvert as shown in plans No. 12 or 27, on which all dimensions are given.

The filtering material is to be laid over a layer of slabs and broken stone arranged so as to form drains towards the culvert, the walls of which on the inner side are to be built of open brick-work to admit water to it throughout its length.

The supply pipes to the filters will discharge into troughs along one wall, whence the water will overflow on to the filter bed down the surface of the wall, at the foot of which rough stone slabs should be laid along the surface of the sand to prevent its disturbance by the overflowing water.

The filtered water will gravitate from the delivery culvert by iron pipes to the pure-water basin, valves at suitable points being fixed to allow of the water being turned on or off, as desired.

The charcoal used for the filtering bed is to be animal charcoal broken to small pieces and closely packed. The sand is to be fine white sand, if possible collected from nullah beds that are first ascertained to receive the drainage from no villages or pools that may possibly be contaminated.

To prevent any accumulation of air in the lower strata of the filters clogging their action perforated iron pipes in the proportion of 1 per 500 square feet of surface are to be set up, their lower ends resting on the flooring of the filter.

The Pure-water Cistern.—Its general construction will be similar to that of the filters, but it will be roofed with masonry arches carried on wrought-iron beams. Details are given on sheet No. 13 or 27. The beams in the outer bays must be tied with iron tie rods at six feet intervals bolted to an angle iron wall plate to take the thrust off the outer walls. Access to the cistern will be obtained through a small roofed chamber with a ladder of iron at one corner. As the openings at the ends of the arches through which ventilation is obtained will be only a few inches above the ground, the reservoir should be enclosed by a low mud wall 2½ feet high to prevent dirt and dust being blown into it.

The Stand-pipe and Mains.—The stand-pipe is to be constructed of cast-iron flange pipes 12″ or 10″ diameter in the form of a tripod braced and guyed as shown on sheets Nos. 14 and 15. The structure will rest on a triangular masonry foundation of brick-in-chunam or concrete, the feet of the tripod being attached to a wrought-iron bed-plate securely bolted down to the masonry by holding down bolts and plates bedded in concrete. The structure will form its own scaffolding during erection.

The mains to the cisterns will be 12″, 7″, 3½″, 3″, and 2″ or 10″, 6″, 2½″, and 2″ cast-iron plain socketed pipes, the general arrangement of which is shown on sheet No. 19.

The pipes are to be supplied under the following conditions :—

They are to be cast in dry sand moulds and to be of uniform bore and thickness throughout. They are to be cast socket downwards with a sufficient head of metal to guarantee solidity, the head being subsequently cut off in the lathe.

The metal used is to be good grey metal, remelted in the cupola, and free from all flaws and defects.

All pipes to be tested to a pressure of 130 lb. per square inch, equal to a column of water 305 feet high.

All pipes are to be coated within and without with Dr. Angus Smith's solution.

The pipes are to be laid in trenches 2 feet deep, and where valves are necessary, these are to be placed in small wells 4 feet diameter, closed in by slab stone covering stones, capable of removal if necessary.

The joints in the flange pipes are to be made water-tight with red lead. In the socket pipes the joints are to be formed by running in molten lead at the sockets.

The pipes are to be laid with the sockets facing the direction of flow to avoid sudden contractions in the case of badly-fitting joints.

Quarters for Establishment.

Engineer's Quarters.—Foundations to be rough stone-in-chunam; superstructure of brick-in-clay. All timber in roofs, doors, and windows to be sound teak. The flooring is to be stone-flagging on concrete.

Engine-driver's Quarters.—Foundations to be rough stone-in-clay; superstructure, brick-in-clay; flooring, stone-flagging on concrete; roofing, ordinary tiled roofing on teak-wood couples with hip ventilators and teak-doors and windows.

Native Stocker's Quarters, Cook-houses, &c.—To be built of sun-dried brick-in-clay or stone-in-clay foundations with jungle-wood timber work and concrete flooring. The stoker's quarters to be enclosed by a mud wall 5 feet high, coped with pantiles-in-chunam.

Store-room and office.—To be built of brick-in-chunam or stone-in-chunam foundations with stone-flagged flooring on concrete and jungle-wood timber. The windows of the store-room to be provided with iron bars $\frac{1}{4}$" thick, let three inches into the frame-work, and secured by iron cap and sill plates.

All the buildings, within and without, to be plastered with two coats of chunam.

Enclosure Wall.—To be rough stone-in-mud, coped with dressed stone and pointed with mortar. An iron entrance gate to be provided.

The whole enclosure to be properly levelled, cleared, provided with suitable metalled paths and proper drains to convey the surface drainage into the adjacent nullah.

All details are shown on sheets Nos. 16 and 17.

Project B.

For the new engines, mains, and boilers the same specifications as given under the head of Project A will suffice.

Additions to Engine-house.—These are to be constructed with brick-in-chunam on stone-in-chunam foundations and teak timber work, the whole to be completed to correspond with the existing buildings.

The Pure-water Basin in general construction will be similar to that described for Project A. It may, however, be provided with an arched roof as in the former design, or the roof of the present pure-water cistern may be removed and placed over the new one. The specification for construction will apply generally to either.

Stand-cocks.—These will be of cast-iron buried three feet in the ground and standing on a bed of concrete two feet square × 6 inches thick. The stand-cocks must be provided with self-closing taps to prevent waste from carelessness.

Condensers.—To be supplied by the Normandy Company, who will afford the necessary specification.

Tower and Cisterns.—The tower to be placed on the top of the Halsúr rock and is to be octagonal in shape. The foundations and lower portion to be built of stone-in-chunam with vertical sides, the upper portion of brick-in-chunam with an outside batter of 1 in 8. The sides are to have arched openings as shown in the Plan Sheet No. 24, and those in the lower portion are to be closed by iron railings six feet high with a gate in one to give access to the tower.

Wrought-iron beams are to be built into the tower, at the levels indicated, to carry four wrought-iron cisterns of the dimensions and construction shown on plan. The iron girders are to be fixed on stone templates and to be painted with Carson's anti-corrosive paint. Over the girders timber balks, well tarred, of the dimensions indicated on the plan, are to be placed to receive the cisterns, the balks to be slightly recessed to fit on to the top flange of the girders.

The girders are also to carry timber platforms as shown in the drawing, to which access will be afforded by iron ladders inside the tower, whence the cisterns can be examined. The tower will be open at the top, a light wooden gallery being carried round above the level of the highest cistern. The upper cistern is to be roofed with corrugated iron sheeting without trusses and supported by tie rods, and a zinc gutter at the eaves of the sheeting is to be connected with zinc rain-water pipes carried down inside the tower and discharging on to the rock at the base.

Two copper lightning conductors projecting five feet beyond the apex of the pediment are to be attached to a copper band carried round the top cornice and then inside and down the tower to its base, where a good connection is to be made with the main in the manner described for Project A.

The girders and cisterns are to be connected with the lightning conductor.

The pipes to supply the cisterns are to be carried up inside the tower, being fastened by collars to wooden bricks built in at six feet intervals, and the valves to control the supply to them will be placed at the foot of inside the tower. At the cisterns themselves branch pipes from the vertical mains with suitable taps will allow of the supply being turned on to whichever cistern is desired.

The waste pipe from each cistern is to discharge into the one immediately below it, the lowest cistern of all surplusing on to the rock at a suitable distance from the base of the tower.

Project C.

The Channel from the Eastern Catchment.—Before execution a line of levels to be run to enable the best possible line to be secured. The channel is then to be excavated to give the fall and bed widths shown on the sections. The earth to be formed into a 3 feet berm and embankment on the lower side, the berm to be 1 foot above F.T.L. and the top of the bank to be 3 feet above the berm. The top breadth of the embankment to be 3 feet or more where there is a surplus quantity of earth to deposit in spoil.

All masonry works to be built of rough stone-in-chunam, and the banks at the junctions of wings to be revetted with rough stone for a length of 6 feet from the end of the wing. All rough stone aprons to be formed of large stones closely packed.

For other works the specifications given under Projects A and B will hold good.

(Signed) F. J. ROMILLY, Captain, R.E.,
Executive Engineer.

for its construction would be wasted, and Colonel Mullins' investigations tend to show that other feasible sources of supply would not be obtainable except perhaps from Nundidroog at an enormous cost.

Under the above considerations, plans and estimates for the alternative schemes suggested by Colonel Mullins for improving the existing arrangements are submitted under the head of projects B and C.

23. Project B.—The proposed arrangements in connection with this project are as follow :—

The source of supply is to be the Halsur tank and Dhobies' wells as at present.
Condensing apparatus and cisterns for producing a supply of pure drinking water are to be located at the rock, the condensers drawing their supply from the tank.
New mains are to be laid down from the drinking-water cisterns at the rock to the barracks communicating with stand-cocks, whence drinking water only will be drawn.
Arrangements for direct pumping to barracks from the Dhobies' wells station.

The details of these arrangements will be as stated below :—

Pumping Station at Wells.

(1) New engines.
(2) Additions to existing engine-house.
(3) Repairs to existing filter.
(4) New pure-water cistern at the wells.
(5) New connection with rock stand-pipe and wells.
(6) Conversion of present pure-water basin at rock into a filter and connection with 5″ main.
(7) Connection of pure water well with Halsúr tank.

Condensing Station.

(8) Condensers.
(9) Tower and drinking-water cisterns.
(10) Mains for drinking water.
(11) Stand-cocks at barracks and water-carts.

Details of the above will be found among the plans or sheets Nos. 19 to 27.

24. Modification suggested in Colonel Mullins' proposal regarding Condensers.—Colonel Mullins proposed that water for condensing should be obtained from the Dhobies' wells. It is submitted that it would be better to use the tank water for this purpose. It would seem that the process of condensation can be relied upon to produce a perfectly pure water however impure the source, and by using Halsúr tank water for condensing, the Dhobies' wells water, which is a better natural source of supply, would still be available for transmission to the service cisterns for other purposes.

The site at the rock also offers great advantages for the location of the condensing apparatus and cisterns, and by very simple additions to the existing engine-house it can be rendered suitable for the accommodation of the condensing apparatus, rendering the construction of new buildings unnecessary, and the pumping stations for the two separate systems of supply would be kept entirely distinct.

Again, if Dhobies' wells water were set apart for condensation, more tank water would have to be filtered. With the present capacity of the filters this would be impossible unless additional filters were constructed, and accommodation for this cannot be found at the rock, but must be looked for at the Dhobies' wells ground, whence filtered water would have to be pumped up to the rock. The wells engine-house too cannot be adapted to contain the condensers as well as the pumping machinery; separate accommodation for each is necessary.

25. New Machinery.—The existing engine at the wells is very expensive as regards fuel. In an experiment in September 1879 the rock engine burnt 2,355 lb. of wood in $15\frac{13}{16}$ hours and during that time raised 128,565 gallons 78·00 feet. The same quantity was raised by the wells engine 36·00 feet on the same day, but it took nine hours to accomplish this and burnt 3,874 lb. of wood.

The effect of the small 5″ main that at present connects the wells engine with the pure-water basin at the rock explains much of the disproportion of fuel expenditure between the two engines. The head necessary to overcome the friction from a discharge of 238 gallons per 1″ (the rate at which the engine was pumping) through 600 yards of 5″ main would be 41·46 feet, so that the engine was practically exerting a force equivalent to a lift of $36 + 41{\cdot}46 = 77{\cdot}46$ feet, or virtually the same as the rock engine. In spite of this, however, the expenditure of fuel in the wells engine is still heavy in proportion. The wells engine is in very good order and could probably be disposed of at a fair price.

The rock engine is an old one, was not new in the first instance, and has been steadily at work in connection with the present water-works for more than ten years. Its boilers are worn and will need renewing at no distant period. With the prospect of important alterations being effected in the present works, a good opportunity offers itself of renewing the machinery and placing it on an efficient footing. At present also, in the event of a breakdown in either engine for want of reserve power, the water-supply must cease for a time or be seriously curtailed. With the wells engine disabled, owing to the slow rate of filtration of the filters, sufficient supply of pure water could not be obtained to enable the rock engine to send up the necessary daily supply, and, in the event of the rock engine breaking down, the wells engine is hardly powerful enough, nor so connected, as to admit of its pumping direct to the barracks.

A single engine at the Dhobies' wells would have to pump the water from the pure-water basin there to the stand-pipe at the rock, whence it would gravitate to the barrack cisterns. The level of the pumps being 2915·00 and that of the top of the stand-pipe 3010·47, the actual lift will be 95·47 feet. As the stand-pipe is situated 600 yards from the wells pumping station, a head of 1·50 feet is required to overcome the friction through this length of 10″ main, assuming the rate of pumping to be 250 gallons a minute, which will raise 120,000 gallons in eight hours. Hence work equivalent to a total lift of 96·97, or say 100 feet for safety, will be required by the engine. This will necessitate an engine of $\frac{250 \times 10 \times 102}{33{,}000} = 7{\cdot}57$, or, adding 50 per cent., say 12-horse power.

As two engines are to be provided to allow for reserve power, this rate of pumping will suffice, as it is considered that both may be worked together—one on the filters at a low pressure and small expenditure of fuel and the other on the cisterns. The simultaneous breakdown of both engines is not probable, and with one disabled, the other, by working twelve hours a-day on the cisterns and filters alternately with one day of rest, could pump up three days' supply if necessary until the disabled engine were in working order again. The double pumping would only be necessary when the supply in the wells proved insufficient.

There are three ways for arranging for new or reserve power:

(i) The present engine may be retained and one new engine added, placed at the Dhobies' wells, the mains being so connected as to admit of direct pumping to the barracks. With this arrangement, suppose the wells engine to be disabled, the new engine could supply the rock pure water basin, whence the supply would be sent on to the barracks by the rock engine. In the event of anything happening to the rock engine, the new one could pump direct to the barracks.

(ii) The present system may be retained intact and a duplicate engine placed at each pumping station.

(iii) The present engines may be disposed of and a pair of new engines supplied to be placed at the Dhobies' wells and pump direct to barracks.

In any case the present 5″ main between the wells and rock should be replaced by a 10″ main as originally intended.

The cost in machinery for these three arrangements would be about as follows:—

	i.	ii.	iii.
	Rs.	Rs.	Rs.
Twelve-horse power engines	2,750	...	5,500
Boiler	2,150	...	4,300
Eight-horse power engine	...	2,000	...
Boiler	...	1,445	...
Twelve-horse power engine	...	2,750	...
Boiler	...	2,150	...
Carriage	1,067	1,067	2,134
New boiler for rock engine	2,150	2,150	...
Total ...	8,117	12,562	11,934

To accommodate the additional engine at the Dhobies' wells engine-house, the alterations detailed on sheet 26 are considered necessary. Owing to the restricted size of the boiler-room, vertical boilers must be adopted, two of which can be readily accommodated in the space available, viz., $27' \times 8\frac{1}{2}'$ with 12 feet headway at eaves.

As the rock engine, which is 12-horse power nominal, would be sufficiently powerful to pump from the wells direct, it might be worth while to retain it as one of the pair to work at the wells, providing it with a new boiler, in which case the cost of one new engine would be saved. Before deciding on this, however, it ought to be thoroughly examined by an expert and, as it might probably be condemned, the estimates provide for entirely new engines.

If either of the two first arrangements is adopted, the present engine-house at the rock must be retained for pumping machinery and a new building for the accommodation of the condensers must be constructed near the rock at a cost of about Rs. 8,000. The third arrangement will, it is thought, be the best and will have the advantage that the machinery for pumping up the two supplies of water will be kept quite distinct and allow an existing building to be utilized for the condensers. To allow of the boilers for both engines being accommodated in the present boiler-room, the new engines must have vertical boilers.

The engines and pumps should be of similar description to those proposed for project A.

26. Pure-water Basin.—To allow of the water from the filters being collected and pumped up at the required rate, the existing small pure-water cistern must be replaced by one of suitable capacity.

Details for two pure-water basins are given on sheet 27—one similar to that designed for the Agaram pumping station with a masonry arched roof on girders and one to allow of the roof on the present pure-water basin being removed and placed upon it. The floor of the pure-water basin is to be placed 1 foot below that of the lowest adjacent filter. With this head at a distance of 10 yards, a 6″ connecting pipe would give an ample discharge. All three filters must be connected with the pure-water basin by suitable pipes and valves.

27. Utilization of the present Pure-water Basin at the Rock.—With pumping direct from the wells, this will no longer be of use as a pure-water cistern. It can however be converted into a filter, and by connecting it and the present filter at the rock with existing 5″ main from the wells to the rock, they could send a supply of filtered water by gravitation into the new pure-water basin at the wells. To enable them to be charged by the wells engine, the new 10″ main from the latter station must be connected with them and provided with suitable valves and junctions.

To convert the pure-water basin into a filter, it is proposed to bring the floor to a slope of 9″ in the whole length with concrete, lay down perforated pipes along it connected with the 5″ main, and put in layers of filtering material as detailed for the other filters. The depth of the cistern being 7 feet, there is room for the storage of 2 feet of water on a filtering bed 5 feet deep. To lead water on to the new filter thus obtained, the 10″ main will be connected with a perforated pipe laid along the top of the inner side of the cistern wall. The roof of this cistern will be removed and placed over the new pure-water basin at the wells. With these arrangements three filters will be available for filtering tank water, should the yield of the wells at times prove insufficient.

The pure-water basin would give a filter with a surface of 3,960 square feet, and would, at 16 gallons per square foot per 24 hours, filter about 64,000 gallons in that time. The floor of the pure-water cistern of the rock being at 2932·29 and the top of the new pure-water cistern at the wells being 2919·00, the fall through the 5″ main, which is 600 yards long, will be 13 feet, say, 130 gallons a minute, could run off from the rock filters to the pure-water cistern at the well, or 187,200 gallons in 24 hours, so that their filtering capacities, which, at the rate observed in the present filters, is about 7 gallons per square foot per 24 hours and would only amount to 66,381 gallons a day, could be fully met.

As the 5″ mains from the rock to the wells are carried along low ground, so that the lowest part is at the centre, valves are to be placed here to allow of their being scoured out; otherwise water will lodge about centre of the piping.

28. New Connection with Stand-pipe.—This is essential and should be carried out even if no other alterations to the works were contemplated. It was originally intended to have an 8″ main to connect the pumps at the wells with the pure-water basin, but from motives of economy a 5″ main was substituted, as pipes of this size were available at hand. The result has been that since the engine came into use, while nominally exerting a pressure equivalent to 40 feet of water about, it has really had to work up to 77·46 feet, or nearly double what was supposed, with of course, a great increase in the fuel used compared with what would have been expended had a main of the size originally proposed been laid down. A 10″ main should be laid to connect the wells pumping station with the stand-pipe and pure-water basin at the rock. See sheets 19 and 25.

29. Connection of present Pure-water Well with the Tank.—To allow of water from the Halsúr tank being drawn off and pumped up to the filters of the rock, the present small pure-water well at the Dhobies' wells is to be connected with the deep bed of the tank by 10″ pipes as is the case with the filters. The tank bed being 2919·37 and the well 500 feet from the tank margir, the pipes may enter it at 2918·00, or 12·61 feet above its floor. This gives a gradient of over $\frac{1}{1,000}$ and a discharge of over 279 gallons per minute, which would enable the engine drawing from this well to put 134,000 gallons into the rock filters in eight hours.

This well must be plastered with surkí mortar and entirely disconnected from the filter at the wells and the pump well of the wells, a separate suction pipe being carried from it to the engines.

CONDENSING STATION.

30. Apparatus and Situation.—It is proposed to erect the condensing apparatus at the rock, and the machinery selected is that of the Normandy Patent Distilling Machinery Company, regarding which full details are given in paragraph 50 of Colonel Mullins' report and the statements accompanying it. For facility of reference the prospectus and statements received from the company in London are attached to this report as appendix VW, and a plan of the apparatus will be found on sheet No. 23.

When, in June 1869, the idea of a separate service for drinking purposes only from the Dhobies' wells was entertained and the plans and estimates for the scheme submitted for sanction, the demand was fixed at 5 gallons per head per day. In 1870 Government ordered certain modifications on the designs forwarded and decided that a demand of 3 gallons per head was sufficient to provide for. On this latter assumption, 7,320 gallons a day would suffice for the troops, but Colonel Mullins suggests that condensers capable of producing 12,000 gallons daily should be provided, which would in six days produce 72,000 gallons, enough for eight days' consumption at 9,000 gallons, or 3·6 gallons per head daily. It is observed from the statements forwarded by the company that the actual production of their apparatus is more than the nominal outturn, and that condensers estimated to produce 9,000 gallons of fresh water in 24 hours really yield as much as 12,000. It is thought, therefore, that 9,000 gallon condensers, if provided, would be found to meet the estimated requirements, and, supposing two complete sets to be purchased and set up to guard against a possible temporary breakdown in the machinery, the occasional working of the

spare set for one day in the week would allow of a reserve supply being sent up so as to enable pumping to be stopped on Sundays.

There is no scale attached to the plan of the apparatus received and the actual dimensions of the boilers and engines cannot be determined. There would probably be no objection to placing the engines and boilers side by side. With slight alterations to provide the space necessary to accommodate the length of boiler the present engine house at the rock could hold the condensing machinery. The additions considered necessary to the existing engine house are shown on sheet No. 22 and a tracing of the building has been sent to the Normandy Company in London to ascertain if it provide sufficient accommodation for their apparatus.

31. The Cisterns.—There are two arrangements suitable for the cisterns, either to have separate cisterns at the Royal Horse Artillery, Cavalry and Infantry Barracks in which case the condensed water would have to be pumped over a stand-pipe at the rock or the cisterns may be placed on the top of the rock and allowed to gravitate to stand-cocks at the barracks. The latter is considered the better arrangement in every way. If the former plan is adopted, the whole of the daily supply would have to be raised the full height required to give the stand-pipe sufficient command over the Infantry Barracks (unless two stand-pipes are provided) and separate foundations and covers will be required for three double sets of cisterns. By placing the cisterns on the rock in a tower, one cistern on a low level will suffice for the Royal Horse Artillery, Royal Artillery and Cavalry supply, and one cistern on a high level will meet the requirements of the Infantry, and the engines will not be called upon to lift the greater portion of the supply higher than is actually necessary with a resulting economy in the expenditure of the fuel. With the supply of condensed water stored at the rock, one set of foundations and one roof will suffice for all the cisterns and the supply and expenditure can be regulated with greater nicety.

The details of the arrangements are given on sheet No. 24. The cisterns are to be placed in an octagonal tower 25 feet internal diameter and arranged in two sets of pairs, one above the other. The lower pair must each hold a day's supply for the Royal Horse Artillery, Royal Artillery and Cavalry, amounting to 6,349 gallons, and their dimensions being 16′ × 16′ × 4′ when quite full, they will each contain 6,400 gallons. The upper pair should each hold 5,651 gallons for the Infantry, and their dimensions being 15′ × 15′ × 4′, they will each hold 5,625 gallons when full. As it is proposed to have duplicate cisterns it is considered that the above provision is sufficient. To allow of cessation of work on Sundays, two days' supply can be stored on Saturdays, and if at any time a cistern requires repair, with continuous pumping, the single cistern could meet the required demands until the defective cistern was in working order again. There would also be a large storage capacity in the mains which would remain full as long as there is any water in the cisterns.

The crest of the rock is perfectly level, the foundations for the large filter originally proposed to be constructed upon it having been built many years back and covering the whole surface which has been brought up to a uniform level with sound concrete. Excellent foundations for the tower therefore already exist at a level of 2,973·97 × M.S.L. It is proposed to place the lowest cistern at a level of 2,982·97, or 8·03 feet above the rock, which will give the lower pair ample command over the Royal Artillery, Royal Horse Artillery and Cavalry Barracks, and the lower cistern of the upper pair at a level of 3,000·77 to obtain the required command over the Infantry Barracks. The total height of the tower will be 45 feet. The uppermost cistern is to be roofed in with corrugated iron sheeting without framing and held together by iron ties, and a wooden gallery will run round the top of the tower inside, to which access will be obtained by iron ladders inside the tower communicating with platforms on the cistern levels whence the valves can be worked and the cisterns inspected. The cisterns will rest on wooden balks 12″ × 3″ carried on three wrought-iron girders, as shown in the drawings. Waste pipes from the cisterns will carry the surplus water into the lower cisterns, except in the case of the lowest one of all which must have its overflow pipe carried back into the tank. The arched entrances at the base of the tower will be closed by iron railings 6 feet high, in one of which a gate with suitable lock will be placed to allow of access to the cisterns and tower by authorized persons.

Full details are given on the plan and necessary calculations in Appendix H.

32. Mains and Distribution.—The detailed calculations for the sizes of the mains are given in Appendix I.

It is assumed that the contents of the cisterns which take 24 hours to fill will be drawn off in 6 hours at the several barracks. The mains from the cisterns will terminate in stand-cocks at the barracks whence the water can be drawn for the use of the troops. The positions of the mains and stand-cocks are shown on sheet No. 19—21. As the mains to the Royal Horse Artillery, Cavalry and to the Infantry Barracks will work under different pressures, it will be necessary to keep the pipes from the two sets of cisterns quite distinct instead of having a single main to carry the whole supply to the point where the mains diverge, as would be the case with the whole supply pumped over a stand-pipe.

In place of the customary water skins for the conveyance of the water about the barracks by the pakali bullocks, it is proposed to provide iron water-carts holding 100 gallons each, which could be drawn by a single bullock. The skins at present used are difficult to keep clean, easily foul and often give rise to considerable waste of water from leakage and primitive arrangements for filling and discharging. The quantity also carried by a pair of skins is very small. Considering the great expense that will be incurred in condensing water for the supply of the troops, it is reasonable to incur some additional expense and provide for its collection and conveyance to the points where it is required in the best possible manner. With iron carts as proposed the water could be collected, transported, and delivered without waste, would be brought to the consumers in a clean and wholesome condition, and the amount of consumption could be closely checked. It would suffice probably to provide 20 such carts, 10 for the Infantry, 4 for the Cavalry, 3 for the Royal Artillery, 2 for the Royal Horse Artillery, and 1 for the Hospitals at the Agaram Barracks. The 20 carts would contain 2,000 gallons and with 6 trips a day to the stand-cocks would carry away the whole contents of the storage cisterns at the rock. Scouring valves are provided at suitable points to enable the mains to be emptied if desired.

33. Cost of Project and Alternative Arrangements.—The total cost of project B. as above described will amount to Rs. 1,67,000.

The cost of the several items is as follows :—

	Rs.
1. Condensers	80,180
2. Tower and cisterns...	9,880
3. New mains and stand-cocks	15,440
4. Additions to rock engine house	2,320
5. Additions to wells do.	2,170
6. New 12-horse power engines and pumps	15,600
7. Repairs to filter at wells	1,570
8. Alterations to pure-water basin	4,000
9. New pure-water basin	2,750
10. Connections from wells to stand-pipe	7,170
11. Iron roof to barrack cisterns	18,910
12. Water carts...	2,000
Total ...	1,61,990
Unforeseen contingencies ...	5,010
Grand Total ...	1,67,000

Should Government object to the proposal for entirely new engines and arrangements for pumping direct from the wells on the score of expense, the addition of a new engine house at the rock for the condensing apparatus would admit of the present system being continued in its present form. A new engine house for the condensers could be built on the ground north of the rock and the cisterns could be placed in the tower on the rock as already proposed, so that the only additions to the existing buildings and machinery would be the details actually necessary for the condensing machinery, and storage and distribution of water. The cost of these would be Rs. 1,14,000, but it is considered that it would be better in every way to arrange for direct pumping from the wells station.

In fact unless this is practicable there must always be the possibility of the system breaking down.

34. Method of Execution.—To enable the work to be carried out without interfering with the supply of water for the troops during construction all that is necessary is to arrange that the new connections with the stand-pipe, new engines and alterations to the engine house, shall be completed before the existing engines are moved. When this is done and the present cisterns and pure-water basins all filled, the supply stored in them would with economy last the troops for three weeks without a fresh supply being required. In this interval, the new engines and boilers at the wells engine house could be fitted up with work continued day and night if necessary. The nature of the additions to the wells engine house will admit of the new pumps being fitted up and connected while the present engine continues to work.

After the new engines are set up at the wells station, the troops can be supplied with water for all purposes from the wells as at present until the condensers are ready for work at the rock, when the dual system of drinking water supplied from the rock and water from the wells for other purposes can be commenced.

With the present system retained and merely the condensers added no interruption in the existing arrangements would take place.

35. General Remarks.—The scheme proposed would ensure the supply to the troops in a readily accessible form at the barracks of a good supply of really pure drinking water and a supply of Dhobies' wells water or filtered tank water for other purposes at a reasonable initial outlay. The great drawback to the project is the heavy annual expenses that will be incurred in fuel, which as explained by Colonel Mullins in paragraph 50 of his report, would probably amount to Rs. 34,600 for working the condensers alone.

The present establishment of the water-works could work the condensing apparatus with the addition of two stokers and perhaps one engine driver to the staff as the condensers to be worked economically should pump 24 hours at a stretch. There would also be additional expense on this account for lighting. Altogether assuming that for the wells engine the expenditure of fuel is 20 lb. per nominal horse power per hour, the monthly cost of the dual system may be estimated as follows :—

	Rs.
Present establishment	506
Additional two stokers and one engine driver	25
Fuel for wells engine	132
Fuel for condensers	3,600
Lighting	6
Oil, grease, sundries, &c.	131
Total per month ...	4,400
Total per annum ...	52,800

The total annual outlay would therefore be—

	Rs.
15 per cent. interest and depreciation or cost of condensers and engines	14,355
10 per cent. on other works	7,422
Working expenses	52,800
Renewing filters	4,023
Total ...	84,600

For which a mixed European and Native population of 4,846 souls will be supplied by a dual service with water for all purposes for themselves and their horses. At 60,000 gallons per day or 21,900,000 gallons per annum the cost per head will therefore be Rs. 17·4 and the cost per 1,000 gallons Rs. 4·32.

III.

36. Suggestions in Colonel Mullins' Report for Improving the Existing Source of Supply.—In paragraphs 33 to 38 of his report Colonel Mullins discusses the feasibility of improving the present source of supply to the Halsur tank, but gives as his opinion that the idea, though quite practicable, is not favourable as regards quality of the supply.

The suggestions made have, however, been worked out in detail as directed, and it is thought possible that, with one or two additions that have suggested themselves, the scheme might be more favourably regarded. Any project resulting in the real improvement of the Halsur tank water would be of immense benefit to the garrison. Many of the houses near the tank inhabited by officers and their families are supplied with water by pakalies, who take it from the tank itself or wells in the immediate vicinity, and those dependant upon this source of supply are, of course, exposed to all the dangers resulting from its impurity.

The municipal authorities, before whom the scheme has been laid, are alive to the great importance of the better conservancy of this reservoir and are prepared to co-operate in the furtherance of some of the measures suggested. They are also about to undertake important alterations in the present system of drainage connected with the main sewer, which will certainly improve the present state of affairs.

Against the most important measure suggested, however, the entire diversion of the town drainage from the tank, the Native Commissioners are opposed owing to its leading to fancied encroachments on their immemorial rights. This objection might, it is believed, be overcome if the Resident gave his support to the scheme.

37. Colonel Mullins' Proposals.—These provide for the diversion of the western feeder, which brings the drainage of the cantonment bazaar into the tank, and the construction of a new feeder to bring in the drainage from about $2\frac{1}{4}$ square miles new catchment to the east of the tank to compensate for that lost by the diversion of the western feeder. Also for an increase to the capacity of the tank of 5·116 M. cubic feet by raising the present water level 1 foot.

The improvements to the tank proposed by Colonel Mullins would undoubtedly do much to improve the quality of the water, and it would also diminish the danger of flooding to which the portion of the cantonment bazaar about the junction of the western feeder and the tank is exposed to, by increasing the fall at the end of the main drain and rendering it better able to carry away the storm water during excessive rains in a limited time. It is thought, however, that more might be done. The crying want for the Halsur tank is a rigid conservancy, and as matters exist this is practically impossible. The population have free access to the tank at every point, cattle can stray down and graze on the exposed parts of the bed where they naturally leave deposits, and any one walking along the tank, morning or evening, will see natives washing their feet and teeth in the tank water, and the undersigned has personally observed native children sitting down in the tank bed and using it as a latrine not far from the pumping station for the water-works. Horses may frequently be seen standing in the tank and being washed, and the numerous pakalies who collect their water from the tank invariably stand their bullocks well in the water. It is believed that by constructing watering places at certain points to which the public can have free access at all times but shut off from the rest of the tank, and fencing the tank in with wire fencing to keep out cattle such conservancy as would be practicable as would remove the evil effects of the practices above described. A further improvement could be effected in connection with the northern feeder and upper tank. It is of importance that the water in the Halsur tank should be kept at as high a level as possible; as the fuller the tank the better the yield of the Dhobies' wells. At present the water collected in the upper tank is often allowed to stand in it for a considerable time before it is passed into the lower tank with the result that the loss by evaporation is increased to a considerable extent, and it is thought that the water from the upper tank should pass into the lower tank as quickly as possible. The gathering ground tapped by the northern feeder contains numerous elements of dangerous contamination, and it is suggested that, by constructing a filter in front of the waste weir of the upper tank through which the supply would have to pass before reaching the lower tank, much of the

impurities contained in the water would be removed. With these improvements and a proper conservancy, the possibility of contamination of the Halsur tank water would be very materially reduced. The suspicious drainage of the cantonment would be entirely diverted from the tank on the north-west and west, the supply by the north feeder would be purified to a certain extent and the curtailment of the water spread by the bunds to divert the west feeder and increased height given to the new waste weir would maintain a greater depth of water in the tank to the improvement of the supply in the Dhobies' wells.

38. The Dhobies' Wells Water.—As explained in paragraph 22, the analysis of the tank and wells water made in 1871-72 showed that the water of the wells was classed as wholesome and was of better quality than that of the tank, but as later analysis shows that there is now little difference in the two waters, and both are classed as bad. The evident deterioration of the wells water can, it is thought, be satisfactorily explained. In 1877-78, when it was decided to construct an additional filter, the site selected was close to the Dhobies' wells. The filter was built here, and is entirely below the ground level. From the first the filter was found to leak considerably, and though subsequent measures diminished the leakage to a certain extent, still it has never been entirely arrested, and the fact of the filter being filled from the tank by gravitation and lying below ground level, caused this leakage to be regarded as immaterial. The result of this leakage has been, it is believed, the mixture with the Dhobies' wells water of unfiltered and imperfectly filtered tank water. The latter is certainly the case, for the filter is in direct communication with the pump well of the Dhobies' wells, so that the water drawn off from the filter circulates freely among the wells, and if any water leaks from the filter without passing through the filtering strata, which apparently it can do, this water at once finds its way through a few feet of earth into the nearest wells. There are therefore grounds for presuming that the troops for some years past have not been supplied with *bonâ fide* Dhobies' wells water, as has been supposed, and that very imperfectly filtered tank water has found its way into the service cisterns.

If the present system is retained in any form, it is recommended that the Dhobies' wells water be filtered previous to its being sent up to the barrack cisterns, and all connection between the wells and the filter completely cut off.

The Dhobies' wells water in any case is admittedly of a better character than that of the tank itself even after filtration, as more than one analysis has proved, among others that taken so recently as August 1883, and it is reasonable therefore to suppose that the water if also subjected to artificial filtration would attain a fair standard of excellence, if not a high one. Artificial filtration of this water has never been resorted to, owing to its character in former years being considered so good as to warrant its transmission to the barrack cisterns in its natural state, and with the present connections of the engine delivery pipes it cannot be turned on to the filter beds to allow of the experiment being tried.

The proposed addition to the present F. T. L., and increased capacity given to the tank thereby may be reasonably expected to increase the yield of the wells, and with the construction of more wells, frequently recommended but never carried out, these wells might be made to meet the yearly demand for the troops with proper economy of consumption with filtered water of unobjectionable quality.

39. Project C.—The proposed arrangements under this head will be as follows:—

The present source of supply to be retained and measures taken to improve the quality of the water in the Halsur tank and the existing arrangements adopted to admit of filtration of the Dhobies' wells water.

The details of the scheme are as stated below:—

Improvements to the Halsur Tank.

1. Diversion of western feeder.
2. Do. of north-west drainage.
3. New supply channel from north-east.
4. Filtration of north drainage.
5. Construction of public watering places.
6. Fencing in of the tank.

Pumping Station at the Wells.

7. Repairs to filter.
8. New filter beds.
9. New pure-water basin.
10. New engine and pump, and new boiler.
11. Addition to engine house at the wells.
12. New connections with stand-pipe.
13. Iron loop to cisterns.

40. Improvements to the Tank.—The first three items under this head, viz., the diversion of the foul drainage and construction of a new supply channel from the north-east are designed generally in accordance with Colonel Mullins' suggestions, and the nature and object of the several arrangements are fully described in paragraphs 33 and 35 and Appendices 16 and 17 of his report. The details will be understood by a reference to plans Nos. 34 and 35.

41. New Supply Channel.—The survey and sections of the feeder from the additional catchment on the east are given on sheet No. 28 and tables of the dimensions and discharges of the channels and weirs are shown in Appendices K. and L.

It has been thought necessary to modify the dimensions proposed by Colonel Mullins in his report. The channels designed by him were calculated to discharge 1″ off the catchment in 24 hours or $\frac{1}{24}$″ per hour, the estimates now sent in provide for a channel capable of running off $\frac{1}{8}$″ of rain from the catchment per hour, and the following are the reasons upon which this modification is based.

The question to be dealt with is that of a channel to carry off the rainfall from a catchment where heavy storms of short duration occur. It is these heavy storms that supply the tanks and a very large proportion of the annual rainfall which falls in moderate showers has no effect whatever upon the tank feeders and must be left out of consideration in designing a channel which has to bring in an appreciable supply into a reservoir of the capacity of the Halsur tank. During the past 3 years 10 heavy falls are registered, averaging ·8″ in 2 hours, 50 minutes, and twice during these storms, as much as ·7″ of rain fell in 30 minutes. In previous years heavy falls have been recorded, and on one occasion as much as 1·2″ fell in 15 minutes. With a channel of such small dimensions as proposed by Colonel Mullins, unless provided with weirs of suitable capacity to pass off such heavy bursts of rain, the banks would be breached in every direction, and if constructed with weirs of proper discharging power, the bulk of the rainfall would pass straight over the channel, which would run full for 2 or 3 hours perhaps, and carry into the tank only a very small portion of a valuable rainfall. Unless the channel is capable of taking full advantage of the heavy falls of short duration, the Halsur tank would derive but little benefit from it. Taking the record of the heavy storms of the past 3 years, it appears that 0·25″ per hour may be taken as the average heavy fall. Supposing half of this to be absorbed by the ground, it is assumed that the remainder, 0·125 or $\frac{1}{8}$ per hour, may have to be carried off by the channel. As the catchment is broken up into several well-defined minor catchments whose drainage will be led into the channel by the numerous nullahs that tap them, this rate of flow is not thought to be under what may reasonably be expected, especially as these heavy falls of rain generally occur after previous continuance of light showers, that more or less saturate the soil before the heavy falls take place. The total area of catchment drained is 2·4 square miles, and the average annual rainfall may be assumed at 36″. Experience shows that ·075 of the annual rainfall may be expected to be the yield of a catchment in the vicinity of Bangalore, and at this rate the channel may bring $2{\cdot}4 \times 36 \times {\cdot}075 \times 2{\cdot}3 = 14{\cdot}9$ M. cubic feet into the tank annually or rather more than 4 years' supply for the troops at 60,000 gallons a-day.

Waste weirs are provided along intervals of the channel to get rid of surplus drainage. They are calculated to dispose of the heaviest probable storm, which is assumed at 1″ per hour, and are arranged along the channel, so that at no point shall the excess water that the channel has to carry exceed what will raise the F. C. L. more than 1 foot above F. S. L. The weirs in most cases are situated at the points where the natural nullahs meet the line of channel, which will afford a ready means of conveying away the storm water. The weirs must be placed where the bed of the nullah is about the same level as that of the channel where they meet it, to avoid the expense of protection against a deep drop for the surplus water. Owing to the rapid

fall of the nullahs this can be secured by a deviation of from 100 to 200 feet from the channel line in most cases. Where deep nullahs are crossed, the channel is to be carried over them by aqueducts, the weir to intercept the drainage being placed at a suitable level higher up the nullah and catch-drains carried from it on either side of the nullah to the main channel. These catch-drains are to be 2 feet deep with 4 feet bottom breadth and sides slopes of 1 to 1. To enable the channel to discharge the rainfall from higher showers at a suitable velocity, a narrow channel is to be carried along the bed on the lower side at a foot lower level with bed width varying from 2 feet in the 4th mile to 6 feet at the tail, and the rest of the bed to slope towards this channel with a slope of $\frac{1}{24}$.

Particulars of their length, discharge, &c., are given in Appendix L.

One culvert is required where the channel crosses the Madras road near Beirnamungalam and others where village tracks have to be provided for. At 1 mile 1,056 feet a nullah receiving the drainage from St. John's cemetery crosses the line of channel. This drainage, it is thought, should not be allowed to enter the channel at all, as besides draining the cemetery referred to, the ground in its basin was once occupied by a cholera camp. To avoid this drainage a syphon is to be constructed to convey it away under the chaunel directly into the Katherampolyam tank. This channel will terminate in a tail weir in the nullah that enters the Halsur tank by the 9-vent culvert on Kensington road, by which the discharge from it will enter the tank.

The gradient of the channel is calculated to give a surface fall of 2 feet per mile, changes of depth being obtained by increasing the bedfall where necessary. The slopes are to be $\frac{1}{2}$ to 1, and the embankment on the lower side only will have slopes of 1 to 1 with a 3 feet berm.

Details of masonry works are given on sheets 33 and 34.

Should the scheme be approved and the channel have to be constructed, it will be necessary to re-level it to obtain a proper working section, as slight deviations at one or two points will enable the quantities of cutting and embankment to be better proportioned.

The points where these deviations are practicable are shown on the survey and numerous well-defined B. M's. legibly lettered have been left along the line now surveyed which will allow of its being readily traced out hereafter. These B. M's. are entered on the survey. The estimates are prepared from the section actually surveyed and may safely be accepted as showing the cost of any better line traced approximately along the same alignment.

42. Capability of the New Catchment to Compensate for that Diverted.—The total area of catchment diverted amounts to 1·9 square miles, of that brought in 2·4 square miles. Of the former area 4/5ths or say 1·5 square miles is occupied by the cantonment bazaar, the remainder, 0·4 square mile, is fairly open ground. The area occupied by the bazaar, consisting as it does of well made metalled roads with numerous tiled buildings may be expected to yield a much greater proportion of the annual rainfall than would be received from a catchment of open country such as it is proposed to bring in.

In paragraph 38 of his report Colonel Mullins goes into the question of the proportion of annual rainfall received in the Ooparhalli and Halsur tanks to that falling on their respective catchments, and it would seem that taking the statistics of years of ordinary rainfall, the Ooparhalli reservoir received 0·12 of the rainfall on its catchment, and the Halsur tank 0·085 and 0·071 of the rainfall according to the rain registers at the Bowring Hospital and Halsur tank respectively. The average proportion for the Halsur tank catchment may be taken at ·078 of the rainfall on its total catchment, the total effective area of which is 4·64 square miles. These figures show that in spite of the very favorable conditions for yield of a portion of the Halsur tank catchment, the proportionate yield of the whole catchment is rather less than that of the Ooparhalli gathering ground, which is all open country. This is explained by the fact that the cantonment bazaar drainage is all carried away by the main sewer except in the case of heavy storms, and does not reach the tank at all, while when heavy rain occurs a portion is still carried away by the sewer. Colonel Mullins calculates that all rainfall on the bazaar catchment not exceeding $\frac{1}{10}$″ per hour is passed of by the sewer without entering the tank.

In the absence of data of duration of period of flow and depth of water in the main channel of the bazaar during these periods, of which nothing of the kind is available, it is not possible to make an accurate estimate of the respective portions of rainfall received and discharged from the two sections of the Halsur catchment, viz., that occupied by the bazaar and that in open country. The tabular statements of rainfall, &c., that accompany Colonel Mullins' report however enable an approximate calculation to be made.

In the year 1882, the total rainfall was 31·13″ and the total quantity of water that the Halsur tank received was 26·7 M. cubic feet. This quantity is about 0·075 of the catchment over the whole area of 4·6 square miles. Out of the total rainfall only 2·24″ fell in storms equal to or exceeding $\frac{1}{10}$″ per hour and would have caused the main channel to discharge into the tank. Now, for the sake of argument, let it be assumed that the whole of this 2·24″ ran off the bazaar catchment of 1·68 square miles, and that of the rest of the catchment of 2·92 square miles, the proportion of rainfall received into the tank was 0·078 of what fell. Taking 1″ of rainfall to give 2·52 M. cubic feet per square mile we have—

2·24″ off	1·68 square miles	= 12·09 M. cubic feet.	
·078 × 31·13″	2·92 ,,	16·46	,,
Total ...	4·60 ,,	28·55	,,

As stated above 26·78 cubic feet was actually received by the tank during the year, so that the preceding calculation errs on the side of excess as may be expected from the fact that the whole rainfall of 2·24″ received by the bazaar catchment is assumed to run off, whereas a definite quantity is known to be diverted by the main sewer and an unknown portion would of course be lost by absorption and other causes.

It is clear therefore that the run off from the bazaar was less than that assumed for the purpose of argument, and if that quantity is decreased, the proportion received from the remainder of the catchment must be increased to make estimated discharge from the entire catchment agree with facts. By increasing the proportion run off from the rest of the catchment, the percentage will agree more closely with that observed to be the case in the Ooparhalli catchment, which possesses similar characteristics, and with what is observed on catchments in open country throughout the province. To keep on the safe side, however, it will be as well to continue to assume the run off from the open catchment at 0·078 of the rainfall. Suppose the bazaar drainage diverted as proposed and the new catchment of 2·4 square miles to the eastward brought in which will give a total catchment of 4·9 square miles to drain into the tank.

In this case taking the rainfall of 1882, viz., 31·13″ and assuming ·075 of this to be run off, the total quantity received by the tank would have been—

31·13 × ·075 × 4·9 × 2·32 = 27·50 M. cubic feet or a little more than that observed when the western feeder brought in a portion of the supply to the tank.

These figures are necessarily approximations, but it is considered that they indicate clearly that the new feeder may confidently be expected to compensate for that diverted. Should experience hereafter prove this not to be the case, an extension of the channel up to the 5th milestone on the Madras road will bring in the drainage of about one mile more of catchment. The alignment up to this point is shown on the survey.

It must also be remembered that with the western feeder diverted and the new catchment brought in, the capacity of the tank is to be increased by 5·16 M. cubic feet, as the new weir that forms part of the arrangements is to have its crest at a foot higher level than the existing one. The loss to the tank by surplus over the weir will therefore be greatly reduced, and the efficiency of the tank as a storage reservoir considerably improved.

43. Compensation.—The line of channel surveyed has been ploughed out and inspected by the Revenue authorities, who estimate the compensation for the land required at Rs. 2,680. The channel will intercept the drainage from part of the catchment of three tanks, and in Appendix J will be found a statement of their

acreage and the probable effect of the channel upon their supply. It is not considered that they will be affected to any extent calling for compensation. They lie in well-defined basins of limited area and it may safely be assumed that a large proportion of the rainfall over their free catchment will run of into them. Probably one-third of the annual rainfall is not too much to expect, and in this case the statement shows that two of the tanks will not receive less water for storage than the crops under them require. No account is taken of the surplus of heavy storms that they will reeeive from the surplus weirs in the channel. Under the Kadarampolem tank 52·7 acres of land may be thrown out of cultivation, for which compensation at Rs. 50 per acre must be paid.

44. Filter for North Feeder.—At present the upper Halsur tank surpluses into the lower tank over a masonry weir with an ogee fall, in which is a small vent for drawing off water from the upper tank when below crest level. The maximum head on this weir has not exceeded 9″ and is generally about 6″. This weir is to be demolished and reconstructed with vents 6′ × 4′ as shown in plan No. 36. In front of the weir a perforated wall is to be constructed, and the space between it and the weir, which will be 10 feet deep, packed with filtering material in vertical layers.

With this arrangement, whenever the upper tank receives a supply, it will be free to gravitate to the lower tank through the filtering material and reach the latter tank in a certainly purer condition than it does now. Considering the few days in the year that the upper tank surpluses directly over its weir, with the large continual draft on its contents that the proposed vents will occasion, it is most probable that the M.W.L. would not again rise above the weir crest. If it did, it could surplus direct as at present, but the quantity so surplused and the duration of the direct overflow would be small.

45. Fencing.—It is proposed to fence in the tank (along the line shown on plan No. , in chain dots) with wire fencing 5 feet high and 7 strands of wire carried on iron standards.

With a fencing of this nature round the tank it would be impossible for pakalies to take their bullocks for water to any but the authorized wells at the watering places, and the access of stray cattle to the bed of the tank would be effectually barred.

With the addition of a hedge planted behind this fence, the public would be shut off from the tank except at the points set apart for their use, and it is probable that the very fact of the fence being there will render people less ready to trespass on the tank-bed than would be the case did no obstacle stand between them and ready access to it. The existence of the fencing combined with proper notices as regards access to it. The supply also will be constantly fresh, drawn from the

46. Watering places.—The places most resorted to in the tank are the north-west, north-east, south and west corners, which are conveniently situated for the inhabitants of the Sapper lines, Kalhalli, Halsur, and the cantonment bazaar, and where any day natives and bullocks may be seen standing in the water and collecting it for use.

At these places it is proposed to build wells, two or more at each as may be necessary for caste distinctions, on the tank side of the present bund. These wells are to be surrounded by a bund and the water from the tank brought into them by pipes arranged, so that the outer end drawing water from the tank is floated about 18″ below the surface of the water to ensure its being drawn off free of silt or surface scum and impurity. To ensure a supply in the wells as long as there is water in the tank, channels are to be cut from the deep bed to the wells in which the fixed end of the delivery pipes will lie, and the bottom of the wells is to be carried down to 3 feet below the deep bed level. The ground round the wells is to be brought up to the level of the tank bund and metalled for about 6 feet round the wells to ensure cleanliness, and suitable wheels, &c., supplied for facilitating the drawing of water.

These wells are to be freely accessible to the public at all times, and with these provided the native population can obtain their water (whatever be the level of the water in the tank) close to the edge of the bund without the necessity of going down into the tank as at present.

best possible source, and pollution of the tank by the continuance of the present primitive and dirty system of obtaining water will be prevented.

The details will be understood by a reference to plan 34.

47. Repairs to Existing Filter.—As explained in paragraph 38 the existing filter at the wells leaks and allows its contents to mix with the wells water. It is probable that much of the leakage takes place through the floor which consists of a thin layer of brick on puddled clay, which probably settled in the first instance under the weight of water brought on it. The filter is to be emptied, the plastering stripped and replaced by Portland cement, and a layer of 6″ of concrete laid over the floor. The filter is also to communicate with a new pure water cistern in place of the present one and not with the pump well of the wells as at present, and a small subsidiary filter to be hereafter described is to be added.

48. Additional Filters.—It is nearly certain that if the present system is retained, the means for filtration must be increased. The slow rate of filtration of the present filters has been noticed in paragraph 9, and were it not that hitherto the bulk of the supply has been obtained from the Dhobies' wells without previous filtration, the limited action of the filter beds would long ago have rendered it necessary to restrict the supply to less than two-thirds of the quantity that the troops have been accustomed to use, or provide additional filters. The two existing filter beds are not capable of purifying more than about 35,000 gallons a-day each.

The only site where new filter beds can be placed is near the Dhobies' wells. There is absolutely no room at the rock; the only unoccupied ground near it at the boat-house is too low, being at nearly 2 feet lower level than the floor of the pure-water basin.

On the assumption that the Halsur water to be properly filtered cannot be allowed to pass through the filter beds at a greater rate than 16 gallons per square feet per 24 hours, an additional double filter—each compartment having an area of 100′ × 70 = 7,000 square feet—is proposed to be constructed at the Dhobies' wells situated as shown on the tracing sheet 25. This, with the existing filter bed, which has an area of 4,000 square feet, will give (allowing for one compartment out of use for cleansing) 11,000 square feet of filtering surface. During 8 hours' pumping $11{,}000 \times \frac{16}{3} = 55{,}333$ gallons would run through, leaving, with 2 feet stored on the surface, 137,500 gallons to be filtered, which at the above rate would be passed off in about 17 hours more, altogether about 25 hours. The quantity stored in the filtering strata is left out of consideration, so the time for completing the filtration would really be less than 25 hours.

In the event of the Dhobies' wells not yielding a sufficient supply, these filters will have also to purify tank water, and to allow of this, the pipes at present connecting the existing filter from the tank must be connected with them. It is proposed, in this case, to allow the delivery pipes from the tank to flow into the main filters through a small subsidiary filter shown on the plan, which will intercept much of the suspended matter, and allow the water to reach the main filters in a chemically purer condition than it does now. The subsidiary filter will in some degree supply the place of settling beds, and being of such small capacity could be cleaned out at least once a week by the water-works establishment at little trouble and expense. As the filters will be filled from the tank by gravitation, the slow rate of supply owing to the flow being retarded by the subsidiary filter will not be of consequence.

The position selected for the filters is shown on the tracing sheet No. 25 and the details on plan No. 27. They are generally similar to those designed for the Agaram pumping station except as regards area, which is calculated on the assumption that when using the Dhobies' wells water or that from the Halsur tank first cleansed by the action of the subsidiary filter, the rate of filtration may be nearly three times as rapid as at present observed. It might be found that with the wells water and Halsur tank water collected as proposed, the rate of filtration may be as much as 30 gallons a minute. This might be tested before constructing the new filters, and if found to be the case, the expense attendant on their provision could be partly or entirely saved.

49. New Pure Water Cistern.—A new reservoir for this purpose would be necessary at the Dhobies' wells; its details would be similar to those described in paragraph 10, part I, except as regards depth. See plan 27.

50. New Engines and Additions to Engine House.—As in this case accommodation for condensers is not required, the new engines might be arranged on either of the three plans explained in paragraph 25, part II, the most economical of which would be the retention of the present machinery and addition of a new 12-horse power engine at the wells. The alterations to the engine house already described would be suitable in the present instance, and new boilers for the engine at the rock and at the Dhobies' wells would be necessary; in the latter case a vertical boiler should be provided on account of limited space.

51. New Connections with the Stand-pipe.—These would have to be made as already described to admit of direct pumping from the wells station if necessary.

52. Additional Wells.—In 1879 the total yield of the wells amounted to 14,419,800 gallons, or 450,620 gallons per well. By adding 10 more wells, a total annual yield of 18,900,000 gallons might be expected, which would rather more than suffice for a daily demand of 50,000 gallons. Additional wells were commenced in 1876, but the works stopped at the request of the Commander-in-Chief on the grounds that their construction on the site proposed endangered the safety of the Halsur tank bund. By sinking the wells on the alignment shown in plan No. 25, in rear of the nullah entering the tank on the east, the tank-bund will in no way be affected. The cost of sinking the ten additional wells and connecting them with the present ones would amount to Rs. 5,580. In the event of the wells not yielding the entire supply for the year, the deficiency to be supplemented by filtered water drawn from the tank would be very small, and at such times special attention might be directed to the water used and the measures adopted for its further filtration at the barracks themselves.

Details of the wells and connecting drains are given on the tracing sheet No. 25.

53. Cost of the Project.—The total cost of Project C would be Rs. 1,33,000. It would improve the conditions of the Halsur tank by completely diverting the town drainage, filtering the northern drainage, and bringing in a supply from a cleaner gathering ground. It would also ensure the proper conservancy of the tank and supply the troops with filtered Dhobies' wells water for all purposes except in years of scanty rainfall, when the yield of the wells might be insufficient and a small quantity of filtered tank water would have to be used.

The cost of the several items would be—

	Rs.
1. New channel, masonry works, compensation	26,130
2. Improvements to tank	33,730
3. New engine and pump	7,800
4. New boilers for present engines	4,360
5. Alteration to wells engine house	2,170
6. New wells	5,580
7. New filters	16,550
8. New pure-water cistern	4,630
9. Connections at station	1,073
10. Do. with stand-pipe	7,170
11. Repairs to filter	1,570
12. Roofs to cisterns	18,910
Total	1,29,673
Unforeseen contingencies	3,327
Grand total	1,33,000

The working expenses would be much the same as at present, the existing establishment sufficing, so that the annual expenditure would be as follows:—

	Rs.
Fifteen per cent. interest and depreciation on new machinery	1,140
Ten per cent. on other works	12,230
Working expenses	9,600
Renewing filters	4,030
Total	27,000

With a supply of 60,000 gallons daily, the cost per head due to the improvements would be Rs. 5·5 and the cost per 1,000 gallons Rs. 1·2.

Adding to the total annual expenditure shown above 10 per cent., or Rs. 3,00,592 previously spent on the works, the cost per 1,000 gallons would be Rs. 2·6.

54. Possibility of improving existing system without diverting the town drainage.—The following remarks are now offered with regard to the possible retention of the existing system in a somewhat improved form, and they are offered with diffidence as it is known the ideas they embody are directly opposed to those of many officers of high standing and experience, and particularly to those of His Excellency the Commander-in-Chief, who has recorded a strong protest against the continuance of the Halsur tank as a source of supply to the troops in any shape whatever.

It is an undoubted fact that previous careful analysis of the tank water has pronounced it "usable" after filtration and that of the Dhobies' wells water as usable without filtration, and at the time when the condemnatory analyses were made (in May last year) a long season of scanty rainfall had lowered the water in the Halsur tank considerably. The recent analysis of the Agaram tank water shows that under similar unfavorable circumstances it may, equally with that of the Halsur tank, be pronounced unfit for domestic use.

It is suggested that, by increasing the supply of the Halsur tank and ensuring the storage of a greater volume of water, its deleterious characteristics may be so reduced in quantity as to remove the objections to its use as a source of water-supply. The question of the unfitness of water for domestic use is one of degree, and a usable water, or even a pure and wholesome one, may contain precisely the same impurities as a bad water, but may be used with safety owing to the smaller relative proportions of the impurities contained. With a small volume of water stored in the tank any impure supply it may receive naturally affects it to a greater extent than it would do if the tank contained a larger volume.

The supply that the Halsur tank receives from the western feeder is undoubtedly derived from a gathering ground containing numerous elements of contamination, but it is believed that the conservancy exercised over the cantonment bazaar together with the action of the main sewer tend to reduce the amount of contamination to a very considerable extent, as in fact analysis has proved.

The cantonment bazaar, which occupies about one square mile of the catchment of the western feeder, is covered with well-metalled roads and good stone drains, all of which discharge direct into the large sewer that runs alongside of the main feeder and on a much lower level, and only during heavy storms, which are of occasional occurrence, can the street drains discharge into the supply channel of the tank. Before they do this, they must have been thoroughly flushed and much of their contents carried away by the sewer. The drains and roads are frequently inspected, cleaned out at intervals during the day, and refuse accumulating about the town and on the roads is collected and stored in proper receptacles to be removed by the conservancy carts. It is certain that a very large quantity of the cantonment refuse has no chance of reaching the tank, and as, from the nature of the surface of this catchment, a large portion of which is occupied by metalled roads and masonry or tiled roofs, the run-off in the case of heavy storms is very rapid, the contact of the drainage with impure matter is probably of shorter duration than in the case of a drainage from open cultivated country, where the rainfall finds its way slowly through soil saturated with manure and other refuse, giving it ample time to absorb impurities. Of course, some portion of the foul cantonment drainage does reach the tank at times, and this fact must be admitted, but, were the tank always fairly full, it is believed that the proportion of impurity in the tank water would not be greater than what proper filtration would remove.

If the western feeder were allowed to supply the tank as at present and the drainage of the additional catchment on the east also brought into the tank (which should at the same time be placed under proper conservancy as proposed in paragraph 37), the quality of the water would certainly be improved.

The Dhobies' wells water is admittedly of a better character than that of the Halsur tank, but filtration of this water has not hitherto been resorted to. With the Halsur tank constantly full, as might be expected with the new drainage brought in,

the supply in the wells would certainly be increased, and by the construction of additional wells as described in paragraph 52, these wells could be made to meet the demands of the garrison with proper economy of consumption.

The working of the present filters might, it is thought, be greatly improved by more frequent renewing. Last year they were cleaned out only once during the year, and it is considered that this should be done oftener, say once in four months, or three times a year.

The surface of the filter beds should be scraped once a week, the top three inches of sand removed and fresh sand to the same depth substituted, for which purpose a sufficient store of fresh sand should be kept stacked at the pumping station. The most expensive item in the filtering strata is the charcoal. This, it is thought, need not be entirely renewed more than once a year, and by keeping a sufficient stock of charcoal on the spot, one supply for the filters could be kept in use for twelve months. The layer of charcoal removed at one cleansing could be screened, sifted, and left exposed to the sun and air to oxydise and be replaced by a fresh layer from the stock, which in turn should be similarly treated at the next cleansing, being replaced by the quantity previously removed. All this, of course, would increase the annual expenditure on the works, but artificial filtration of water is an expensive matter, and, unless proper measures are taken to ensure the filtration being really efficient, it had better not be undertaken.

If the drainage of the eastern catchment is brought in without at the same time diverting the western feeder, the present waste weir must be lowered as proposed and the new weir constructed in the tank about the point shown on plan 34 and connected with the south-west embankment by a cross bund. The drainage area being in this case 7 square miles, the flood discharge might be $= 350\sqrt[3]{72} =$ * 1,505 cubic feet per 1″. This could be discharged with a head of $1\frac{3}{4}$ feet by a weir 188 feet long, and the bridge over the existing weir, which has nine bays of 10 feet span (if the weir be lowered 4 feet), would pass the above discharge with a velocity of 4·3 feet per second and a depth of 4 feet of water on its floor.

* Over $\frac{1}{4}$″ per hour over the whole catchment.

All the other arrangements, excluding those for the diversion of the western feeder, should be the same as proposed under the head of project C.

The cost of this scheme would be Rs. 1,10,000, allowing for a new engine at the Dhobies' wells to provide reserve power, new wells, and filters.

IV.

55. General Remarks on the Projects.—The Agaram tank project, though the most expensive, is undoubtedly the best owing to its greater simplicity, but it labors under the disadvantage of the quality of the supply being even now of doubtful character and the possibility of its being condemned at some future time.

Tanks receiving the drainage off cultivated land must not be expected to yield a pure and wholesome supply, and the remarks in Colonel Mullins' report on the tanks he visited indicate this very clearly. The results of the numerous analyses lately made prove that such examinations really give most uncertain data to work upon in deciding on the fitness of tanks as a source of supply. They show that the water in the same reservoir is liable to constant change, and in fact can only be accepted as indicating the character of the water at the time of its examination and do not give any guarantee as to its average or permanent quality. The Agaram tank water has been pronounced "usable" at one time and "bad" at another; so has the Halsur tank water, and it is more than probable that analyses of other tank waters at different times would give equally contradictory results.

The only course open is to accept this fact, and, where tanks have to be resorted to as a source of supply, to provide ample arrangements for thoroughly efficient artificial filtration. With this object, large filters have been provided in the Agaram scheme and the possibility of its being found necessary to still further increase them pointed

out. The filters once provided, some considerable outlay annually must be provided for to enable them to do their duty efficiently.

The scheme for condensing water will ensure the troops being supplied with drinking water entirely above suspicion, and by no other means can this be done. The cost of the scheme is considerable, though little more than half that of the Agaram scheme; the heavy annual expenditure it will involve in fuel is a serious drawback to it. The outlay incurred, however, will ensure a perfectly certain result and may be expected to settle definitely the perplexing question of a pure water supply for the troops, which schemes based on the natural sources of supply attainable cannot do. It may be so arranged that the present system remains unchanged or be adapted to arrangements for direct pumping from the wells. This latter proposal is strongly urged, for, as pointed out in paragraph 25, the present system is liable to a temporary collapse unless direct pumping from the wells is practicable.

The schemes for improving the Halsur tank, unless the town drainage is entirely diverted as proposed for Project C, can only be regarded as doubtful expedients, as they cannot guarantee results that will satisfy the conditions laid down by analysts as the standards for chemically "pure" or "usable" drinking water. The uncertain data that analyses afford has been noted in paragraph 53, and in Appendix X will be found a letter from the Sanitary Commissioner at Madras to the Chief Secretary to Government quoting the views of various eminent authorities, among others Professor Tyndall, as to the slight practical value of analyses as a basis of opinion regarding the suitability of a water for domestic purposes. In the letter under reference a water reported on by the Chemical Examiner as "bad" and containing *a very large amount of albumenoid ammonia* is considered by the Sanitary Commissioner to be not injurious to health. It is believed that no scheme of water-supply for the troops at Bangalore with any of the tanks in the neighbourhood as the source of supply will fulfil the chemical conditions that will admit of their waters unless artificially filtered being classed as pure or usable.

If the town drainage is diverted from the Halsur tank (and it must be remembered that at present a very large proportion of the actual sewage never reaches the tank, and only part of the storm water of the town enters it), it seems reasonable to suppose that the conditions of its catchment would then be very similar to those of the Agaram tank, and that its water, which undoubtedly in previous years bore a high character, might regain its former quality.

So long as the tank receives a supply from the western feeder, the fact must remain that a portion of its supply is derived from a foul source, and no improvements in the town drainage can entirely divert this. It is a question for doctors to decide as to whether, by increasing the supply of water to the tank as proposed and providing greater facilities for filtration, its water may be rendered wholesome and fit for use. On this point opinions will probably differ. The Rivers Pollution Commissioners in England reported that the waters of the Thames and Lee were so foully polluted that by no possible means could they be rendered suitable as a source of water-supply for London, and therefore recommended their entire abandonment for such a purpose. The "Water-supply Commissioners" on the other hand reported that with proper filtration the waters of these rivers could be rendered perfectly wholesome and fit for use. Both committees included men of high scientific reputation and of unquestioned ability, and their irreconcilable views on this important subject only tends to illustrate very forcibly the uncertainty that exists in all questions where a natural source of supply of doubtful or suspicious quality has to be considered.

With either of the schemes for utilizing the Halsur tank it has been proposed to filter the Dhobies' wells water, so that, except occasionally, when the wells might not yield a sufficient supply, an already naturally-filtered water would be further subjected to artificial filtration previous to use.

A return kindly furnished by the Deputy Surgeon-General shows that in the years 1879 and 1880, when the Halsur tank contained a large volume of water throughout the year and nearly the whole supply the troops received was obtained from the Dhobies' wells in a natural state, there were no deaths at all in the station from causes that could be attributed to a bad water-supply. Deaths from such causes have increased regularly in the three successive years during which the Halsur tank has received a scanty supply and has been steadily getting lower. Of course all tanks and

wells in the cantonment suffered to a similar extent. This would go to prove that with a good supply of water in the tank it may be used with safety, and the suggestions for increasing its supply are perfectly practicable and would ensure a greatly-increased storage, the maintenance of a higher level throughout the year, and a better supply in the Dhobies' wells.

To sum up, the arguments for and against the several schemes may be thus stated—

AGARAM TANK SCHEME, PROJECT A.

Pro.	*Con.*
Simplicity. Quality of water at present better than that of the Halsur tank.	Present doubtful quality of water and possibility of its being found bad hereafter. Possibility of requirements for cultivation at times interfering with the demands of the garrison.

SCHEME FOR CONDENSING, PROJECT B.

A certain supply of perfectly pure drinking water. Utilization of existing works.	Dual system of supply. Heavy annual expenditure in fuel.

SCHEME FOR IMPROVING HALSUR TANK, PROJECT C.

Utilization of existing works. Supply from a source known to be sufficient as regards quantity and to interfere with no existing rights. Improvement in quality of supply. Bulk of the supply obtained from a naturally-filtered source further purified by artificial filtration.	Doubtful quality of supply. Objections on the part of the municipality to a portion of the scheme, viz., that for diverting the town drainage.

Alternative Suggestion.

Improvement in quality of supply and utilization of existing system. Bulk of supply derived from a naturally-filtered source and further purified by artificial filtration. Increased storage and consequent increase in the Dhobies' wells supply.	Doubtful degree of improvement in quality. Known inflow of a certain quantity of drainage from a foul catchment.

56. CONCLUDING REMARKS.—It is believed that all possible requirements are included in the estimates submitted, and allowances have been made for unforeseen contingencies.

The prices of machinery and iron work have been taken from the published catalogues of Messrs. Richardson and Cruddas, Bombay, and Messrs. Bolling and Lowe, London, and the charges for carriage allow for freight by sea from Bombay to Madras and rail from Madras to Bangalore except in the case of machinery, for which carriage by rail from Bombay is allowed. The rates by sea include bunder fees.

In selecting the engines, the only guide has been the descriptions in the illustrated catalogues, and possibly communication with the firm from whom it is decided to procure the machinery would enable more suitable engines to be selected. The prices of engines of similar power, but different construction, do not differ greatly, and the amounts entered in the estimates may be relied upon to cover the cost of whatever engines are ordered.

The "Cornish" direct acting steam pump (Tonkin's patent) might be found suitable, and, if so, would occupy less space, be more easily set up, and cost less than the engines and pumps proposed. It is impossible, however, to decide from the catalogues whether these would be suitable to the present case, and personal inspection of this machinery, with information gathered on the spot from the makers, would be necessary to enable the point to be decided.

Prices of piping are rather higher in Madras than in Bombay, but the carriage from the former city of course less. It is, however, suggested that it would be better to obtain the whole of the plant from one firm, and Messrs. Richardson and Cruddas of Bombay seem to be a suitable firm to contract with; they have already supplied material and machinery for the Jabbalpore, Sholapúr, Tanna, and Kola water-supply schemes, so that they have had a good deal of practical experience in this particular

work. The cost of the piping supplied for the Jabbalpore works amounted to Rs. 3,00,000.

In all the projects provision is made for reserve engine power. This does not exist in the present system, and, as already pointed out during the last fourteen years that the troops have been drawing their supply from the Halsur water-works, they have been liable to an entire failure in the supply in the event of the breakdown of one of the engines.

An abstract of the cost of the various items for the different projects is tabulated in Appendix Y, from which, if desired, a decision can be arrived at as to what savings may be effected by the partial execution of one or other of the projects. It is possible that some of the additions or alterations proposed may not be considered necessary, but all the suggestions have been carefully thought out, and it is believed that none of the proposals made are unsupported by sound arguments in favor of their adoption.

The report on the water-supply for the troops at Bangalore now submitted deals with all the suggestions made by Colonel Mullins in detail, and is of much greater length than was at first anticipated to be necessary. Looking, however, to the fact of the doubtful analysis of the Agaram tank water that was obtained subsequently to Colonel Mullins' investigations, and with the past experience of the uncertainty of tanks, although pronounced suitable at first, continuing to yield a satisfactory supply as regards quality, it was thought advisable to go as thoroughly as possible into the whole question of the various schemes suggested in Colonel Mullins' report. In attempting to do this, the undersigned ventures to hope he will not be considered to have exceeded his instructions, nor to have been at all desirous of advancing his own views on the subject in opposition to those expressed by Colonel Mullins.

In all the projects numerous alterations have been proposed in the existing works in case they should be in any way retained. When the Halsur water-works were originally designed, it was unfortunately assumed that the summit of the rock had sufficient command over the various barracks to allow of their being supplied by gravitation from a large filter constructed on its crest. When the works were considerably advanced, this was found to be impossible owing to the infantry barracks standing at a higher level than the rock itself attained. The result has been that the pumping station at the rock is situated where there is insufficient filter accommodation.

Doubts as to the suitable quality of the Halsur tank water that arose during the construction of the works led to the commencement of the Dhobies' wells scheme for a separate supply of drinking water. Careful analysis of the Halsur tank water having in the interval proved it to be of a sufficiently good quality to warrant its use by the troops for all domestic purposes, the two schemes were amalgamated; but, as they at present exist, they are entirely dependent the one on the other and are incapable of affording reserve power. The possibility of a breakdown in the system through one of the engines becoming temporarily disabled has been commented on in previous paragraphs.

COIMBATORE,
16th November 1884.

(Signed) F. J. ROMILLY, Captain, R.E.,
Executive Engineer.

APPENDIX A.

PROJECT (GENERAL).

Statement of Troops, Families, &c., to be supplied with Water.

Corps.	Europeans.				Native Followers.	Horses.	Remarks
	Men.	Women.	Children.	Total.			
Battery, R.H.A.	181	31	48	260	1,303	196	R.H.A. cistern.
2 Batteries, R.A.	324	39	60	423	489	234	} Cavalry B.K. or R.C.
1 Regiment Cavalry	482	48	82	612	1,307	396	} cistern.
1 Battalion Infantry	993	58	94	1,145	207	14	Bakery square cistern.

Statement of Gallons required daily at 14 gallons per European, 1 gallon per Native, and 12 gallon per Horse.

Corps.	Europeans.	Natives.	Horses.	Total.	Remarks.
1 Battery, R.H.A. ...	3,640	1,303	1,352	6,295	R.H.A. cistern.
1 do. R.A. ...	5,922	489	2,808	9,219	} R.C. cistern.
1 Regiment Cavalry ...	8,568	1,307	4,752	14,627	}
1 Battalion Infantry ..	16,030	207	168	16,405	Bakery cistern.
Total ...	34,160	3,306	9,080	46,546	

Statement of Working Demand adopted.

	GALS.
For Royal Horse Artillery	8,000
,, Royal Artillery and Cavalry	30,000
,, Infantry	22,000
Total ...	60,000 per diem.

APPENDIX B.

PROJECT A.

Statement of probable Engine-power and Fuel required.

By experiment it has been found that the 12-horse power (nominal) engine at the Halsur rock consumes 230 lb. of wood per hour, with a resulting indicated horse power of 25·5, or more than double the nominal. The expenditure of wood-fuel may be assumed at 20 lb. per nominal horse power per hour.

The water from the pumping station at the Agaram tank will have to be raised 150 feet above the pump level, and this can be effected in two ways:—

I. With a single engine pumping on to the filter beds and to the pure-water reservoir alternately, in which case it must be capable of raising three days' supply, or 180,000 gallons in 8 hours, which would require a rate of pumping of 370 gallons per minute.

II. With two engines, one to fill the filters and one to pump to barracks, in which case two days' supply only need be sent up at one day's pumping and the rate of delivery may be 250 gallons per minute.

The lift to the filters will be 10 feet. Hence the horse power required will be as follows:—

I. With a single engine—

To pump to cisterns $\frac{370 \times 10 \times 150}{33,000} = 16{\cdot}8$-horse power, or adding 50 of, say 24-horse power.

To charge the filters $\frac{370 \times 10 \times 10}{33,000} = 1{\cdot}1$, say 2-horse power.

II. With two engines—

To pump to cisterns $\frac{250 \times 10 \times 150}{33,000} = 11{\cdot}3$, or adding 50 of, say, 18-horse power.

To charge filter $\frac{250 \times 10 \times 10}{33,000} = {\cdot}7$, say 2-horse power.

With an expenditure of 20 lb. of fuel per hour per nominal horse power the daily (8 hours) expenditure of fuel will be—

I. With a single engine—

	LB.
To pump to barracks	$20 \times 8 \times 24 = 3,840$
To charge filters	$20 \times 8 \times 2 = 320$

II. With two engines—

	LB.
To pump to barracks	$20 \times 8 \times 18 = 2,880$
To charge filters	$20 \times 8 \times 2 = 320$

I. With a single engine when once the cisterns are full, 11 days' pumping to barrack and 11 days' pumping on the filters will keep the reservoirs full. Hence expenditure of fuel would be—

	LB.
11 days at 3,840 lb.	= 42,240
11 „ at 320 „	= 3,520
Total ...	45,760

∴ cost at 268½ lb. per 1 rupee = 170 rupees about.

II. With the two engines 17 days' pumping by both engines will keep the reservoirs full and expenditure would be per month—

	LB.
17 days at 2,880 lb.	= 48,960
17 „ at 320 „	= 5,450
Total ...	54,410

∴ cost at 268½ lb. per rupee = 202 rupees about.

To fill all the cisterns would require 18 days' continuous pumping with a single engine on the filters and cisterns alternately, and the expenditure of fuel would be—

	LB.
18 days at 3,840 lb.	= 69,120
18 „ at 320 „	= 5,760
Total ...	74,880

And the cost = 278 rupees.

With the two engines the cisterns could be filled with 9 days' continuous pumping at an expenditure of 27,800 lb. of fuel costing Rs. 105.

APPENDIX B-2.

Project A.

Summary of above.

Machinery.	To maintain supply in Cisterns when filled.			To fill Cisterns if emptied.			Remarks.
	Days.	Fuel.	Cost.	Days.	Fuel.	Cost.	
	NO.	LB.	RS.	NO.	LB.	RS.	
Single engine	22	45,760	170	18	74,880	278	Pumping 370 gallons per 1'.
Two engines	17	54,410	204	9	27,800	105	Do. 250 do.

APPENDIX B-2.

Project A.

Probable amount of Pumping required to fill the Cisterns and meet the demand when pumping up three days' supply at a time.

Days.	Filter.	Royal Horse Artillery Cisterns, capacity 179,000 gallons.			Cavalry Barrack Cisterns, capacity 280,000 gallons.			Infantry Barrack Cisterns, capacity 112,500 gallons.			Total Quantity pumped up.		Remarks.
		Received.	Used.	Balance stored.	Received.	Used.	Balance stored.	Received.	Used.	Balance stored.	To filters.	To barracks.	
Sunday	180,000	..	..	..	..	..	..	..	..	..	180,000	..	
Monday	..	30,000	8,000	22,000	100,000	30,000	70,000	22,000	22,000	..	180,000	180,000	Total capacity of cisterns = 571,500 gals.
Tuesday	..	..	8,000	14,000	..	30,000	40,000	..	..	..	180,000	180,000	
Wednesday	180,000	30,000	8,000	36,000	100,000	30,000	110,000	22,000	22,000	..	180,000	180,000	
Thursday	..	..	8,000	28,000	..	30,000	80,000	22,000	22,000	..	..	..	The several cisterns hold the following number of days, supply at 60,000 gallons daily :—
Friday	180,000	30,000	8,000	50,000	100,000	30,000	150,000	22,000	22,000	..	180,000	180,000	
Saturday	..	..	8,000	42,000	..	30,000	120,000	22,000	22,000	..	..	..	R.H.A., 2$\frac{2}{3}$ days for R.H.A.
Sunday	180,000	30,000	8,000	64,000	100,000	30,000	190,000	22,000	22,000	..	180,000	180,000	C.B., 3 days for 2 Battalions
Monday	..	..	8,000	56,000	..	30,000	160,000	22,000	22,000	..	..	..	Royal Artillery, 1 Regiment Cavalry.
Tuesday	180,000	60,000	8,000	108,000	60,000	30,000	190,000	22,000	22,000	..	180,000	180,000	
Wednesday	..	..	8,000	100,000	..	30,000	160,000	22,000	22,000	..	..	..	I.B., 2$\frac{1}{6}$ days for 1 Battalion Infantry.
Thursday	180,000	60,000	8,000	152,000	60,000	30,000	190,000	22,000	22,000	..	180,000	180,000	
Friday	..	..	8,000	144,000	..	30,000	160,000	22,000	22,000	..	..	..	
Saturday	180,000	43,000	8,000	179,000	77,000	30,000	207,000	22,000	22,000	..	180,000	180,000	
Sunday	..	..	8,000	171,000	..	30,000	177,000	22,000	22,000	..	..	..	
Monday	180,000	16,000	8,000	179,000	111,500	30,000	258,500	22,000	22,000	..	180,000	180,000	
Tuesday	..	..	8,000	171,000	..	30,000	228,500	22,000	22,000	..	..	..	
Wednesday	180,000	16,000	8,000	179,000	81,500	30,000	280,000	22,000	22,000	..	180,000	180,000	All cisterns full.
Thursday	37,500	..	8,000	179,000	30,000	30,000	280,000	22,000	22,000	..	37,500	151,500	
Friday	22,500	8,000	8,000	171,000	..	30,000	250,000	22,000	22,000	..	22,500	60,000	
Saturday	180,000	..	8,000	163,000	..	30,000	220,000	22,000	22,000	..	180,000	..	
Sunday	..	..	8,000	171,000	90,000	30,000	280,000	22,000	22,000	..	..	180,000	
Monday	180,000	24,000	8,000	179,000	..	30,000	250,000	22,000	22,000	..	180,000	..	
Tuesday	..	..	8,000	171,000	90,000	30,000	280,000	22,000	22,000	..	..	180,000	
Wednesday	..	24,000	8,000	179,000	..	30,000	250,000	22,000	22,000	..	..	120,000	
Thursday	180,000	..	8,000	171,000	60,000	30,000	280,000	22,000	22,000	..	180,000	..	
Friday	..	16,000	8,000	179,000	..	30,000	250,000	22,000	22,000	..	..	180,000	
Saturday	..	..	8,000	171,000	60,000	30,000	280,000	22,000	22,000	..	..	..	
Sunday	180,000	..	8,000	163,000	..	30,000	220,000	22,000	22,000	..	180,000	..	
Monday	..	24,000	8,000	179,000	90,000	30,000	280,000	22,000	22,000	..	..	180,000	
Tuesday	..	..	8,000	171,000	..	30,000	250,000	22,000	22,000	..	..	..	
Wednesday	..	24,000	8,000	179,000	90,000	30,000	280,000	22,000	22,000	..	..	180,000	
Thursday	180,000	..	8,000	171,000	..	30,000	250,000	22,000	22,000	..	180,000	..	
Friday	..	16,000	8,000	179,000	60,000	30,000	280,000	22,000	22,000	..	..	180,000	
Saturday	..	..	8,000	171,000	..	30,000	250,000	22,000	22,000	..	..	..	
Sunday	180,000	..	8,000	163,000	..	30,000	220,000	22,000	22,000	..	180,000	..	
Monday	..	24,000	8,000	179,000	90,000	30,000	280,000	22,000	22,000	..	..	180,000	
Tuesday	..	..	..	..	..	..	..	..	..	..	..	..	

APPENDIX C-2.

Project A.

Statement showing probable amount of Pumping monthly, supposing three days' supply sent up at a time.

Date.	Gallons pumped. To filter.	Gallons pumped. To cisterns.	State of pure-water basin at 6 A.M.	Gallons required to fill cisterns at 6 A.M.	Remarks.
S. 1	..	..	Full	6,000	Demand 60,000 gallons per day.
2	..	180,000	Full	120,000	
3	180,000	..	Empty	..	The pumps would be working five days a week alternately on the filter beds and cisterns.
4	..	..	Full	60,000	
5	..	180,000	Full	120,000	
6	180,000	..	Empty	..	For four days it would only be necessary to send up two days' supply at a time; on other days three days' supply must be pumped up, which at 60,000 gallons a day = 180,000 gallons.
7	..	120,000	Full	60,000	
S. 8	..	..	½ full	..	
9	120,000	..	¾ full	60,000	
10	..	180,000	Full	120,000	
11	180,000	..	Empty	..	
12	..	..	Full	60,000	
13	..	180,000	Full	120,000	
14	180,000	..	Empty	..	To fill all the cisterns while meeting the daily demand, would require eighteen days' continuous pumping on the cisterns and filters alternately. See Appendix C-1.
S. 15	..	..	Full	60,000	
16	..	180,000	Full	120,000	
17	180,000	..	Empty	..	
18	..	..	Full	60,000	
19	..	180,000	Full	120,000	
20	180,000	..	Empty	..	
21	..	120,000	Full	60,000	
S. 22	..	..	½ full	..	Lift .. .. 150 feet.
23	120,000	..	¾ full	120,000	Rate of pumping .. 370 gallons per minute.
24	..	180,000	Full	..	Horse power of engine .. 24.
25	180,000	..	Empty	60,000	
26	..	..	Full	120,000	
27	..	180,000	Full	..	
28	180,000	..	Empty	60,000	
S. 29	..	..	Full	120,000	
30	..	180,000	Full	..	
31	180,000	..	Empty	60,000	

APPENDIX C-3.

Project A.

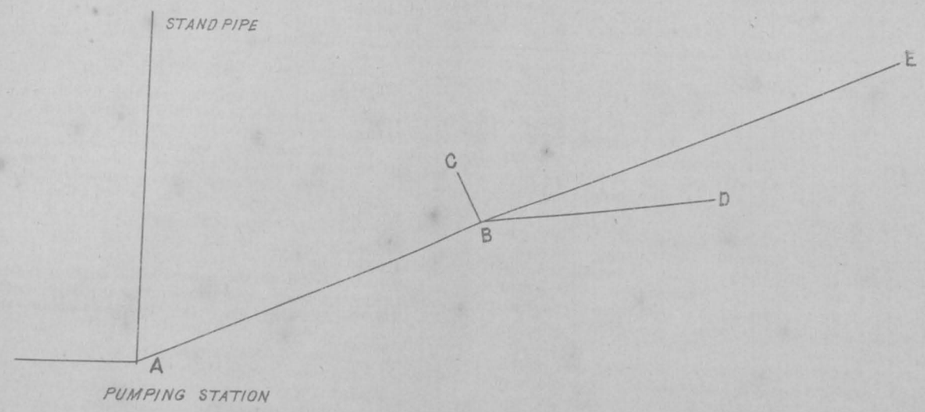
Statement showing probable amount of Pumping required per month, supposing two days' supply sent up at a time.

Date.	Gallons pumped. To filter.	Gallons pumped. To cisterns.	State of pure-water basin at 6 A.M.	Gallons required to fill cisterns at 6 A.M.	Remarks.
S. 1	..	..		..	Demand 60,000 gallons per day.
2	120,000	120,000		60,000	
3	..	..		..	
4	120,000	120,000		60,000	The two pumps would work four days a week, on one day only sending up one day's supply.
5	..	..		..	
6	120,000	120,000		60,000	
7	60,000	60,000		..	
S. 8	..	..		..	
9	120,000	120,000		60,000	Both pumps working for nine days continuously will fill all the cisterns while meeting the daily demand.
10	..	..		..	
11	120,000	120,000		60,000	
12	..	..		..	
13	120,000	120,000		60,000	
14	60,000	60,000		..	Lift .. .. 150 feet.
S. 15	..	..		..	Rate of pumping .. 250 gallons per minute.
16	120,000	120,000	Full ..	60,000	Horse power of engine .. 18.
17	..	..		..	
18	120,000	120,000		60,000	
19	..	..		..	
20	120,000	120,000		60,000	S. = Sundays.
21	60,000	60,000		..	
S. 22	..	..		..	
23	120,000	120,000		60,000	
24	..	..		..	
25	120,000	120,000		60,000	
26	..	..		..	
27	120,000	120,000		60,000	
28	60,000	60,000		..	
S. 29	..	..		..	
30	120,000	120,000		60,000	
31	..	..		..	

APPENDIX D.

Project A.

Calculations for Mains from Ayaram Pumping Station to Barrack Cisterns.



The mains from the pumping station at A will have to deliver water over the stand-pipe at S to the Race-course cistern at C, the Royal Horse Artillery cistern at D, and the European Infantry Barrack cistern at E. The following are the levels, length of mains, &c. :—

Level at pumps at A	... ...	2879·00	
Do. at top of stand-pipe	... ...	3030·00	
Do. of main at B	... ...	2967·00 AB =	6,400 yards.
Do. do. at C	... ...	2975·00 BC =	60 ,,
Do. do. at D	... ...	2973·00 BD =	600 ,,
Do. do. at E	... ...	3000·00 BE =	2,300 ,,

The required discharges are as follows :—

Into the cistern at C	... ...	190 gallons per 1′.
Do. do. at D	... ...	50 do.
Do. do. at E	... ...	130 do.
	Total ...	370

The total quantity must be delivered at B in 8 hours, which at 370 gallons per 1′ = 180,000 gallons.

The question is solved by Box's hydraulic tables—

(1) Assume a 7″ main from B to E. By the tables, the head necessary to discharge 130 gallons per 1 minute through a 7″ pipe = ·00413 feet per yard. Hence head necessary = ·00413 × 2,300 = 9·49 feet. As B is 3000·00 — 2,967 = 33·00 feet below E, the total head required at B to secure the necessary discharge = 42·49 feet, say 42½ feet.

(2) The main BD rises 6 feet from B to D, hence head available at D = 42·50 — 4 = 38·50. The length being 600 yards, the working head = $\frac{38·50}{600}$ = ·0641. The required discharge is 50 gallons per 1 minute, and by the tables a 3″ pipe will discharge this with a head per yard of ·043. A 3″ pipe may be adopted, and will allow a margin for loss of head due to bends, &c.

(3) For the branch to the cistern at C, the head per yard with C 8 feet above B $\frac{38·50 - 8}{60}$ = $\frac{30·50}{60}$ = ·508. To discharge 190 gallons per 1 minute with this head, a 3½″ pipe will more than suffice, the actual head per yard required being ·28 feet.

(4) At B the total head necessary to secure the necessary discharge in the branches is 42·08 feet. The top of the stand-pipe being at 3030·00, and the main at B = 2967·00, the command over B = 63·00 feet and the head available to work on the main AB = 63·00 — 42·50 or 20·50, say 20 feet. Hence head per yard = ·00312. The required discharge at B being 370 gallons per 1 minute, a 12″ pipe would discharge this with a head per yard of ·00228, leaving a margin of 7 feet per head to overcome loss due to bends, &c.

Hence the mains may be as follows :—

AB	...	...	...	...	...	...	...	...	...	12″
BC	...	...	...	...	...	...	...	...	...	$3\frac{1}{2}$″
BD	...	...	...	...	...	...	...	...	...	3″
BE	...	...	...	...	...	...	...	...	...	7

and the above sizes will meet contingence of loss due to bends, incrustation, &c.

Suppose two days' supply at a time pumped up, which would require a discharge of 250 gallons a minute, the water must be delivered in the following proportions :—

At C	...	...	...	...	...	...	124	gallons	per minute.
„ D	...	...	...	...	...	...	30	do.	do.
„ E	...	...	...	...	...	...	96	do.	do.
Total ...							250	gallons	per minute at B.

Calculating as before, it is found that the dimensions may be as follows :—

AB	...	...	...	...	...	...	...	...	9″, say 10″ pipe.
BC	...	...	...	...	...	...	...	...	$2\frac{1}{2}$″
BD	...	...	...	...	...	...	...	...	$2\frac{1}{2}$″
BE	...	...	...	...	...	...	...	...	6″

APPENDIX E.

Project A.

Calculations for Dimensions of Stand-pipe.

It will consist of three cast-iron flanged pipes bolted together in 15 feet lengths, each pipe having a total length of 150 feet. The diameter of each to be 12″ and thickness of metal $\frac{5}{8}$″. Taking the weight of such pipes at 77 lb. per lineal feet, the weight of each length will be $150 \times 77 = 11{,}550$ lb. $= 5{\cdot}15$, say $5\frac{1}{2}$ tons, and total weight of three pipes $= 15\frac{3}{4}$, say 16 tons. The pipes to be connected at the top, and set up with a batta of $\frac{1}{10}$ or 15 feet base.

It is necessary to examine whether the structure is safe, (1) against overturning under wind pressure, (2) against crushing near the bed joints under its own weight, (3) against collapsing inwards under its weight.

(1) *As regards overturning.*—Taking the wind pressure at 50 lb. per square feet horizontal and assuming the pressure on a cylindrical surface to be $\frac{1}{2}$ that on a flat surface, of a breadth equal to the diameter, we have the total wind pressure on one length of pipe $= 1{\cdot}16 \times 50 \times \frac{1}{2} \times 150 = 4{,}350$ lb. $= 2$ tons nearly.

The centre of pressure will be 75 feet above the ground, hence moment of wind pressure about base of structure $= 3 \times 2 \times 75 = 450$ tons. The total weight of the three pipes is $= 16$ tons, and the weight of the braces, &c., would probably amount to at least another ton. Taking, however, the weight of the pipes alone which would act vertically through the apex of the structure, and cut the base at a point 15 feet from the points of contact of the tripod with the base, the moment of stability about any foot will $= 16 \times 15 = 240$ tons, or less than the moment of wind pressure. The structure, therefore,—supposing the pipes to be rigid—will not be quite safe against overturning and must be guyed.

(2) *As regards crushing at the base.*—Each pipe has to support its own weight +, say 1 ton extra material for braces, &c., or say 6 tons. The area of the annulus of the pipe at the base $= 0{\cdot}79$ square inches ; which, taking the resistance to crushing of cast iron at 36 tons per square inch, could sustain a weight of 26·4 tons; giving a factor of safety of about 4. The structure is, therefore, safe against crushing.

(3) *As regards collapsing.*—The long lengths of pipe would have a tendency to bend inwards under their own weight, and this must be met by horizontal compression stays.

Two pipes will always be full of water, hence the weight in each $= 6$ tons $+ \frac{1}{2}$ ton water, say altogether $6\frac{1}{2}$ or 7 tons. This will act vertically through the centre of figure of each pipe, producing a horizontal thrust of about $\frac{1}{2}$ a ton at the centre of the structure. At each joint along the pipes, there will be two horizontal compression stays, and if they are designed to sustain a thrust of $\frac{1}{2}$ ton each, they will be of ample strength and the structure rigid with regard to the effect of its own weight.

For the braces, each section of the pipe must be tied down to the one below to prevent lifting under the wind pressure. If each brace can sustain a tension of 1 ton, they will be amply strong, or $\frac{1}{4}$″ diameter braces will suffice.

For guys. Suppose them to be attached 100 feet from the ground at an angle of 45°. The tension on the guy, supposing the pipe unsupported by the rest of the structure, would be under $\frac{1}{2}$ ton and $1\frac{1}{4}$″ circumference wire rope would be ample,—having a breaking strength of 3 tons.

Calculations of Compression Braces.

Let

W = force in lb. in direction of length $= (\frac{1}{3} \times 2{,}240) = 1{,}120$ lb.
c = ultimate resistance to crushing = 36,000 lb.
a = factor of safety for live load = 8 lb.
$\frac{c}{a} = 4{,}500$ lb.
l = length in inches.
h = dimension in which bending will take place = diameter for round bars.
$q = \frac{1}{3{,}600}$ for both ends fixed.

$$\therefore \quad W = A\frac{c}{a} \div \left(1 + q^2 \frac{l^2}{d^2}\right)$$

$$\therefore 1{,}120 = \frac{22}{7} \times \frac{d^2}{4} \times 4{,}500 \div \left(1 + q^2 \frac{l^2}{d^2}\right)$$

$$\therefore \quad \frac{22}{7} \times \frac{d^2}{4} = \cdot 32 \left(1 + q^2 \frac{l^2}{d^2}\right)$$

$\therefore$ If $l = 216''$ $\quad d = 2\frac{1}{4}''$
$= 108$ $\quad = 1\frac{1}{4}''$
$= 48$ $\quad = \frac{5}{8}''$

APPENDIX F.

Project A.

Calculations for dimensions of Chimney Shaft.

Let a = area of firegrate in square feet = 32,
h = height of chimney in feet,
A = least area of flue in square inches,

$$\therefore \quad A = \frac{108 \times a}{\sqrt{h}}$$

Make diameter at base $\frac{1}{10}\,h$ feet.

$\therefore$ If batta = ·3″ per foot, the diameter at the top will $= \left(\frac{1}{10} - \frac{\cdot 6}{12}\right) h$ feet $= \frac{1}{20}\,h$ feet

$$= \frac{3}{5} h''$$

$$\therefore \quad A = \frac{22}{7} \times \frac{9}{25} \times \frac{h^2}{4}$$

$$\therefore \quad \frac{22}{7} \times \frac{9}{25} \times \frac{h^2}{4} = \frac{180 \times 32}{\sqrt{h}}$$

$$\therefore \quad h^{\frac{5}{2}} = \frac{180 \times 32 \times 28 \times 25}{198} = 20363{\cdot}63$$

$$\therefore \log. h = \frac{2}{5} \log 20363{\cdot}63$$

$$= \frac{2}{5} \times 4{\cdot}3088552$$

$$= 1{\cdot}72354208.$$

Log. $52{\cdot}91051 = 1{\cdot}7235420.$

Chimney may be	...	...	...	...	=	52·90 feet high, say 53 feet.
Top diameter	...	...	...	...	=	2·645 feet, say $2\frac{1}{2}$ feet.
Bottom diameter	...	...	...	...	=	5·290 feet, say $5\frac{1}{2}$ feet.

APPENDIX G.

Project B.

Estimate for Demand for Drinking Water and sizes of Cisterns.

						GALS.
1 Battery, R.H.A.,	260 souls, at 3 gallons	...	...	...	=	780
2 Batteries, R.A.,	423 do.	do.	...	...	=	1,269
1 Regiment, Cavalry,	612 do.	do.	...	...	=	1,836
1 Battalion, Infantry,	1,145 do.	do.	...	...	=	3,435
				Total ...		7,320

There being two cisterns, one high-level cistern for the Infantry and a low-level cistern for the Cavalry, Royal Artillery, and Royal Horse Artillery, they may be made to hold the following quantities:—

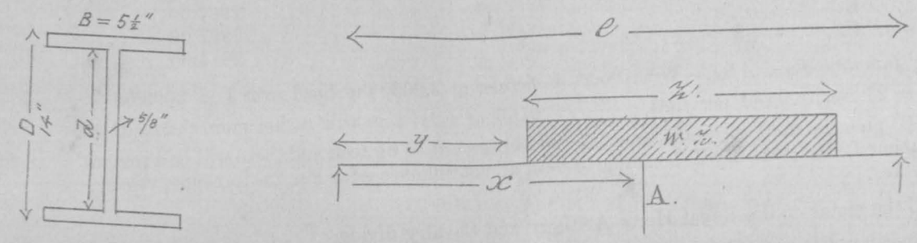
	GALS.
For Infantry	5,651
For Cavalry and Artillery	6,349
Total ...	12,000

which will allow a margin and give a supply per head of 4·6 gallons daily for all the Europeans in the barracks including women and children.

APPENDIX H.

Project B.

Calculation of strength of Girders carrying Cisterns.



The clear span is 24 feet and the larger cisterns 16 × 16 are carried over [illegible] 16 feet of the girder. The total weight full of water being 27 tons, each of the three girders will carry 9 tons on the centre 16 feet.

The section selected is No. 5 on the catalogue of Messrs. Richardson and Cruddas, shown above.

In the figure showing the position of the load which is partially distributed on the girder, the letters have the following values:—

$l = 24'$, $y = 4'$, $z = 16'$, $x = 12'$, $wz = 9$ tons.

The moment of flexure is greatest at the centre A and is equal to

$$\frac{l-(y+\frac{1}{2}z)}{l}\,wzx + \tfrac{1}{2}(x-y)^2 w$$

$$= \frac{24-(4+8)}{24}\,9 \times 12 + \frac{64}{2}\,\frac{9}{16}$$

$$= \frac{9 \times 12}{2} + \frac{64 \times 9}{16 \times 2} = 72 \text{ tons.}$$

The moment of resistance $= \dfrac{f_o\, I}{y_o}$

$$I = \frac{BD^3 - 26\,d^3}{12}$$

$$= \frac{5\frac{1}{2} \times 14^3 - 4\frac{7}{8} \times (12\frac{3}{4})^3}{12}$$

$$= \frac{4948}{12} = 412{\cdot}3.$$

$f_o = 5$ tons, $y_o = 7$

$\therefore$ moment of resistance $= \dfrac{5 \times 412}{7} = 295$ tons

or rather more than four times the moment of flexure. The section chosen is therefore of ample strength. The safe distributed load for this section and span entered on the catalogue is 11 tons.

APPENDIX I.

Project B.

Calculation of sizes of Drinking-water Mains.

For plan and sections of line-piping, see sheet No. 19.

Main ABI	= 5,966	feet,	say	1,990	yards.
Do. ABG	= 2,725	„	„	908	„
Do. GD	= 3,100	„	„	1,034	„
Do. CE	= 1,500	„	„	500	„
Do. FH	= 3,000	„	„	1,000	„

The mains should deliver in six hours at H, D and E the quantity required for the Infantry, Cavalry, Field Batteries and Royal Horse Artillery respectively, *i.e.*—

At I	5,651	gallons, or	16	gallons	per	1 minute say.
„ D	5,082	„	14	„	„	1 „ „
„ E	1,267	„	4	„	„	1 „ „

The levels at these points are—

At I	2988·00
„ D	2967·00
„ E	2957·00
„ H	2944·00

For Infantry Main ABI.—With floor of cistern at 3,009, the head over I = 3009·00 — 2988·00 = 21 feet, $\therefore$ head per yard $= \frac{21}{1990} = {\cdot}0105$, or a 2½″ pipe will rather more than suffice. Using a 3″ pipe the head necessary would be ·0043 per yard or 8½ feet, and there will be a reserve head of about 12 feet, which will be ample to meet all contingence—for loss due to bends, velocity of entry, &c.

At C the mains to the Royal Horse Artillery and Cavalry divide.

The portion CD must deliver 14 gallons a minute at D at a level of 2967·00, the level of C being 2958·50. To discharge 14 gallons a minute through CD with a 2½″ main, the head per yard must be ·00825 or 8·47 feet above D, and a total head at C of 2967·00 — 2958·5 + 8·47 = 16·97.

To deliver the quantity required at C for the Cavalry, Artillery, and Royal Horse Artillery or 18 gallons per minute through a 3″ pipe, the distance being 910 yards, the head per yard must be ·0055 or 5·05 feet the whole distance. Hence the total head above C must be 5·05 + 16·97 = 22·02 feet. This would be obtained with the cistern floor at a level of 2958·5 + 22·02 = 2980·52. It is placed at 2982·00, so that there is a reserve head of 1½ feet to overcome loss due to bends, &c.

The point E being 2957·00 or 1·5 feet below C where the head is 5·05 feet, the total head on the branch CE is 6·55 feet, and the head per yard $\frac{6{\cdot}55}{500} = {\cdot}013$. Hence to discharge 4 gallons per minute, a 1½″ pipe will more than suffice.

The lower cistern at the rock might perhaps be placed 2 feet higher with advantage.

The level at D being 2967·00, and that at the further stand-cock in the Royal Artillery barracks, G, being 2,951, the head on this main is 16 feet. To deliver the quantity for the Royal Artillery of 6 gallons a minute through 1,800 feet, the head per yard being $\frac{16}{600} = {\cdot}026$, or a 1½″ pipe will be ample.

The branch FH to the hospitals is 1,000 yards long and the head 2,966 — 2,944 = 22 feet, $\therefore$ head per yard = ·0022, a ¾″ pipe will discharge nearly 3 gallons per minute.

All the branch pipes to stand-cocks may be ½″ pipes.

The drinking-water mains, therefore, will be as follows:—

ABI	3″ piping.
ABC	3″ „
CD	2½″ „
CE	1½″ „
DF	2″ „
FG	1½″ „
FH	¾″ „

APPENDIX J.

Project C.

Statement showing Tanks along the line of new Supply Channel for the Halsur Tank.

Name of Tank.	—	Acreage in round numbers.	Quantity of water required in cubic feet.	Area of Catchment in Acres.		Discharge of catchment in cubic feet per year of ½rd of the annual rainfall or 12″ is run off from the free catchment.	Sufficient for acres.	Number of acres thrown out of cultivation.	Surplus.	Sufficient for acres.	Remarks.
				Cut off by the channel.	Free catchment.						
Nagianpulya ..	1	10	2,160,000	173·63	56·46	2,459,397	11·4	..	..	..	The first three tanks would only be affected by a channel 9½ miles long. For 52·7 acres thrown out of cultivation, 2,635 rupees compensation must be paid.
Kagadoss ..	2	26	5,616,000	70·97	96·81	4,216,608	19·5	..	..	..	
Bhyeasundra ..	3	8	1,308,000	61·71	137·88	6,002,568	27·7	..	..	..	
Thippasandra ..	4	7	1,512,000	204·96	53·27	2,321,748	10·7	..	..	..	
Kodihally ..	5	12	2,592,000	168·15	203·19	8,851,392	40·9	..	..	..	
Binamangalem.	6			Not affected.							
Kadrayenpolya.	7	64	13,834,000	..	56·32	2,452,428	11·3	52·7	..	..	

APPENDIX K.

Project C.

Statement of dimensions of new Supply Channel from Eastern Catchment.

Mile.	Feet.	Acreage of catchment.	Depth.	Bottom breadth.	$\sqrt{r}$	$a\sqrt{r}$	$c\sqrt{s}$	V in feet per section.	Discharge in cubic feet per 1″.	Inches off area.	Discharge with 1 foot more water.	Remarks.
V	987	50	2	4	1·09	10·87	·99	1·07	10·08	$\frac{1}{8}$″ per hour = 3″ in 24 hours.	16·11	These calculations are for the main channel alone and do not take in the low-level channel cut in the bed to carry off light rainfall.
..	4,262	90	..	5	1·13	13·51	1·02	1·15	13·5		20·30	
..	2,663	180	..	6	1·16	16·19	1·05	1·21	24·8		34·1	
..	1,531	200	..	6	1·16	16·19	1·05	1·21	24·8		34·1	
..	900	254	3	6	1·33	29·9	1·16	1·54	34·5		56·1	
..	500	300	..	7	1·36	34·7	1·17	1·59	40·5		70·3	
IV	..	424	..	9	1·42	44·6	1·21	1·71	53·9		88·9	
..	3,600	450	..	9½	1·42	47·1	1·21	1·71	56·9		94·4	
..	1,800	480	..	10	1·44	49·6	1·22	1·75	59·3		99·3	
III	..	500	..	11	1·46	54·5	1·22	1·78	67·4		109·0	
..	3,000	580	..	12	1·47	59·6	1·23	1·80	73·5		120·7	
II	246	650	..	13	1·49	64·6	1·24	1·84	80·1		128·9	
..	3,351	830	..	15	1·51	74·7	1·25	1·88	93·3		148·9	
I	1,920	1,170	..	23	1·54	115	1·26	1·94	144·9		245·2	
..	4,228	1,250	..	24	1·55	120	1·28	1·98	153·6		247·8	
..	1,900	1,300	..	25	1·58	126	1·30	2·05	163·8		268·3	
..	..	1,417	..	26	1·58	131	1·30	2·05	170·3		277·0	

APPENDIX L.

Project C.

Statement of Position and Dimensions of Waste Weir on New Supply Channel.

Position.			Acreage.		Discharges supposing ¾″ to run off per hour.		Weir.			Remarks.
—	M.	F.	Part of total catchment.	Portion drained by weir.	To be disposed of by weir.	Surplus that channel can carry.	L.	H.	D.	
							FEET.	FEET.	FEET.	
							10	½	12·6	The weirs are placed so that at no point will the channel have to carry a discharge in excess, or only very slightly in excess of what it can discharge at F. C. L.
1		3,793		18	13·5	..	4	..	5·0	
2		2,543	50	6	4·5	6·3	4	..	5·0	
3		1,789		6	4·5	6·3	4	..	5·0	
4		987		6	4·5	7·9	6	..	7·9	
5		577		18	7·5	7·9	6	..	7·9	
6	V	100		18	7·5	7·9	6	..	7·9	
7		4,653		18	7·5	7·9	6	..	7·9	
8		4,260	205	47	33·25	32·6	10	1	35	
9		3,698		50	37·5	32·6	10	..	35	
10		2,663		30	22·5	32·6	6	..	21	
11		2,078		38	28·5	32·6	8	..	28	
12		1,531		45	33·75	74·3	10	..	35	Weirs 13 and 14 might be amalgamated, but it is better to surplus at the points proposed, so as not to interfere with the existing supplies to tanks.
13	IV	..	168	66	49·5	79·3	15	..	52·5	
14		3,758		57	41·75	86·0	12	..	42	
15	III	100	76	76	57	62·2	40	½	50·0	
16	II	3,314		70	52·5	58·0	40	..	50·0	
17		4,885	179	110	82·5	68·4	70	..	88·2	
18		3,796		340	25.5	68·4	200	..	252	
19		2,480	340	88	66	68·4	50	..	63·0	
20		1,065	88	51	38·25	70·0	30	..	37·8	
21		3,650	51	170	72·75	73·2	18	2	180	Tail weir.
22	O	778	1,417							

APPENDIX M.

Project (General).

Particulars of Compound Condensing Direct Acting Steam Engines.

					Remarks.
Nominal horse power	8	12	20	25	
Actual horse power at 60 lb. pressure ..	20	30	50	64	
Diameter of high pressure cylinder ..	7″	8½″	10½″	11¾″	Taken from the catalogues of Messrs. Richardson and Cruddas, Bombay.
Diameter of low do.	12″	14¼″	18″	20″	
Stroke of piston	9″	12″	18″	20″	
Diameter of crank shaft	3¼″	3¼″	4¾″	5½″	
Length of do. (over all)	4′ 6″	5′ 3″	6′ 2″	7′ 0″	
Diameter of fly wheel	3′ 0″	3′ 9″	6′ 0″	7′ 3″	
Width of face of fly wheel	8″	9½″	14″	15″	
Number of revolutions per minute.. ..	175	140	95	85	
Price of engine	Rs. 1,100	Rs. 1,550	Rs. 2,550	Rs. 3,200	
Feed pump	,, 60	,, 80	,, 95	,, 100	
Condenser and connections	,, 510	,, 630	,, 825	,, 900	
Automatic expansion gear	,, 185	,, 185	,, 430	,, 430	
Foundation plates and bolts	,, 30	,, 40	,, 45	,, 50	
Weight of engine complete	Cwt. 30	Cwt. 56	Cwt. 120	Cwt.150	

APPENDIX N.

Project.—(General).

Particulars of Boilers.

					Remarks.
Nominal horse power... ...	8	12	20	25	
Length	14′ 6″	17′	23′	25′	Taken from the catalogues of Messrs. Richardson and Cruddas, Bombay.
Height	...	...	...	...	
Diameter	4′	4′ 8″	5′ 4″	6′	
Weight complete, horizontal.	Cwt. 55	Cwt. 77	Cwt. 125	Cwt. 182	
Do. vertical ...	,, 29	,, 42	,, 60	,, 73	
Price complete, horizontal ...	Rs. 1,400	Rs. 2,100	Rs. 3,375	Rs. 4,950	
Do. vertical ...	,, 1,375	,, 1,575	,, 2,350	,, 2,800	

APPENDIX O.

		Agram Tank.	
Total solids ...	Grms. per litre	0· 46	Without filtration 1·07.
Volatile solids ...	Do. do.	0· 17	Do. do. 0·24.
Chlorine ...	Do. do.	0·071	
Total hardness	Clark's scale	3°·85	
Permanent hardness	Do. do.	1°·4	
Free ammonia ...	Mlgrms. per litre	0·16	
Albumenoid ammonia	Do. do.	0·40	
Nitric acid ...	Do. do. ... .. (as ammonia)	9·0	
Apparent quality of the water as inferred from the results obtained on examination		Bad	

Remarks.—The water is very opaque and of brownish yellow color owing to suspended mud. Ordinary print can scarcely be distinguished through $\frac{3}{4}$ inch of it. It is still muddy after several filtrations through paper. The water remains muddy after keeping for 48 hours. It clears pretty well after boiling. The deposit is principally clay and sand. The albumenoid ammonia is probably mainly of vegetable origin. The most favorable feature of the water is its softness. This water might *perhaps* be rendered of good potable quality by filtration through sand and charcoal after depositing heavier suspended matters in settling tanks, but the filters would require frequent cleansing. It is still very muddy after filteration through three inches of sand.

APPENDIX P.

From Brigadier-General R. C. STEWART, Quartermaster-General, to the Secretary to Government, Military Department, dated Ootacamund, 18th September 1884, No. 981 C.

I have the honor, by order, to submit, for the consideration of Government, letter No. 349, dated 30th August 1884, from the General Officer Commanding Bangalore Division, requesting the publication of the analysis of three samples of water taken on the 24th August 1883 from the sources as per margin, and to state that His Excellency the Commander-in-Chief sees no objection to the analysis being published.

I. Direct from Halsur tank.
II. After passing through the filter bed.
III. Dhobies' wells.

From Major-General H. ROWLANDS, V.C., C.B., Commanding Bangalore Division, to the Quartermaster-General, Ootacamund, dated Bangalore, 30th August 1884, No. 349.

I have the honor to forward letter, No. 202, dated 27th August 1884, from the Engineer in Charge, Halsur Water Works, with copies of analysis of three samples of water taken on 9th May 1883 and on 24th August 1883.

2. The analysis of the water taken on the 9th May 1883 appears in the report on the water-supply of Bangalore by the Chief Engineer on special duty, dated 31st March 1884, as shown in appendix No. 26 B., page 95 of that report. The three different samples of this water are reported as "bad."

Proceedings of Government, No. 1473 W., dated 13th June 1844.

3. But the three samples of water taken on the 24th August 1883 from the same sources are reported by the Chemical Examiner to be—No. I "bad," Nos. II and III "usable." This analysis does not appear in the report alluded to.

4. I have, therefore, the honor to solicit the publication of the analysis of the water taken on 24th August 1883.

From J. SMITH, Esq., Engineer in Charge, Halsur Water Works, to the Assistant Quartermaster-General, Bangalore Division, dated Bangalore, 27th August 1884, No. 202.

I have the honor to enclose, for your information, a copy of the analysis of three samples of water taken on the 9th May 1883, and shown in appendix No. 26 B. of the report on the water-supply of Bangalore by the Chief Engineer on special duty, dated 31st March 1884.

It will be seen from this analysis that the water is stated to be bad. This was probably owing to the long drought which prevailed at that time,—only half-an-inch of water having been received into the tank for upwards of four months before these samples were taken,—as also to the water in the tank being very low, viz., 5 feet $11\frac{1}{4}$ inches below the level of the waste weir, and to the large quantity of water being used at that time, viz., 72,249 gallons per diem.

I also beg to enclose a copy of the analysis of three samples of water taken from the same places as those above alluded to on the 24th August 1883, or three and-a-half months later, and after the

tank had received $18\frac{3}{8}$ inches of fresh water, which shows that the water taken after passing through the filter bed * and that taken from the Dhobies' wells† was *usable;* the quantity of water used at this time being 52,144 gallons per diem.

* No. 3.
† No. 2.

As this analysis does not appear in the report above alluded to, I would respectfully submit that, in fairness to the general quality of this water, the analysis of the samples of water taken on the 24th August 1883 should be made as well known as the analysis of the samples of water taken on the 9th of May 1883 and published in the Chief Engineer's report of 31st March 1884.

		No. 1. Sample of water taken direct from the Halsur tank.	No. 2. Sample of water taken direct after passing through the filter bed.	No. 3. Sample of water taken direct from the Dhobies' wells.
Total solids	Grms. per litre.	0· 27	0· 26	0· 23
Volatile solids	Do. do.	0· 12	0· 06	0· 09
Chlorine	Do. do.	0·081	0·078	0·053
Total hardness	Clark's scale	3°· 5	2°· 8	3°· 86
Pemanent hardness	Do. do.	2°· 45	1°· 75	3°· 15
Free ammonia	Mlgrms. per litre.	0· 4	0· 48	0· 08
Albumenoid ammonia	Do. do.	0· 56	0· 48	0· 8
Nitric acid	Do. do.	3· 0	3· 0	3· 3
Remarks.				
Apparent quality of the water as inferred from the results obtained on examination		Bad.	Bad.	Bad.

Remarks.—No. 1. Deposit abundant and composed of vegetable debris.
No. 2. Deposit scanty and composed of vegetable debris and argillaceous matter.
No. 3. Deposit scanty and composed of vegetable debris. All three samples contain a very large amount of organic impurity.

(True Copy.)

(Signed) E. H. EYRE, Lieut.-Col.,
Offg. Deputy Quartermaster-General.

Taken 9th May 1883.

		No. 1.	No. 2.	No. 3.	Remarks.
Total solids ...	Grms. per litre.	0· 27	0· 25	0· 31	No. 1—A sample of water taken direct from the (Halsur) tank at 4 p.m. on the 24th August 1883.
Volatile solids ...	Do. do.	0· 08	0· 07	0· 08	
Chlorine ...	Do. do.	0·085	0·042	0·089	
Total hardness ...	Clark's scale ...	2°· 8	2°· 45	3°· 5	No. 2—A sample of water taken direct from the Dhobies' wells on the 27th August 1883.
Permanent hardness.	Do. do.	1°· 4	1°· 75	1°· 75	
Free ammonia.	Mlgrms. per litre.	0· 4	0· 24	0· 48	
Albumenoid ammonia.	Do. do.	1· 92	0· 4	0· 48	No. 3—A sample of water taken direct from the Halsur tank water after passing through the filter bed on the 24th August 1883.
Nitric acid	Do. do. (as ammonia)	0· 75	2· 4	2· 4	
Apparent quality of the water as inferred from the results obtained on examination.		Bad.	Usable.	Usable.	

Remarks.—No. 1. A very abundant deposit composed of vegetable debris.
No. 2. A scanty deposit composed of vegetable debris and sand.
No. 3. A very scanty deposit composed of vegetable debris and argillaceous matter.
No. 2. Is the best sample.

(True Copy.)

(Signed) J. SMITH.

No. 4665, Military.

Transferred to the Public Works Department.

(By Order.)

(Signed) A. R. KENNEY-HERBERT, Lieut.-Col.,
Offg. Secretary to Government.

19th September 1884.

ORDER—dated 2nd October 1884, No. 2438 W., Public Works.

Recorded in continuation of G.O., No. 1473 W., dated 13th June 1884.

(True Extract.)

(Signed) J. SHAW-STEWART, Colonel, R.E.,
Secretary to Govt., P.W.D.

APPENDIX Q.

PROJECT (GENERAL).

Tabulation of results of above analyses.

—	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.
Total solids .. Grms. per litre.	0·428	0·27	0·27	0· 26	0· 25	0· 23	0· 31	0· 25	0· 25	0·46
Volatile solids .. Do. do.	0·043	0·12	0·08	0· 06	0· 07	0· 09	0· 08	0· 10	0· 10	0·17
Chlorine .. Do. do.	0·043	0·08	0·08	0·078	0·042	0.053	0·089	0·043	0·043	0·07
Total hardness .. Clark's scale ..	..	3°· 5	2°· 8	2°· 8	2°· 45	3°· 86	3°· 5	4°· 2	4°· 55	3°·85
Permanent hardness. Clark's scale	4°	2°·45	1°· 4	1°· 75	1°· 75	3°· 15	1° 75	1°· 75	1°· 4	1°· 4
Free ammonia. Mlgrms. per litre	0· 05	0· 4	0·42	0· 48	0· 24	0· 08	0· 48	0· 12	0·096	0·16
Albumenoid ammonia. Mlgrms. per litre ..	0· 10	0·56	1·92	0· 48	0· 4	0· 8	0· 48	0· 16	0· 16	0·40
Nitric acid .. Mlgrms. per litre.	..	3·00	0·75	3· 0	2· 4	3· 3	2· 4	3· 0	3· 0	9·00
Apparent quality of the water as inferred from the results obtained on examination ..	U	B	B	B	U	B	U	U	U	B

A. Dr. Parkes' standard for usable water.
B. Halsur tank water, May 1883.
C. Do. do. August 1883.
D. Do. do. May 1883, filtered.
E. Dhobies' wells water, August 1883.
F. Dhobies' wells water, May 1883.
G. Halsur tank water, August 1883, filtered.
H. Agaram do. May 1884.
I. Do. do. do.
J. Do. do. August 1884.

APPENDIX R.

Letter from the Surgeon-General, Her Majesty's Forces, to the Quartermaster-General, dated 18th August 1884, No. 180 O.

I have the honor, with reference to G.O., No. 1814 W., dated 25th July 1884, to remark as follows for the information of His Excellency the Commander-in-Chief.

2. In paragraph 1 of the above, the alternative scheme is alluded to, viz., that for supplying drinking water from the Dhobies' wells by condensation, while for ablution purposes, water is to be drawn from the Halsur tank. With reference to this, I beg to point out to His Excellency that the dual supply here proposed for the use of the men is, in my opinion, objectionable. It will be very difficult, if not impossible, to prevent men from making use of the impure ablution water for drinking purposes. Enteric fever has been very prevalent amongst the cavalry and artillery during the present year, and since the occurrence of rain, there has been a renewed outbreak of the disease in the infantry regiment, there being at the present time as many as thirteen cases under treatment in the north station hospital.

3. In connection with this matter, I beg to remark that as regards the Dhobies' wells supply I do not consider that the large natural filtration of this water through the laterite bank is any safeguard against such subtle impurities as the germs of typhoid or any other contagious fever. It is well known that the enteric fever poison has passed from village to village in England by

means of water which has filtered naturally through long distances of solid earth, and I allude to the subject, particularly, at the present time to show that, in the event of the condensing apparatus breaking down hereafter, the garrison would be dependent for its water upon the Dhobies' wells, a supply which would be dangerous to health.

4. I therefore beg to represent the great need for a supply of pure water being provided for the garrison of Bangalore, and this end can, I believe, be best attained by the abandonment of the Halsur tank altogether and the adoption of the Agaram tank scheme.

Letter from the Quartermaster-General, to the Secretary to Government, Military Department, dated 20th August 1884, No. 768 C.

The Commander-in-Chief has perused order of Government, No. 1814 W., Public Works, dated 25th July 1884, relating to the Bangalore water-supply, which was communicated to His Excellency with G O., No. 3812, dated 7th August 1884, and which provides for consideration of the alternative scheme suggested by Colonel Mullins, R.E., for condensing a supply of water from the Dhobies' wells at Bangalore sufficient to meet the requirements of the troops for all drinking and cooking purposes.

2. The Commander-in-Chief cannot too strongly deprecate the entertainment of any measure which would tend to perpetuate the use of the waters of the Halsur tank, and His Excellency desires me to say he hopes the Government will support him in the opinion he has already expressed that the Halsur tank should be entirely abandoned as a source of supply of water.

3. I am herewith to forward, for the perusal of Government, a letter on this subject (number and date as per margin) from the Surgeon-General, Her Majesty's Forces, and to express the Commander-in-Chief's entire concurrence in the views therein contained.

No. 180 O., dated 18th August 1884.

4. However pure the water may become after condensation, it must be remembered that the water drawn from the Halsur tank for all purposes besides that of cooking and drinking, must reach the barracks by the same means and through the same pipes as the pure water, and the difficulties of preventing men and families from using the impure water would, in Excellency's opinion, be insurmountable.

5. It would, moreover, be extremely dangerous to rely on a single condensing apparatus for supplying pure water, there being no source to fall back upon in case of accident, except that which has been universally condemned.

6. This question of water-supply at Bangalore has been for many years under discussion, and it has at last arrived at a stage at which a solution seems possible. An experienced officer has reported on the feasibility of a scheme which is calculated to afford a pure supply of water, and His Excellency trusts Government will concur with him in thinking it exceedingly impolitic to consider any scheme which contains the retention of the Halsur tank as a source of supply.

No. 4497, Military.

Transferred to the Public Works Department for consideration and orders.

(By Order.)

(Signed) A. R KENNEY-HERBERT, Lieut-Colonel,
Offg. Secretary to Government.

12th September 1884.

No. 673 E, Public Works.

Endorsement in the Military Department, No. 4497, *dated* 12*th September* 1884, *on letter from the Quartermaster-General, dated* 20*th August* 1884, *No.* 768 *C.*

Copy forwarded to Captain Romilly, R.E., through the Superintending Engineer, V Circle, in continuation of G.O., dated 25th July 1885, No. 1814 W.

2. The objections urged by the Military authorities to the alternative scheme for condensation at the Dhobies' wells should be carefully considered and dealt with in the report under preparation.

(Signed) J. SHAW-STEWART, Colonel, R.E.,
Secretary to Government, P.W.D.

OOTACAMUND,
15th September 1884.

No. 2358.

Forwarded to Captain Romilly, R.E., Executive Engineer, on Special Duty at Bangalore.

(Signed) H. L. PRENDERGAST, Colonel, R.E.,
Superintending Engineer, V Circle.

18th September 1884.

APPENDIX S.

Statement showing the Lands below the Agaram Tank.

Village.	Particulars of Land.	Description of Land. Dry. Extent.	Dry. Assessment.	Wet. Extent.	Wet. Assessment.	Garden. Extent.	Garden. Assessment.	Irrigation. Cess.	Total. Extent.	Total. Assessment.	
		AC. GS.	RS. A. P.	AC. GS.	RS. A. P.	AC. GS.	RS. A. P.	RS. A. P.	AC. GS.	RS. A. P.	
Agaram.	Kandayem land.	26 2	34 6 0	53 26	263 2 0	7 21	66 0 0	30 8 0	87 9	394 0 0	
	Kharat land ..	4 8	5 2 0	19 17	82 8 0	..	..	..	23 25	87 10 0	
	Inam land ..	2 21	3 0 0	36 9	167 8 0	..	..	..	38 30	170 8 0	This includes dry land also as per account.
		32 31	42 8 0	190 12	513 2 0	7 21	66 0 0	30 8 0	149 24	652 2 0	

BANGALORE,
12th August 1884.

(Signed) A. W. MACINTIRE,
Deputy Commissioner.

APPENDIX T.

From the Deputy Commissioner, Bangalore District, to the Executive Engineer, on Special Duty, dated Bangalore, 6th November 1884, No. 1138.

With reference to your letter, No. 145, dated 29th ultimo, I have the honor to state that the lands below the Agaram tank are held by inamdars and ryots, of whom some have already expressed their intention to retain their lands if the assessment is altered into dry rates, and others will have to be sent for, and after taking their statement, exact amount of compensation is to be fixed. This will take much time, so a rough calculation has been made, which amounts to about Rs. 4,000.

APPENDIX U.

From the Assistant to the Resident in Mysore, to the Executive Engineer, on Special Duty, Madras Public Works Department, dated Bangalore, 15th October 1884, No. 1454/760.

With reference to your letter, No. 127, dated 7th instant, I am directed to state that the Resident has no doubt that the Mysore Government would agree, if pressed to do so, to the taking up of the land on which the houses of the Jacksundra village stand and the removal of the houses to another site in the same village estate on the other side of the road; but compensation would have to be paid to the Government and to the villagers for both plots of land, and to the villagers also for disturbance and for damage to houses, &c., by removal and for cost of reconstruction; all this would, I am to add, probably cost some 5,000 rupees or more, and if the villagers are to be prohibited in future from bathing, watering cattle, and washing in the tank as heretofore, a small separate tank would have to be constructed for them for these purposes, near the village, below the waste weir of the tank.

2. After visiting the place, Mr. Lyall thinks, and understands that you agree with him, that the drainage of the village can be diverted from the tank without moving the village; if so, it seems to the Resident that it would be better not to move the village at any rate till necessity is proved, but simply to make a diverting drain and to construct a small separate tank for watering cattle, &c.

3. If you require estimates of cost of removing the village, Mr. Lyall will ask the Durbar to allow the Deputy Commissioner to have them prepared.

4. The Resident observes that it is assumed that by raising the weir and embankment of the tank, and so increasing its capacity, all necessity of paying compensation for damage to wet cultivation will be avoided. This does not seem to Mr. Lyall to be a safe assumption. In seasons of scanty rainfall the supply of water in the tank will often probably be low, even when its capacity has been increased. The Military authorities are then likely to object to water being drawn off for cultivation and disputes will occur.

5. The taking up for cantonment supply of a tank used hitherto by villagers for irrigation, as well as for other purposes, is, in fact, rather a difficult business, and it is not easy to decide how the compensation ought to be assessed; if you wish, Mr. Lyall will ask the Durbar to have an estimate prepared.

APPENDIX V.

From A. NORMANDY, Esq., to Captain F. J. ROMILLY, R.E., Executive Engineer, on Special Duty, Public Works Department, Bangalore, dated London, E., 15th August 1884.

In reply to your letter, dated 14th ultimo, respecting the water-supply at Bangalore, I beg to observe as follows:—

The annexed No. 1 Condenser List gives particulars of the various sizes and kinds of our distilling machinery; they all produce good cold drinking water from sea or brackish water, but, as you will observe, the economy of coal varies very considerably according to the kind of apparatus selected.

If you require a large quantity of water produced per day, with a small consumption of fuel, the kind of apparatus most suitable for your requirements would be our complete treble or quadruple distilling machinery, including as described in note A of annexed No. 1 Condenser List, and we have supplied several large machines of this type for the Government at Aden and Gibraltar, also for private Companies.

I therefore send you below estimates for a few sizes of these types, and the cost of other sizes would be in nearly the same proportion to the production.

The annexed drawing No. 624 shows two complete arrangements of treble distilling machinery including as described in note A of annexed No. 1 Condenser List, and the dimensions A, B, F, for various sizes would be as marked on this drawing.

The general arrangement of double and quadruple distilling machinery would be very similar to that of the treble distilling machinery as shown on annexed drawing No. 624, but, for *equal daily productions*, the boilers would be *larger* in the double distilling and *smaller* in the quadruple distilling, and the dimensions A, B, F, would be nearly the same in the quadruple distilling, but in the double distilling the dimensions A and B would be rather larger.

The machinery could be arranged to burn wood instead of coal if desired, but of course much more would be required as it is an inferior fuel.

As to using the existing pumping engine in connection with our distilling machinery, possibly it might be used to pump up, somewhere, the condensing water usually allowed to run to waste from our distilling machinery, as it escapes therefrom at about 120° Fah. and might be useful for other purposes, if the blow off water from the boiler was not run into the waste water pipe as shown on drawing No. 624; but to secure really good cold drinking water and economy of fuel, you should have our complete arrangements as described.

We shall be happy to render any further information you may require.

Number of estimate.	Gallon of water produced per 24 hours.	Gallons of water produced per 1 ton of coal.	Prices of complete machinery packed and delivered in London.
			£
1	9,000	3,400	2,689
2	...	4,200	3,052
3	...	4,800	3,560
4	12,000	3,470	3,538
5	...	4,500	4,046
6	...	5,150	4,720
7	15,000	4,500	4,946
8	...	5,150	5,770

Above are the estimates for complete arrangements of Normandy's patent distilling machinery for producing good cold drinking water from sea-water, including as more particularly described in annexed printed estimate form.

Prices of other sizes in about the same proportion to the production.

Estimate for complete sets of Normandy's improved patent distilling machinery for producing good cold drinking water from sea-water, and for forcing the fresh water to a great height or distance, with letter, 15th August 1884, to Captain Romilly.

The drinking water, as it flows from under-mentioned machinery is clear, cold, bright-looking and agreeable, without any peculiar taste, and equal in quantity, taste, and appearance, to the best river-water as usually supplied for drinking in towns.

(*See the reports on other side.*)

Full instructions for putting together and working will be supplied with the machinery, and, if desired, special arrangements will be made for the machinery to be supplied and erected

abroad, *and also worked for an agreed time, the consumption of coal, and the quantity and quality of the fresh water produced being guaranteed.*

NOTE A.—Under favorable circumstances, this machinery will produce from 20 *to* 30 *per cent. more water* per 24 hours, than is stated below, and the quantity of fresh water produced by 1 ton of coal will be increased *by* 10 *to* 15 *per cent.* *See results of Flushing trial on other side.* For long continued working, however, the best results will be obtained by working so as not to produce much more than the quantity specified below, as the production per 24 hours.

Each *complete set of machinery* includes one of Normandy's improved patent condensers with filter, suitable steam boiler and steam pumps for supplying sea-water to the condenser, and boiler, and for *forcing the fresh water produced to a great height or distance.* Also *all connecting parts and pipes in between above, the whole being arranged to a suitable plan, ready for putting together on a level surface abroad.* It also includes iron chimneys for the boilers, complete with guy chains, 40 yards of suction pipe from sea to machinery, 20 yards of waste sea-water pipe, and 20 yards of fresh water delivery pipe. Also a quantity of useful stores and tools, such as spare fire bars, stoking and cleaning tools, spanners for tightening up, oil cans, gauge glasses and sundry useful stores, so that the whole may be readily set to work, and kept in order without delay or difficulty. The surface on which the machinery stands should not be more than 8 yards (or 7 metres) above the sea level.

The condenser tubes are of solid brass, tinned inside and outside. The pumps are of strong and simple consumption, and easily adjustable to compensate for wear. The water is drawn and forced by plungers moving through stuffing boxes, easily packed and kept tight by an *external* gland, thus avoiding the troublesome, and difficultly repaired leaks, which so frequently stop other kinds of pumps. They *work at a moderate speed*, so as to avoid the excessive wear, and knocking about of the valves and other parts, always resulting from quick speed. They have fly wheels, and have all valves, bearings, plungers and working parts in contact with water, made of *brass or copper, wrought-iron crank shafts, and steel piston rods.* The *boilers* have furnace plates of *low moor or bowling iron*, and have dampers, Bourdon's pressure gauges, safety valves, *and all necessary fittings.* They are proved to double the working pressure, and the working pressure is from $\frac{1}{6}$ to $\frac{1}{8}$ of the bursting pressure.

NOTE B.—If delivered in less than the maximum times stated below, then 4 per cent. extra on prices for every 10 per cent. less time.

Number of Estimate.	1	2	3	4	5	6	7	8
Number of complete and independent apparatus included in each estimate ..	1	1	1	1	1	1	1	1
Type of the apparatus included in each estimate (single, double, or treble distilling) ..	Double.	Treble.	Quadruple.	Double.	Treble.	Quadruple.	Treble.	Quadruple.
Type of boilers included in each estimate ..	Lancashire.	Do.	Do.	Do.	Do.	Do.	Do.	Do.
Fresh water produced per 24 hours. (See Note A above.)								
Gallons	9,000	9,000	9,000	12,000	12,000	12,000	15,000	15,000
Tons, or cubic metres (1 *cub. metre equals* 1,000 *litres or kilogs.*)	..	..	..	..	..	..	..	..
Economy of Coal. (See Note A above.)								
Coals consumed for producing the quantities of water stated above as the production per 24 hours (weight in tons or 1,000 kilogrammes)	..	..	..	..	..	..	..	..
Gallons of water (or cubic metres) yielded per 1 ton (or 1,000 kilogrammes) of coal ..	3,400	4,200	4,800	3,470	4,500	5,150	4,500	5,150
Time required from receipt of order for delivering the machinery in London.								
Days for delivering all the independent apparatus included in above estimates	to	to	to	to	to	to	to	to
or else (See Note B above.)								
Days for delivering the first independent apparatus included in above estimates	to	to	to	to	to	to	to	to
Do. do. second do. do. ..	to	to	to	to	to	to	to	to
Do. do. third do. do. ..	to	to	to	to	to	to	to	to
Do. do. fourth do. do. ..	to	to	to	to	to	to	to	to
Prices delivered packed and free on board in London.								
Prices for *all* the complete apparatus in each estimate as described above .. £	2,689	3,052	3,560	3,538	4,046	4,720	4,946	5,770
Extras if required.								
Iron roofs supported on iron columns to contain the above machinery .. £	..	..	..	..	..	..	..	..
Tanks of galvanized iron to contain the quantities of fresh water stated above as the production per 24 hours .. £	..	..	..	..	..	..	..	..

Reports on Normandy's improved patent machinery for producing from sea-water, pure, cold, and agreeable fresh water for drinking purposes.

Result of the trial of Normandy's improved patent distilling machinery, erected at Flushing for the Dutch Government, January and February 1877.

This machinery was supplied as suitable for producing 6,000 gallons, or 27 cubic metres of good cold drinking water, per 24 hours, from sea-water.

By the direction of Mr. Van Diesen, Chief Engineer of the Waterstaat, in the Province of Zealand, Holland, this machinery was carefully tested by being worked under the inspection of officials appointed for the purpose, the result being, that *in* 19 *hours' work*, this machinery produced 28,500 litres of fresh water, and consumed 1,545 kilogrammes of coal. This is equal to 6,270 gallons (or 28 tons) of fresh water, produced with $1\frac{1}{2}$ tons of coal in 19 *hours' work.*

The fresh water produced, as it flowed from the machinery, *was bright-looking, clear, cold, and agreeable, without any peculiar taste, and, in fact, equal in appearance and taste to the best river or spring-water.*

It will be seen, therefore, that this machinery, when worked *for* 19 *hours*, produced 33 *per cent. more water than it was told to produce* in that time, and yielded 4,100 *gallons* (*or* 18·3 *tons*) *per* 1 *ton of coal* (equal to 18·3 cubic metres per 1,000 kilogrammes of coal); the economy of coal would have been still greater, had the machinery been less overworked, as similar machinery at *Aden* and *Alicante* has yielded over 20 *tons* of water per 1 ton of coal (or 20 cubic metres per 1,000 kilogrammes of coal).

In the above trial, the productive power and consumption of coal were ascertained as follows:—The machinery having been fairly started, *the coals were removed from the furnaces* and the working was continued under inspection, with *weighed coals.* After 19 *hours'* working, *the unconsumed coals were removed from the furnaces and weighed*, and their weight was deducted from the quantity of weighed coals put into the furnaces the difference being taken as the weight consumed. The fresh water produced from the sea-water was collected in an iron tank and carefully measured. The results were as above stated.

OPINION OF DON JOSE SOLER Y SANCHEZ.

Licentiate in Pharmacy, Doctor in Sciences, late Professor of Chemistry to the Faculty of Sciences of University of Madrid, Professor of Chemistry and Physics to the Institute of Alicante, &c., &c.

I hereby certify that having analysed in my laboratory a sample of pure fresh water in order to see if the same was drinkable, and which sample was delivered to me by the Presidente Alcalde (Mayor) of the most illustrious Municipality of Alicante, the said sample being drawn according to his declaration from Mr. Normandy's distilling engine.

This sample of fresh water was received in the presence of the Notary, Mr. Nereo Albert, in two glass bottles duly sealed and stamped with the letters J.C.B., the result being as follows:—

1*st.* Its hyrotimetrical degree is 5°.
2*nd.* A litre of water contains 0,085 grammes of mineral substance.
3*rd.* Does not contain any organic matter.
4*th.* Contains 1,764 c.c. of air per litre of water.
5*th.* Does not prevent soap from dissolving.
6*th.* Is clear, without colour, limpid, and transparent.

Therefore, by its character and condition, it is to be considered *a most eminently drinkable water.*

And in order that the interested party make use of this certificate as he may think fit, at his own request I grant the present document attaching my signature thereto.

(Signed) Dr. J. SOLER Y SANCHEZ.

ALICANTE,
11th September 1879.

REPORT OF DR. NOAD, F.R.S.

I find the water to be *absolutely free from organic matter*, which all river and well waters contain, more or less, and which is acknowledged to be a predisposing cause of disease, it is also bright, colourless, well aërated and agreeable, and it contains an exceedingly small percentage of saline matter, which is the case with all waters derived from the best natural sources.

From a sanitary point of view, I consider this water to be quite equal, and, in its absolute freedom from organic matter, superior to that obtained from the purest natural sources, it is therefore well suited for alimentary purposes.

(Signed) HENRY M. NOAD, PH.D., F.R.S.,
Professor of Chemistry at St. George's Hospital, London.

REPORT OF DR. LETHEBY, M.B., M.A.

The sample was colourless and well aërated, and it was agreeable to the palate. It contained a very small proportion of saline matter, which I regard as an advantage, as it approximates the quality of the water to that derived from the best natural sources. For dietetical purposes, the proper aëration of the water is essential. *The water was absolutely free from organic matter*, and it is very soft.

I am of opinion, from these results, that the water is very wholesome and is well adapted for all domestic purposes.

HY. LETHEBY, M.B., M.A., &c.,
Professor of Chemistry in the Medical College of the London Hospital and Medical Officer of Health for the City of London.

KRASNOVODSK, 1st October 1880.

I, the undersigned, *Doctor of Medicine, Doctor-in-Chief of the Trans-Caspian Expedition*, certify that the water of the Caspian Sea, rendered potable by Normandy's distilling apparatus has been submitted to me, by being taken as it flowed from the apparatus, and that after an examination of fifteen days I found it to have the following qualities:

The water was *perfectly pure, free from all organic matters, contained a sufficient quantity of air*, was without any taste of machinery, or of any other unpleasant flavor. I personally used it, and found it suited me well. I consider it *perfectly suitable for alimentation, and for all domestic purposes.*

In consideration of which I have delivered the present certificate.

DOCTOR OSCAR HEYFELDER,
Councillor of State.

All sizes supplied, producing from 100 to 15,000 gallons of water per 24 hours, and yielding up to 20 tons, or 4,480 gallons of water per 1 ton of coal consumed.

APPENDIX W.

Extracts from Report by Colonel Mullins, R.E., Consulting Engineer on Water-supply of Bangalore.

* * * * *

32. *Halsur Tank.*—This tank, the present source of water-supply for the European troops, had naturally a catchment basin of about square miles ... ... 5·50
A small portion of the western part of this area was diverted prior to the early part of the century into the Sampangi tank ... ... 0·33
5·17

And between the years 1854 and 1867 the construction of the four tanks known by the name of Miller's tanks, near the Madras Railway (cantonment) station, further curtailed the area by ... ... 0·53

Present effective area ... 4·64

In 1877 an upper Halsur tank was formed by throwing a bund across the northern margin of the old tank, and the catchment is now divided therefore into two sections of 2·54 and 2·10 square miles, respectively, for the supply of the upper and lower tanks. The upper tank discharges its surplus into the lower, and its contents are also from time to time turned into the lower tank to supplement the supply of the latter when required.

33. The greater part of the catchment or gathering ground of the lower tank, with the exception of less than one-fifth of a square mile to the eastward, is occupied by the large population of the cantonment bazaar, and, until the completion of the main sewer in 1864, most of the filth from a population of about 75,000 was washed down into the tank whenever a heavy fall of rain occurred. The sewer has much improved matters, as it is capable of carrying off all the bazaar drainage, provided the rainfall does not exceed about one-tenth of an inch an hour. There is no doubt, however, that the water flowing into the tank after a considerable period of dry weather followed by heavy rainfall is decidedly foul and unsuitable for drinking and culinary purposes.

The whole of the drainage of the 1·68 square miles which reaches the tank by the western feeder, which runs from just below the lowest of Miller's tanks, through the bazaar, might without difficulty be diverted from the tank by running a bund across from the culvert by which it passes

REPORT ON THE WATER-SUPPLY OF BANGALORE.

Appendix to G.O., No. 2292 W., dated 10th September 1886.

INDEX TO ESTIMATES ACCOMPANYING REPORT AND PLANS FOR WATER-SUPPLY FOR EUROPEAN TROOPS AT BANGALORE.

Number of Estimates.	Amount.	Reference.		Subject.
		Paragraph of Report.	Number of Plan.	
		PROJECT A.		
	Rs.			
1	17,010	5	5, 6, 7, 8, 9	Increasing capacity of Agaram tank.
2	16,290	6	3, 5, 10	Settling beds.
3	9,260	8	11	Engine-house.
4	30,900	8	...	Pumping machinery, 25 H.P.
4-A	20,820	16	...	Do. 16 do.
5	19,410	9	10	Filters.
6	7,350	10	13	Pure-water cistern.
7	1,900	...	...	Values and connections at pumping station.
8	6,390	11	14, 15	Stand-pipe.
9	14,740	15	16, 17	Accommodation for establishment.
10	1,18,240	12	18, 19	Mains, 12″, 7″, 3½″, 2″.
10-A	1,00,310	16	18, 19	Do. 10″, 6″, 2½″, 2″.
11	18,910	13	35 A & B	Iron roofs to cisterns.
12	15,082	5	...	Compensation.
		PROJECT B.		
1	80,180	30	23	Condensers.
2	2,320	30	22	Alterations to rock engine-house.
3	9,880	31	24	Tower and cisterns.
4	15,440	32	19, 20, 21	Mains for drinking water.
5	2,170	25	26	Alterations to Dhobies' wells engine-house.
6	15,600	25	...	New engines.
7	1,570	38, 47	...	Repairs to filter at wells.
8	2,750	26	27	Pure-water cistern.
9	4,000	27	...	Alterations to pure-water cistern at rock.
10	7,170	28	...	Connections between wells and stand-pipe.
11	18,910	13	35 A & B	Iron roofs as for project A.
		PROJECT C.		
1	20,130	37	34	Diversion of town drainage.
2	2,030	37	34	New weir for Halsur tank.
3	2,360	37	...	Lowering present water weir.
4	1,850	37	35	Alterations to upper waste weir.
5	5,320	46	34	Watering places to Halsur tank.
6	2,040	45	...	Fencing.
7	26,130	41—43	28—33	New supply channel and compensation.
8	4,630	49	27 fig. 2	Pure-water cistern.
9	7,800	50	...	New engines.
10	16,550	48	25, 27	Filter at wells.
11	4,360	50	...	New boilers to existing engines.
12	1,073	51	25	Connections at wells station.
13	5,580	52	25	New wells.
14	18,910	...	35 A & B	Iron roofs to cistern as for project A and B.
15	7,170	28	...	Connections as for project B.

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Survey of Agaram tank	5
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Plan of new weir for Agaram tank	7
Cross sections of bund of Agaram tank	8 & 9
Plan of settling beds	10
Do. engine-house	11
Do. filters	12
Do. pure-water cistern	13
Do. stand-pipe	14 & 15
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WATER-SUPPLY FOR THE EUROPEAN TROOPS AT BANGALORE.

REPORT to accompany Plans and Estimates for Projects for improving the Water-supply for the European Troops at Bangalore.

1. PREVIOUS CORRESPONDENCE.—Report by Colonel Mullins, R.E., Chief Engineer, upon the water-supply of Bangalore, forming appendix to G.O., No. 1473 W., dated 13th June 1884; G.O., No. 1814 W., dated 25th July 1884.

2. ACTION TAKEN ON COLONEL MULLINS' REPORT.—The results of the investigations carried out by Colonel Mullins, which are summed up in paragraph 51 of the above report, were accepted by Government, who accordingly directed the elaboration of the scheme proposed with the Agaram tank as a new source of supply, and the undersigned was deputed to prepare the necessary plans and estimates for this purpose.

In the Government Order of 25th July quoted above the further investigation of Colonel Mullins' suggestions with regard to the possible improvement of the Halsur tank, the present source of supply for the troops, was also directed together with the proposal to condense water for the troops, to afford a separate supply of pure water for drinking and culinary purposes only.

3. PROJECT NOW SUBMITTED.—Plans and estimates are now submitted for three projects, viz. :—

Project A.—For new pumping gear, mains, and the necessary buildings for supplying the existing cisterns in the barracks from the Agaram tank.

Project B.—For retaining the present system and providing for a separate service for condensed water for drinking and culinary purposes only.

Project C.—For improving the Halsur tank and utilising the present system with certain additions and modifications.

The three projects will now be reported on in detail.

4. PROJECT A.—The arrangements in connection with this project will be as follows :—

The source of supply to be the Agaram tank. The water from it to be collected in settling beds and conducted thence by earthen pipes to a well in a pumping station situated below the tank weir at its north-west extremity. From this well the water will be pumped on to filter beds, whence it will gravitate into a clear-water basin. From this clear-water basin it will be pumped up over a stand-pipe through cast-iron mains up to the existing cisterns at the various barracks, whence it will be drawn as required by the present distributing pipes and stand-cocks.

The pumping station will comprise the following buildings and machinery :—

1. Engine-house with double set of engines, pumps and boilers.
2. Pump well.
3. Double set of filter beds.
4. A pure-water cistern.
5. A stand-pipe.
6. A store-shed and office.

7. Quarters and out-houses for the Engineer in charge.
8. Do. do. for two European Assistants.
9. Quarters for native stokers.
10. An enclosure wall.

Arrangements for increasing the capacity of the tank will consist of—

11. Additions to the present weir.
12. Provision for an additional new weir.
13. Raising the present bund and construction for cross bunds to divert the Agaram and Jacksandra village drainages, and protect the Venkatapur village.

5. The Agaram Tank.—The circumstances of the Agaram tank, the proposed source of supply, are fully described by Colonel Mullins in paragraphs 44 to 48 of his report, and an examination of sheets Nos. 1, 2, and 4 will make its position clear.

It has a catchment of 32·1 square miles, about 1,062 acres of which are occupied by 26 smaller tanks, varying in waterspread from 3 acres to 237 acres. No information regarding the waste weir discharges of these tanks was procurable from the Mysore Department of Public Works, so that it is not possible to determine with any approach to accuracy how far they will affect the supply in the Agaram tank into which they all surplus. Assuming all the tanks to have an average depth of 3 feet the 200 acres of tank would absorb 138½ M. C. feet. of the rainfall. The annual rainfall may be taken at 36 inches, and, judging by the statistics of rainfall over the Halsur tank catchment and volume of water received, given in Colonel Mullins' report, 0·075 of the annual rainfall may be expected to run off the catchment or 2·7″. Thus a total yield of 199·68 or 200 M. C. feet may be calculated on from the catchment of 32·10 square miles. Supposing the whole 138½ M. C. feet absorbed by the minor tanks to be lost to the Agaram tank, its net annual receipt would be 62 M. C. feet, or about 38 M. C. feet in excess of its present capacity at F.T.L., which Colonel Mullins estimates at 24·068 M. C. feet.

Below the tank is a tract of cultivated land 223 acres in extent, of which 199 acres is classed as wet. Assuming the supply required per acre for six months to be 216,000 cubic feet (*vide* circulars of Chief Engineer for Irrigation) the amount required for this land will amount to about 43 M. C. feet, so that the tank in its present condition must be twice filled to meet the yearly requirements of the land below it.

This will leave about 19 M. C. feet of the surplus that runs to waste, and as the inflow to the tank is generally much more rapid than the draft for cultivation, the surplus is probably excessive, and the tank can at present do little more than supply what is required for the lands under it. When visited on 14th September the tank was nearly quite dry, and in its condition on that date a week's supply for the troops would probably have drained it completely. Colonel Mullins proposed to increase the capacity of the tank by an addition of 3 feet to the waste weir, which will afford a total storage capacity of 44 M. C. feet. Provision for this is made in the project. With the tank thus enlarged existing requirements will in no way be affected, and the tank once filled over six years' supply for the troops will be stored, which should prove ample for all contingencies. It is, however, considered that with the tank as a source of supply for the water for the troops, the regulation of the irrigation sluices should be placed in the hands of the "Water-works Establishment."

The Resident of Mysore, however, does not concur in this view, and on the grounds that occasions might occur, such as years of scanty rainfall, when objection might be taken to water being drawn off for irrigation as curtailing the supply for the troops; he considers that compensation should be paid for the irrigation below the tank, and the amount estimated by the Mysore Government is entered in the estimates.

Further compensation, amounting to Rs. 10,944, must be paid for 114 acres of land submerged by raising the level of the weir.

At the north-west and north-east corners of the tank are the two villages of Agaram and Jacksandra. The former at the north-east corner is a large one containing a large temple, 260 huts and houses, and over 1,000 inhabitants. The latter is a small one containing 61 huts.

Two other villages also lie near the margin of the tank at the south end, and when the F.T.L. is raised as proposed they will be situated close to the margin of the water when the tank is full.

The tank therefore receives the immediate drainage of four villages, the inhabitants of which together with their cattle resort to it for water, bathing and washing their garments and household utensils. If the tank is to be adopted as a source of water-supply for the troops these latter practices are very objectionable. Where villagers and their cattle have free access to a tank the water must be contaminated more or less by the washing in it of foul, probably at times infected, clothes and contact with human or animal ordure. The rapidity with which the germs of disease are generated and disseminated from such causes is generally admitted, and no source of water-supply can be regarded as entirely satisfactory which is liable to such contamination.

Inquiries have been made as to the possibility of acquiring these villages so as to ensure the immediate neighbourhood of the tank being kept as free as possible from pollution, but the expense and numerous difficulties that such a course would entail render it practically prohibitive.

With the two villages of Venkatapur and Polliam on the south nothing can be done to divert their drainage from the tank; it must pass into it. The drainage of the village of Jacksandra can be diverted and carried into the surplus channel below the tank by a culvert on the road just west of the existing weir.

In the case of the Agaram village the tank can be cut off from it by a cross-bund proposed to be run across the eastern area of the tank (marked on plan *x*7), forming a small tank at the eastern corner close to the village, to which the inhabitants should be compelled to resort for their water. This small tank will be supplied by a sluice from the main tank, and an additional surplus weir will also be constructed in the cross bund as proposed by Colonel Mullins in paragraph 3, appendix 24 of his report, which will carry part of the surplus of the main tank away by the smaller one. The estimates for raising the tank bund, &c., are based on the proposals made by Colonel Mullins in the same appendix, and all details are given in plans.

With the tank weir raised a bund must also be constructed to protect the village of Venkatapur, which is close to the present F.T. waterspread of the tank, and part of which will be brought into the waterspread with the weir raised as proposed.

6. Settling Beds.—These were not proposed by Colonel Mullins, but their provision is thought to be most essential. From the analysis of the Agaram tank water given in appendix O attached it will be seen that the amount of suspended matter in the water is very considerable, and the Chemical Examiner himself regards settlement prior to filtration as necessary. Mr. Baldwin Latham, C.E., in lecturing at Chatham in 1871 on this subject states "the advantages of subsiding reservoirs are very great. In some experiments which I made I found that four-fifths of the total impurities in the water, which could be removed by filtration, could be removed by subsidence," and it is believed that the slow and unsatisfactory working of the Halsur filters—regarding which more will be said further on—is due to the want of these important accessories in the existing water-works.

The general arrangements of the proposed settling beds will be understood by a reference to plan Nos. 5 and 10. It is assumed from the data given in appendix A that 60,000 gallons a day may be taken as the demand for the European troops, and it is proposed to provide three settling beds, each capable of containing twelve days' supply for the troops, so that the water in any one reservoir will have twenty-four days to settle before it is drawn off. The settling beds are to be situated in the tank bed near the north-west end and are to be, by a bund, run parallel to the existing bund 100 feet in front of it connected with it by four cross bunds at right angles to both bunds, forming three rectangular reservoirs each 300′ × 100′, or 30,000 square feet area. These with 4 feet depth of water will each contain 750,000 gallons or a little over twelve days' supply.

The water from the tank is to be drawn off by a perforated masonry tower connected with a masonry culvert through the bund of the centre settling bed branching into three culverts at the inner end connected with each settling bed severally by earthenware pipes. Each culvert is provided with a shutter, so that water can be turned on to any settling bed at will. The perforated tower is to be surrounded by rough stone loosely packed to induce the deposit of suspended matter before the tank water enters the culvert. The sill of the collecting tower and culvert is placed at 2,866 + M.S.L., about the deep bed level of the tank at this point. The earthenware

pipes from the inner end of the culvert to the separate settling beds will each have an internal diameter of 12 inches. These with a head of 6 inches will discharge 3·6 cubic feet per second, and could fill a settling bed in about thirty hours.

The water from the settling beds will be drawn off by sluices in the cross bunds connected with cast-iron pipes with the upper end floated a little below the surface of the water, so that only the upper layer of water will be drawn off, and the lower end connected with the sluice by a flexible joint. From these sluices earthenware mains connected with a common main beyond the settling beds will convey the water to a pump well in the pumping station. The distance from the west end of the settling beds to the pump well in the pumping station will be about 900 feet, and with a slope of 1,000 the 12 inches earthenware pipes would deliver 450 gallons a minute at the pumping station, rather more than required.

7. The Pumping Station.—The general arrangement of the different buildings is shown on plan No. 3. The site is on a hard red soil, and good foundations may be expected. The surface has a slight slope from west to east, and is bounded on the east by the surplus nullah from the Agaram tank, into which all drainage can be easily turned. The average level of the ground is at 2,883·35, or about 17 feet above the bed of the Agaram tank, and the engine-house and pump well from which the tank water is to be drawn should be placed at the south-east corner, where a well 18 feet deep will have a floor level of 2,865·00, or a foot below the beds of the settling reservoirs, and secure the necessary gradient for an ample supply in the pump well.

8. The Engines.—The highest point to which the water will have to be forced will be the cistern for the infantry barracks, where the supply level is 3,000·00 + M.S.L., or 117 feet above the level of the ground at the pumping station. The calculations given in appendix D show that a command of 30 feet above the infantry cistern is necessary, so that the water must be lifted to a level of 3,030 or 151 feet above the level of the pumps, which will be about 6 feet below the ground.

The engines must perform a double duty; they must first lift the water on to the filter beds, and when it has gravitated through to the pure-water cistern they must pump it from that to the service cisterns at the barracks. It is presumed that continuous daily pumping is not expected, and that on Sundays the establishment will not be required to work. If this is the case at times an interval of three days must elapse before the engines can supply the service cisterns at the barracks, so that they must be capable of sending up three days' supply or 180,000 gallons in one working day. Supposing a separate engine is provided to charge the filters, pumping two days' supply or 120,000 gallons would suffice. In appendices B, C_1, C_2, C_3, data are given regarding engine power, probable expenditure of fuel and amount of pumping required. Supposing the engines to work for eight hours a day it seems that the more economical arrangement will be to have one engine capable of pumping up three days' supply when required, which could be accomplished by a 24-horse power engine (nominal). To allow of reserve power two such engines are provided for.

Compound condensing engines should be adopted, and the additional expense at first incurred in their provision will be eventually covered by the economy in fuel that this type of engine renders practicable. Illustrated specifications of numerous engines have been consulted, and the most suitable engine of this description seems to be "Shanks' patent compound double-acting horizontal steam-engine," described in the catalogue of Messrs. Richardson and Co., Bombay. This engine seems very compactly arranged, the number of its working parts is small, and it would probably occupy less space than many other engines of equal horse-power, though of different design, as the fly wheel and crank shaft are placed parallel to the cylinders instead of as in most cases beyond and in the same alignment with them. It is suggested that this engine, if adopted, should also be fitted with "Patent automatic variable expansion gear." When this gear is fitted it varies the cut off in the high pressure cylinder and governs the engine, enabling it to exert only the power actually required, and thereby it is stated effecting a saving of about 20 per cent. in fuel. The cost of this gearing according to London catalogues is about £1 per horse power extra.

The calculations usually adopted to estimate the horse power of engines show in this case that about 16 nominal horse power is required to lift the desired quantity of water the necessary height, and to this 50 per cent. is arbitrarily added to allow for extra power required for unforeseen contingencies, giving as the result a 24-horse power engine. The estimates provide for two engines of this power. The nominal horse power of an engine is always however considerably below its actual strength, and the actual horse power of a 25-horse power engine of the pattern proposed is according to the catalogues as much as 64-horse power with steam at 60 lb. pressure per square inch. This is about the maximum working pressure of the boiler, and it would never be advisable to work the boilers regularly up to this pressure. Probably an engine of smaller nominal horse power working at, say, 40 lb. pressure would give an actual horse-power greater than required in the present case,—for instance, an engine of 16-horse power nominal at 60 lb. gives an actual horse power of 40, and working at a lower pressure might still suffice. When ordering the engines this matter might be inquired, and the firm from whom the engines are obtained may be able to guarantee the performance of the work required by an engine of lower nominal horse power than that estimated. The saving however would not be very great—not more than Rs. 2,000 about on each engine.

The Boilers.—The estimates provide for Lancashire boilers of the ordinary type, which for a 24-horse power engine should each be 25 feet long and 6 feet diameter, requiring a boiler room quite 35′ × 25′ and a masonry chimney. It is however strongly recommended that vertical boilers be adopted, which appear to offer numerous advantages over the ordinary horizontal type. With vertical boilers the boiler room required is very much less, and there is no necessity for an expensive masonry chimney, as the boilers are fitted with iron chimneys. The saving in cost and weight is also considerable, a 25-horse power Lancashire boiler costing Rs. 4,950 and weighing 182 cwt., while a vertical boiler of similar horse power weighs 72 cwt. and costs Rs. 2,800. The pattern recommended is the new patent vertical steam boiler (described in the catalogues of Messrs. Richardson and Cruddas, Bombay, and Messrs. Bolling and Lowe, London), which is said to effect a saving of 40 per cent. in fuel over the ordinary vertical cross tube boiler. It has great effective heating surface, is not liable to prime, and the tubes can be readily crushed out. The working pressure should not exceed 60 lb. per square inch, and, if desired, they can be adapted for wood fuel at about Rs. 20 extra per nominal horse power.

The Pumps.—Ordinary treble-barrelled plunger pumps are provided to raise 370 gallons with about 18 strokes per minute. The length of stroke is to be 24″, and with this the diameter of each barrel should be 10″. They are to be 12″ to allow of the usual addition of one-fourth to meet loss from slip, bad fitting, &c. To equalize the flow in the delivery pipe a cast-iron air vessel of about eight times the capacity of one pump barrel is to be attached in the usual manner. The capacity of one barrel being 1·57 cubic feet the air vessel should be a cylinder 4 feet long and 2 feet diameter, giving a capacity of 12·56 cubic feet.

The Engine-house.—This is designed to accommodate two 24-horse power engines with two Lancashire boilers, and all necessary details are given on sheet No. 11. If vertical boilers are adopted, as suggested, the boiler room can be reduced to the dimensions indicated on the plan.

9. Filter Beds.—The rate of filtration through 5 feet of filtering bed is stated in the "R.E. Aide Memoire" to range from 38 to 75 gallons per foot super in 24 hours. In the "Calcutta Water-works," where the filtering beds are $3\frac{1}{2}$ feet deep, the rate of filtration is 50 gallons per square foot, and in those at "Almora," where the beds are 6 feet deep, the water runs through at the rate of 78 gallons per square foot in 24 hours. The existing filters at the "Halsur Water-works," where the depth of the filtering strata is 5 feet, are peculiarly slow as compared with the above theoretical and practical data, and has never exceeded 9 gallons per sqaure foot in 24 hours, and it is believed that this slow rate of filtration may, to a certain extent, be attributed to the want of settling beds, which were proposed in the original scheme, but never constructed.

In the present project it is assumed that with the water previously clarified by subsidence a yield of 30 gallons per square foot per 24 hours may be expected, and the dimensions of the filters are calculated on this data. The filter must be capable of purifying 180,000 gallons in the 24 hours, and supposing the engines to take 8 hours to fill the filter, during the process of filling $180{,}000 \times \frac{8}{24}$ or 60,000 gallons would be

run through, leaving a balance of 120,000 gallons to be stored on the filter bed to run through in the remaining 16 hours, which would require an area of 6,000 square feet. As, however, the head of water on the filter bed should be limited to 2 feet, otherwise the rate of flow will be too rapid, this quantity should be stored in an area of 9,600 square feet, 2 feet deep or 19,200 cubic feet. A filter 140×60, giving 8,400 square feet of surface, will fulfil the required conditions and would purify 189,000 gallons within 24 hours with a margin for slower rate of filtration.

During the 8 hours pumping 84,000 gallons would run through, leaving 105,000 gallons stored on 2 feet depth of its surface, which would pass through in about 13 hours at the assumed rate.

At least two filters must be provided, and it would be advisable to have three, allowing for one in use, one oxydising and one cleaning.

The details of the filters will be understood by a reference to plan No. 12. The water will be led on to the surface by a masonry channel in one wall, from which it can overflow down the sloping face of the wall on to the surface of the sand. After descending through the strata it will be collected in a culvert at one end of the filter, whence cast-iron mains will convey it into the pure-water cistern. The filtering strata are to be composed of 2 feet 6 inches sand, 4 inches animal charcoal, 3 inches quarry sweepings, 11 inches stone jelly, 1 foot of slab stones on a flooring of brick on edge concrete, and the filter will be sunk 6 feet deep in the ground.

10. The Pure-water Cistern.—As the pumps will send up water three times as fast as the filters can purify it, the filtration requiring 24 hours to complete while the pumping is done in 8 hours, the capacity of the pure-water cistern should be at least half that of the filters, or it should hold about 100,000 gallons. The proposed pure-water basin has interior dimensions of $52\frac{1}{2}' \times 80'$, which with 4 feet depth of water will contain 105,000 gallons. It is to be roofed with arches carried on wrought-iron girders, open at the ends, to allow of free ventilation above the surface of the water. All necessary details are given on sheet No. 13.

11. The Stand-pipes.—These will be formed of three pipes, viz., up pipe, down pipe, and waste pipe, the last discharging into the pure-water basin and consisting of cast-iron flanged pipes 12 inches internal diameter, $\frac{7}{8}$ inches thickness of metal, fitted together, as shown in plates 14 and 15, on which all necessary details are given. The total height of the stand-pipes to secure the necessary command will be 146 feet above the ground level of the pumping station, giving a total lift from the pumps of 150 feet. Data on which the dimensions of the struts, braces and guys are based are given in appendix E.

12. The Mains.—The mains will have to supply three existing service cisterns, viz, the Race-course cistern, whence the cavalry and two field batteries draw their supply, the Royal Horse Artillery cistern, and the cistern in the Commissariat square that supplies the battalion of European Infantry.

Detailed calculations of the sizes of the mains are given in appendix D, and sections along the lines of piping are shown in sheets 18 and 19.

The pipes are to be laid in trenches 2 feet deep, and, as no part of the ground traversed by the main will rise above the hydraulic gradient, the highest point being 25 feet below the top of the stand-pipe, the pipes may follow the configuration of the ground. Where nullahs are crossed the pipes are to be carried down and into their beds, across which masonry walls built of rough-stone rubble in chunam are to be constructed to carry the pipes and check the scouring out of the beds by heavy showers and possible displacement of the pipes thereby.

In calculating the sizes of the mains the levels of their discharging points are assumed to be 1 foot above the tops of the cistern walls which they supply, and the lengths are taken in even yards slightly in excess of the actual distance, so that any errors are on the side of safety.

13. Roofs to Service Cisterns.—The existing service cisterns were constructed without roofs, and in 1877-78 an estimate for Rs. 66,598 was sanctioned for additions to the "Halsur Water-works," which included items for roofing the three cisterns and the pure-water basin, but only the latter and one cistern (that at the Bakery Square) were roofed. The cistern at the race-course barracks and the one for the Royal Horse Artillery still remain uncovered. The result of this is that kites, vultures,

and other birds which frequent the barracks in large numbers are able to drop garbage or other refuse they may pick up and carry away for food into the water and further contaminate it by sitting on the cistern walls and letting their droppings fall into the cisterns.

There ought to be no traces of ammonia in good drinking water, and, when it is remembered that the solid and liquid evacuations of birds are highly ammoniacal, it is evident that under existing circumstances the water stored in the Race-course and Royal Horse Artillery cisterns is liable to contamination of a most deleterious character. This is particularly the case at the Race-course cistern, which is situated close to several cook-houses and is a favourite rendezvous for numerous birds, who wait and watch for the refuse of the cook-rooms. The undersigned personally on one occasion fished a large dead snake out of the water of this cistern, which, from the very advanced state of decomposition it presented, must have been in the water many hours, and bones and other foreign subtances are frequently found in it. Considering the great expense incurred in filtering the water at the pumping station and conveying it to these cisterns, where it is presumably in as pure a state as artificial filtration can make it, it is most important that it should be protected as far as possible from pollution while in the cisterns.

The estimates and plans for iron roofs for these two cisterns are recorded in the division office and copies are submitted with this report. They amount to Rs. 18,910 altogether, and this amount is included in the total estimate for Project A.

14. Minor Distribution.—This will remain as at present and calls for no remark.

15. Quarters for Establishment.—In Appendix V is given the sanctioned scale for the present Water-works Establishment. The estimates provide for quarters for the Engineer in charge, two European subordinates, and the native fireman and peons. Accommodation for the latter is not absolutely essential, as they could in all probability find suitable dwellings in Agaram or one of the villages near the tank, but accommodation for the former officials must be provided on the premises. All necessary details are given on sheets 16 and 17.

16. Cost of Project A.—The total cost of the project will amount to Rs. 2,90,000, and is made up of the following items:—

	Rs.
Improvements to Agaram tank	17,010
Settling beds	16,290
Engine-house and chimney	9,290
Double set of 25-horse power engines and pumps	30,900
Filters	19,410
Pure-water cistern	7,350
	6,390
	1,900
Stand-pipe	1,18,240
Mains	10,758
Accommodation for establishment	3,982
Enclosure wall	18,910
Roof to cisterns	15,082
Compensation	
Total	2,75,482
Unforeseen contingencies	14,518
Grand total	2,90,000

Compensation has been estimated on information supplied by the Mysore Government after personal inspection by the Revenue authorities of the lands affected by the project.

If vertical boilers are used, savings could be effected on the following items to the amount stated below:—

	Rs.
Engine-house	1,810
Machinery	4,300
Carriage	1,034
Total saving	7,144

A further saving in the initial outlay could also be effected by arranging that only two days' supply is sent up at a time, which would allow of pumping at the rate of 250 gallons per minute. In this case, both engines provided should be constantly in use, and, starting with the pure-water cistern full, could pump as shown in Appendix C_3. In the event of one engine breaking down—and it is improbable that both would do so simultaneously—the other could, by pumping a few more hours daily and working uninterruptedly, meet the demands for the troops with a little economy of consumption until the disabled engine were in working order again. This system would involve a slightly greater expenditure of fuel, but in this case the mains could be reduced from 12″, 7″, 3½″, and 3″ to 10″, 6″, and 2½″.

The saving in cost of engines, piping, and carriage by this arrangement would amount to Rs. 28,010.

Supplemental estimates for the less powerful engines and smaller mains are submitted.

For the above amount, 60,000 gallons of water a-day can be purified and delivered at the barrack cisterns for a European and Native population of 4,846 souls and horses—the water to be used for all purposes.

The annual cost for working the system would be approximately as follows, the present establishment being considered sufficient for the new pumping station at Agaram :—

	Rs.
Establishment	506
Fuel	170
Sundries (repairs, oil, &c.)	124
Total per month ...	800
Do. year ...	9,600
Cleaning and renewing filters ...	8,000
Total ...	17,600

So the annual expenditure may be thus estimated :

15 per cent. interest and depreciation on machinery	4,635
10 „ „ on other works	22,150
Working expenses	17,600
Total ...	44,385

With a daily supply of 60,000 gallons for the above expenditure, the cost per 1,000 gallons amounts to Rs. 2·02.

17. General Remarks.—The above project will probably be found ample for the requirements of the troops, but the following points in connection with it must not be overlooked :—

(i) The source of supply from the Agaram tank must not be regarded as a pure one, and on this point more will be said subsequently. The whole supply the tank receives runs off cultivated ground; four villages lie within its waterspread, one of which is a large one; and, with the removal of the water-works establishment to this tank, the population of these villages and the traffic about the tank are liable to be increased to no small extent. The Engineer in charge must be invested with distinct powers to enable him to check practices liable to result in the pollution of the tank, and conservancy of the tank will be a difficult matter.

(ii) The supply to the tank is to a certain extent precarious, situated as it is at the extremity of a long chain of tanks. All these have the power of retaining and utilising much of the rainfall, and in years of scarcity the demands for water for cultivation and for the supply for the troops might interfere with one another and give rise to complications, more especially as the lands in question lie in foreign territory. If once the tank, with its capacity increased as proposed, were filled, it would meet all requirements amply and tide over several years of scarcity, but data are wanting to show that this may be safely counted upon. Up to date, in spite of the heavy rains of the past few weeks, the water level in the tank is still 3 feet below the crest of the present waste weir, while a few weeks ago it was very nearly dry.

(iii) In the Agaram scheme the troops will be entirely dependent upon the filters for their supply, and the assumed capacity of these reservoirs to meet the required demand is based upon theoretical data that in the case of the Halsur water-works filters have been found to be unreliable. It may be found necessary to double the number of filters provided, and for this there is ample space in the ground selected for the pumping station.

The details of the project could be carried out without interference with the present system, which would continue to supply the barrack cisterns until the various parts of the new project were completed. Probably, with a good supply of labor forthcoming, the whole work could be carried out in twenty-four months. A great deal of the work, such as raising the tank-bund, construction of protective bunds, excavation for cisterns, foundations, &c., could be readily carried out by Pioneer labor.

II.

18. Alternative Projects.—In paragraph 50 of his report Colonel Mullins writes as follows :—"It is nearly certain that water of perfectly satisfactory quality could be obtained at Bangalore only by distillation," and in G.O., No. 1814 W., dated 25th July 1884, the consideration was ordered of an alternative scheme suggested by Colonel Mullins, viz., to retain the present system with the Halsur tank as the source of supply, improve the conditions of the tank or provide a separate supply of pure drinking water obtained by distillation.

19. Views of His Excellency the Commander-in-Chief on the Subject.—On the communication of the above Government Order to the Military Department, the opinion of the Surgeon-General of Her Majesty's Forces on the subject was obtained, and his letter, No. 180-O, dated 18th August, forwarded to the Chief Engineer with letter, No. 768-C, dated 20th August 1884, from the Quartermaster-General, stating that His Excellency is most strongly opposed to any scheme with the Halsur tank as a source of supply, is forwarded with this report, and will be found in Appendix R.

20. Objections raised in the letters from the Surgeon-General and Quartermaster-General.—Before proceeding further, it will be as well to discuss the above letters and the points set forth in them.

In the letter from the Surgeon-General, that officer raises the following objections :—

(*a*) He objects to the system of dual supply on the grounds that "it will be very difficult, if not impossible, to prevent men from making use of the impure ablution water for drinking purposes."

(*b*) He considers "that the large natural filtration of this (the Dhobies' wells) water through the laterite bed is no safeguard against such subtle impurities as the germs of typhoid or any other contagious fever." He refers to the well-known fact that the enteric fever poison has passed from "village to village in England by means of water which has filtered naturally through long distances of solid earth," and he alludes to this to show "that, in the event of the condensing apparatus breaking down hereafter, the garrison would be dependent for its water upon the Dhobies' wells, a supply which would be dangerous to health."

(*c*) He, in conclusion, represents "the great need for a supply of pure water being provided for the garrison of Bangalore," and expresses his opinion "that this end can be best obtained by the abandonment of the Halsur tank altogether and the adoption of the Agaram tank scheme."

The Quartermaster-General, in his letter forwarding that from the Surgeon-General, expresses—

(*d*) The entire concurrence of the Commander-in-Chief with the views expressed by the Surgeon-General and his deprecation of "the entertainment of

any measure which would tend to perpetuate the use of the waters of the Halsur tank."

(*e*) Points out "that, however pure the water may become after condensation, it must be remembered that the water drawn from the Halsur tank for all purposes, besides that of cooking and drinking, must reach the barracks by the same means and through the same pipes as the pure water."

(*f*) His Excellency's opinion is also stated that "the difficulties of preventing men and families from using the impure water would be insurmountable."

(*g*) The danger of relying on a single condensing apparatus is commented upon, "there being no source to fall back upon in case of accident except that which has been universally condemned."

(*h*) It is stated, in conclusion, that the question of water-supply at Bangalore "has at last arrived at a stage at which a solution seems possible. An experienced officer has reported on the feasibility of a scheme which is calculated to afford a pure supply of water."

21. Discussion of above Objections—*Objection* (*a*).—The difficulties attendant upon a dual system of supply. It has been ascertained by a reference to the Commanding Officers of the several European corps stationed at Bangalore that at present the following system is practised with regard to the drinking water for the troops. At stated intervals the regimental pakalies draw a supply of water from the stand-cocks, which is taken to the cook-houses, boiled, and then again taken by the pakalies and placed in the Macnamara filters in the verandahs of the different barrack blocks. This is practically a dual system; the only difference in that now proposed would be that a few additional stand-cocks will be erected whence the pakalies will draw drinking water only and probably convey it direct to the Macnamara filters instead of first to the cook-rooms for the purpose of being boiled. The men will very naturally go for their drinking water where they can get it with the least trouble, and it seems reasonable to presume that they will find it easier and more comfortable for themselves to get it from the filters standing in the verandahs of their barracks than from stand-cocks situated out in the open, and in many cases at no little distance from them. Of course there is always the possibility of men, while in the ablution rooms, drinking water from the taps there intended for other than drinking purposes. This possibility might, it is thought, be reduced to a minimum by the provision of additional Macnamara filters in such places. It is also submitted that, supposing a plentiful supply of absolutely pure water to be available for the barracks themselves, there is no means of preventing men when out and about the cantonment drinking water or liquors mixed with water of an infinitely impurer nature than that now sent up to the cisterns from the Halsur tank. The danger to the troops from the improper use of the dual system of supply, over which considerable control could undoubtedly be exercised, is insignificant compared with the latter entirely uncontrollable source of danger to which the men are universally exposed.

(*b*). *The imperfect natural filtration of the Dhobies' wells.*—It has been customary hitherto to send the Dhobies' wells water up to the barrack cisterns without previous filtration. It is believed that artificial filtration at the pumping station, previous to transmission to the service cisterns, will considerably improve the quality of this water. On this point, however, more will be said subsequently.

(*c*). *Contamination of the pure condensed water by transmission through the same lines of pipes as the water for other purposes.*—A single line of mains for the dual system is not contemplated. If condensed drinking water is supplied, an entirely separate set of cisterns and mains are provided for its collection and distribution. It would, in fact, be impossible to work the dual system with a single set of mains.

(*c*) & (*h*). *Necessity of a supply of pure water and opinion that the Agaram tank affords such a supply.*—The necessity for a supply of pure water is an undoubted want seriously felt, but the question as to the source of such a supply remains still unsettled. There seems to be some slight misconception with regard to the portion of Colonel Mullins' report upon the Agaram tank. In paragraph 44 he states that this tank "on the whole affords the best prospect of being a suitable source of supply," and in paragraph 45 he goes on to say "that the water has obtained only the qualified character 'usable,' but that is the highest character given in any of the analyses of Bangalore water, and it seems more than doubtful whether anything more favorable

is likely to be found." This is scarcely a report of a pure source of supply, and in paragraph 50 of his report Colonel Mullins states, "it is nearly certain that water of a perfectly satisfactory character could be obtained at Bangalore only by distillation."

In August last, when the Agaram tank was very low, the undersigned collected some samples of the water from the end near the village of Agaram, but on the side of the tank away from the village. These samples were submitted to the Chemical Examiner for analysis, and the results are given in Appendices O and Q. It will be seen that he now classes the water as bad, and expresses uncertainty as to its being rendered potable by filtration.

The following remarks regarding this recent analysis are offered, though perhaps the points commented upon are, properly speaking, the province of a qualified Chemical Analyst. Comparing this analysis of the Agaram tank water with analyses of Halsur tank water, given in Colonel Mullins' report, Appendix 26 B, and analyses of the same water made from samples collected by the undersigned last August, it will be seen that the proportion of nitric acid is excessively high, being 9·00 against 7·5 in the Halsur water of August's collection and 3·0 in that collected by Colonel Mullins. The amount of albumenoid ammonia is high, though not so great as in the Halsur water. In Dr. Parkes' "Manual of Hygiene" it is stated that a marked excess of albumenoid ammonia . . . . . would be a fair cause for condemning a water even if its other characters are good. Elsewhere, in the same manual, it is stated, "a large quantity of ammonia in water is always suspicious. If nitrates, &c., be also present, it is more likely to be from animal substances, excreta, &c." The recent sample of water taken from the Agaram tank certainly shows indications of contamination that render it suspicious, and being classed as "bad" by the Chemical Examiner equally with the sample of the Halsur tank water collected about the same time, there appears to be nothing to choose between the two waters as a source of supply.

It must be remembered that the later sample from the Agaram tank was collected under the greatest possible disadvantages. The tank was very low, and the water obtained from a point near a large village where the chances of contamination are undoubtedly greater; but, in the case of deciding upon a tank as a source of supply, the worst possible aspect of the water should be taken as the basis of decision. It is quite possible that with a large quantity of water stored in the tank very favorable analyses would be obtained of samples collected from it, but there can be no doubt that the Agaram tank water is liable to dangerous contamination, and, if adopted as the future reservoir for the troops, it is urged that the source of supply must not be accepted as, or expected to be, pure.

22. Remarks on tanks as a source of supply.—From the geographical position of Bangalore, situated on the highest point nearly of the Mysore plateau, the question of water-supply is naturally a very difficult one. No large rivers pass near the city, and the numerous tanks and wells in the vicinity of the cantonment are the only sources whence water is obtainable. Wherever there are tanks there is also cultivation and generally a village or two, so that the surface water stored in the tanks must pass over cultivated land, and the tanks but too often receive the whole drainage of a village. In speaking of sources of supply, Dr. Parkes in his "Manual of Hygiene" classes surface water from cultivated land as suspicious but palatable, and again he writes while discussing the question of impurity of storage: "In India especially the tank water is often contaminated by clothes washed near or actually in the tank, by the passage even of excrement directly into it, as well as by surface washings, so that, in fact, in some cases the village tank is one of the chief causes of the sickness of the people." At the outset, therefore, tanks as sources of supply must be regarded with suspicion. The qualities of the water stored in them also vary with the season of the year, and a recapitulation of past experience in this respect with regard to the Halsur tank is now given:—

In 1862, when the exsisting water-supply scheme was first being worked out, the water of the Halsur tank was analysed and favorably reported upon. In 1863 a sample was sent to Calicut for examination by Assistant Surgeon Nicholson, whose report still appears to have been satisfactory. In 1868 the tank water obtained a bad reputation, and was reported on by the Chemical Examiner at Madras as containing fæcal matter. This report led to the adoption of the Dhobies' wells as a source of supply. In 1871-72 a special officer—Assistant Surgeon Nicholson—was deputed by

Government to examine and report upon the waters of the Halsur tank and Dhobies' wells. These reports were further verified and commented upon by the Chemical Examiner and Sanitary Commissioner. The conclusions arrived at were as follow :—

(i) That the tank water contained no fæcal matter.
(ii) That after filtration it was perfectly wholesome and fit for drinking.
(iii) That the total absence of nitric and nitrous acids and ammonia showed the water to be free from mineral remains, the effects of former sewage contamination, and the amount of organic matter found was very small.
(iv) Compared with the analysis of the same water in 1863 a considerable improvement was discernable. The greater freedom from organic matter and chlorides in the latter analyses was attributed to the beneficial action of the main sewer constructed in the interval and to the better conservancy of the tank.
(v) The Dhobies' wells water was found to be practically identical with the tank water, but to contain less organic matter.
(vi) Compared with Dr. Parkes' standard, first for pure water, second for usable water, the tank water was found equal to the second standard after filtration, and the Dhobies' wells to the first standard.

The opinion of the Sanitary Commissioner upon these analyses was recorded in G.O., No. 528, dated 8th February 1872, and stated that, "although under ordinary circumstances the water of the Halsur tank when filtered is perfectly pure and wholesome and may be safely issued to the troops, the Dhobies' wells water owing to its greater freedom from organic matter is the safest and best."

Since the above investigations, several analyses of the tank and wells water have been made from time to time with more or less satisfactory results, and so recently as August 1883 analyses of the water from the Dhobies' wells without filtration and from the tank after passing through the filter beds gave results which classed the water as usable, although analyses of the same waters made in May 1883—four months earlier—condemned them as bad.

From the above brief history of previous analyses and investigations in connection with the Halsur tank water, it is an undoubted fact that so short a time as twelve years back after careful and searching inquiry by competent analysts, a very favorable opinion was arrived at as to the suitability of the Halsur tank and Dhobies' wells as a source of water-supply for the troops, an opinion which was further endorsed by the entire concurrence therewith of the chief medical authority in the presidency.

There are no grounds for assuming that the data upon which this opinion was formed were otherwise than thoroughly sound. On the contrary, every precaution seems to have been taken to ensure a most careful and minute investigation, and, as the inquiry was undertaken at the time when there was a very strong prejudice against the Halsur tank water, it is not probable that any possible condition of impurity in the water was overlooked. The opinion then arrived at must be accepted as indicating without a shadow of a doubt the sanitary condition of the tank water at that time, and, since equally authoritative opinions are now pronounced condemning it, it is clear that the conditions of the Halsur tank and Dhobies' wells water are liable to vary in character.

The water from these sources having been once pronounced as "bad," a fresh scheme for supplying the troops from a new tank—that at Agaram—has been proposed and worked out, the cost of which is estimated at Rs. 2,90,000.

Granted that the present conditions of the new tank are better than those of the Halsur tank—and this they apparently now are—there is no guarantee that these conditions may not change for the worse as those of the Halsur tank have done; and with the Agaram tank scheme, the prospect of its being found at some future time as unsatisfactory as the existing one is thought to be within the bounds of possibility. With the formation of the pumping station by the Agaram tank and the removal of the establishment there, the population of the existing villages will be increased, as will also traffic to and about the tank; and, while the conservancy of the Halsur tank lying within the cantonment limits is a difficult matter, that of the Agaram tank, three miles off, will be more so. With the Agaram tank scheme found unsatisfactory owing to the deterioration of the water, the whole of the very heavy expenditure required

2894 W

9229/8

Cno 8172

To Dir.

For orders whether it is considered desirable to interfere with the action of the municipality in this matter. If so, the Resident must be addressed.

Cn
19.10.97

Yes. I think it is — It has been said about the necessity of keeping the Ulsoor tank clean, in order to provide ~~clean~~ pure water for the troops, that it would be inconsistent to run any risk of contaminating the water merely for ornamental purposes. The question should be compared to ~~some~~ others.

Chas W/a/97