MADRAS CORPORATION WATER-WORKS.

NOTE BY THE

SPECIAL ENGINEER

ON

REPORT BY

MAJOR JUSTICE, I.M.S.

AND

MR. W. HUTTON.

J. W. Madeley.

M.A., M. Inst. C.E., M. Am. Soc. C.E., Etc.,
SPECIAL ENGINEER,
CORPORATION OF MADRAS.

NAPIER PARK, MADRAS,
24th August, 1918.

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(Being Report on the Water-works prepared by Special Engineer for the Committee.)

APPENDICES TO REPORT.

Information asked for in paragraph 2 of the Minutes of a Meeting held on 22nd September 1917, by the Committee appointed by Government to report on the Madras City Water-supply, and not given in preceding Report.

PLATES.

(Bound up with Report.)

4 76/92

CORPORATION OF MADRAS,
SPECIAL WORKS DEPARTMENT,
NAPIER PARK,
MADRAS, 24*th August* 1918.

FROM

J. W. MADELEY, ESQ., M.A., M. INST. C. E., M. AM. SOC. C. E., ETC.,
SPECIAL ENGINEER, CORPORATION OF MADRAS.

TO

THE PRESIDENT,
CORPORATION OF MADRAS.

SIR,

MADRAS WATER-WORKS REPORT BY MAJOR JUSTICE AND MR. HUTTON.

1. In compliance with your instructions, I have prepared and send you herewith, a note on the Madras Water-works Report submitted by Major Justice, Sanitary Commissioner, and Mr. Hutton, late Sanitary Engineer, to the Government of Madras.

To avoid repetition, and for ease of reference, the Report on the Water-works that, under your instructions, I prepared for the Committee in October 1917, is attached as an annexure to the note.

2. There is very little new in the Committee's report. With some of the principal recommendations, *e.g.*, the placing of the pump suctions outside the station, and the proposed methods of regulating the supply—I disagree. Whether any benefit would be derived from others—*e.g.*, inserting numerous scours on the Distribution System, and removing the conduit syphons—is extremely doubtful, and the expense of adopting them will not be justified until it is proved that the existing arrangements are defective, and that the proposed action will provide a suitable remedy.

The report bears fresh testimony to the need of a bacteriologist-chemist with a properly equipped laboratory at the filter beds, to keep continuous records of the performance of the filters, and to investigate the numerous, interesting, but as yet unsolved, problems connected with our water supply. At present we are working in the dark, and anything we may do now on the strength of isolated experiments, may well prove a mistake in the light of fuller knowledge.

The Committee did not consider it as part of its duty to deal with the financial aspect of its proposals (Report, page 50). Unfortunately this is a most important factor in determining what the Corporation can do, and I have endeavoured to estimate the cost of the principal recommendations. Some of these—*e.g.*, the acquisition of the Red Hills Lake margin—are necessarily only rough approximations, which give no more than an idea of the order of magnitude of the cost of the proposals.

3. In the note I have dealt in detail with all the important recommendations. A brief summary of them, together with my remarks is given in the following table :—

Page of Report.	Recommendation.	Remarks.	Approximate cost.	See note, page *infra.*
			Rs.	
43	1. Acquire margin 1000-ft. wide round the Red Hills Lake and make fence and path.	Seeing that the water in the lake is considered "good," the question arises whether the results would justify the expenditure. For less expensive methods of reducing contamination see page 41 *infra.*	12,00,000	10 & 11
	Provision of dry weather water supplies to villages.		50,000	
	2. Fence supply channel from Cholavaram tank and area between Tiruvellore Road, Red Hills Village, and tank.		50,000	40 & 41
	3. Remove Village of Kannadayapallayam.		15,000	
43	4. Move Valve House and Fix 14-inch scours.	Unnecessary. No useful results will be obtained.	8,000	23 & 24
	5. Convert Roughing Filters into sedimentation and sunning basins.	Further experiments are necessary. It may be well, eventually, to abandon the Roughing Filters entirely. On the other hand they may prove beneficial.	1,000	12
43	6. Alter syphons on the conduit.	Necessity has not been proved.	20,000	24
	7. Provide additional ventilators to conduit.	Unnecessary.	6,000	
	8. Provide cycle path along conduit.	Under construction.	3,000	
14 & 22	9. Provide 30 Walker's sand washers.	This type is out of date, 4 improved sand washers to deal with the whole of the filters are being installed. One is already in use.	10,000	18
	10. Construction of 2 additional filters.	Totally inadequate.	1,75,000	15 & 16
46	11. Alter filtering materials.			
	(1) Conversion of 3-ft. margin extending under drains in broken stone to side walls.	This may be done in one filter and the results compared with another filter in which the margin is retained.	16,500	17
	(2) Increase of depth of filtering sand by 3-inches.	Unnecessary and undesirable.	10,500	17
	(3) Increase in thickness of broken stone under layers by 6 inches.		54,600	18
		Carried forward ...	16,19,600	

5

Page of Report.	Recommendation.	Remarks.	Approximate cost.	See note, page *infra.*
			Rs.	
	Brought forward.		16,19,600	
	(4) Screen and wash sand used in filter beds.	Unnecessary.	42,000	18
46	12. Construct pump wells outside engine-house with connections to filtered water tanks and new suctions to engines.	Undesirable. Present arrangement is better.	80,000	25
47	13. Clear water reservoirs. Provide ventilators 15-feet long "to induce upward current."	Useless. The flow of air is determined by the rise and fall of the water in the tank.	3,400	
26 & 48	14. Steel Tank. Provide six scours distributed over the flat bottom of the tank.	A diaphragm has been designed to divide the tank into two halves, each to be provided with a scour. This is considered better than the Committee's recommendation.	10,000	25 & 26
49	15. Distribution system. Provide scour valves on all pipes larger than 4-inch.	Unnecessary except at dead-ends and depressions where they either have already been provided or will be provided.	2,15,000	26
49	16. Fix meters on a quarter of house services.	The Corporation has already settled the policy of fixing meters. It is in abeyance because meters cannot now be obtained at reasonable prices. The policy will doubtless be carried out when circumstances permit. After these meters have been fixed, the necessity for others may be determined.	12,00,000	21 & 22
49	17. Engineer's house at Kilpauk.	Desirable.	20,000	
	18. Increase staff.	A larger staff would be an improvement if it could be afforded, but present orders are to maintain staff at a minimum.		
	Total cost of principal recommendations		Rs. 31,90,000	

4. From the above table it will be seen that, of the principal recommendations, I consider that some are undesirable, others unnecessary, and that the need for most of the remainder has still to be proved.

With regard to work to be executed :—Before the appointment of the Committee, we already had in hand the construction of sand-washers, and screens at the filter inlets. These are proceeding. It is already practicable to patrol most of the conduit line on a bicycle, and steps are being taken to make the whole length rideable. The drainage of the filtered water tank roofs, and the contamination of the conduit, have been dealt with. An experiment is in hand to determine the effect of removing the sand margin from one filter. Undesirable features of the old distribution pipe system are being removed. Rules for the staff have been issued from time to time, and will be modified or added to as circumstances require.

On the questions of further steps to prevent pollution of the Red Hills Lake, increase in staff, construction of a house for the Assistant Water-works Engineer, the Corporation probably does not require definite recommendations from me. In the note information is given to assist the Commissioners to arrive at a decision, on these points. I recommend that no action be taken, on the other principal recommendations of the Committee until their need is proved.

The Committee's minor recommendations are of the nature of inspection notes, and may be referred to the Assistant Water-works Engineer for action.

Other important works—not recommended by the Committee—which should be carried out when circumstances permit are—

(1) The construction of seven additional filters and one filtered water tank, to enable the whole water-supply to be filtered.

(2) The raising of the F. T. L. of the Red Hills Lake and the lowest level of issue of water for irrigation, to remove the danger of water famine.

(3) The installation of a waste-water detection meter system, so that the scientific investigation and prevention of waste may be undertaken.

(4) The completion of the Water Distribution System as designed by the Special Engineer.

(5) The removal of silt accumulated in the old pipes.

(6) The construction of a low level Elevated Tank, to reduce the cost of pumping and facilitate the distribution of water.

These five works are mentioned in what at present appears to be the order of urgency, though this may be altered by change of circumstances. Nos. (1), (3) and (4) have already been sanctioned, but were cut out of the Restricted Programme owing to lack of funds. It is hoped that Government may carry out No. (2) at their own cost in view of the straightened financial circumstances of the Corporation, and the increased revenue which Government derive from the increased consumption of water by the city.

5. Some remarks on the Committee's report appear to be called for. They are given in this and the succeeding paragraphs.

The question in which we are all most interested—the results that may be obtained from the filters—remains where it was. Before the Committee was appointed, it was known from Dr. Gibson's experiments that individual filters would give consistently good results for considerable periods. The Committee's isolated experiments carry us no further. The report makes no mention of any investigation of the means to overcome the breaking of the filter skin, and provides no solution of our difficulties in this respect.

6

The Committee states that two additional filters are sufficient to provide a wholly filtered water-supply to Madras. For reasons given in the note (page 15 *infra*), I consider this is a mistake and that nothing less than the seven already sanctioned by Government will suffice.

From the remarks on the filtering head, and from the three plates illustrating the filters, it appears that the Committee does not wholly understand the working of the Madras Filters (*see* page 15 *infra*).

The recommendations for the working of the filter-beds differ very little indeed from the existing methods. The only way to determine if the slight modifications proposed will be beneficial, is to work two filters—one with the proposed modifications, and the other without, otherwise the conditions to be identical in both cases. The result cannot be judged until a bacteriologist is available to carry out the necessary tests. It is true that the equipment for a Laboratory cannot be obtained till after the war, but perhaps the Director of the King Institute may be willing to train a skilled chemist in the bacteriological examination of water, so that by the time the war ends we may have a man capable of analysing the Madras water, and furnishing data for the solution of the problems peculiar to our supply.

6. I take strong exception to the statement made on page 36 of the report that "*prior to the appointment of the Committee . . . . . a large number of samples had been examined at the King Institute of Preventive Medicine, Guindy, and the general result of such examination may be summed up in a statement that the filtered water was worse in quality than the unfiltered water.*"

Isolated analyses apart, the continuous experiments carried out by Dr. Gibson proved definitely that the filters improved the quality of the water, and this is borne out by the Committee's own examination of the filtered water, see especially pages 58 and 63 of its report. Except for the experimental filter, the water examined was filtered exactly as it had been filtered for some time previous to the appointment of the Committee, and the results given on page 63 of the Committee's report show that the filters were working quite well, and on the average were as good as the experimental filter worked under the Committee's special instructions.

7. With regard to increasing the water-supply available for Madras by raising the F.T.L. and the lowest level of irrigation at Red Hills Tank the Committee states: "*We deprecate the extension of the Red Hills Tank if the idea is to continue to supply more water to the present population than they are entitled to receive.*"

The idea is not at all that suggested by the Committee. It is to prevent a water famine such as under present conditions, is almost certain to occur when the monsoon fails. Indeed the late Superintending Engineer, V Circle, has informed me that in three years similar to those 1904, 1905 and 1906 there would be shortage of water with a consumption by Madras City equal to that of 1916. Hence it appears in the highest degree desirable to increase the available supply, which may be most readily done by raising both the F.T.L. of the Red Hills Tank and the lowest level for issue of water for irrigation.

8. On pages 33 and 34 of its report the Committee condemns the present method of restricting the consumption by regulating the pressure, and recommends the supply of fixed quantities between stated hours. The suggestion is impracticable. The fact that Bombay and Calcutta both adopt the same method as Madras, is sufficient to show that it is not quite as bad as the Committee imagines.

Experience shows that the method works well in Madras, and combined with regulation of street valves, has secured a reasonably equitable distribution of water.

9. The Committee was much struck with the large amount of water wasted, and dwells upon the importance of reducing it. There is no doubt that it is far more economical to reduce waste and thereby render the present sources of supply, and the present works, sufficient for a long period, rather than to allow waste and improper use of water, which, if not checked, will eventually mean additional works, and possibly the necessity of going to further sources of supply, which would cost the city an immense sum.

These points have been brought before the Corporation on many occasions. Since the new Water works were opened, the President has taken great personal interest in the matter. The Commissioners have considered it, and have decided on means to check excessive waste, which go beyond the recommendations of the Committee. New rules have been formulated, but it has been impossible to give them full effect owing to the exorbitant cost of meters at the present time. The Assistant Waterworks Engineer is however doing all he can to reduce waste by enforcing the rules as far as practicable, and by house to house inspection.

10. With regard to the remarks of the Committee on divided control, it may be pointed out that during the last few years there has necessarily been some division of control. The Special Works Department constructs new works, and maintains them long enough to be sure that they are in good working order. They are then handed over to the Works Department for maintenance. Under this arrangement the Special Works Department has maintained the whole of the works from Red Hills Lake to the Distribution System, and also the Waste Detection works of the Distribution System, while the Range Engineers have continued to maintain the distribution system in other respects. This divided control has now ceased, for the Corporation has appointed a separate Water-works Assistant Engineer, whose sole duty it is to look after the whole of the water-works. He took up his duties on the 1st April, 1918.

11. With reference to the contamination of the conduit to which the Committee refers: there has been a continual struggle between the villagers to take water from the conduit, and the Corporation staff to prevent them. The points attacked have been the manholes which are provided every 1,000 feet or so to give access for inspection and repairs, and also to provide air vents.

To begin with, wooden manhole covers of a type designed in the Sanitary Engineer's Office were fixed. These were soon wrenched off, and as quickly as they were replaced, they were again removed. The wooden manhole covers were replaced by cast-iron covers specially designed to prevent the villagers opening them. They proved effectual for a time, but eventually the

villagers succeeded in getting at the water by attacking the masonry with crowbars, hammers and chisels. By these means they removed the manhole covers and frames bodily. The next defensive measure adopted by the Corporation was to bolt down the manhole covers to steel beams fixed inside the manholes. This proved effective so long as the nuts were placed inside the manholes, so that they could not be loosened from outside. For a time this defeated the villagers. Indeed the inhabitants of Surapet wrote to Government that "*The manholes which were hitherto kept oben have been now closed under the orders of the Municipality and they would nowhere to go for water and it would be impossible to take water even stealthily as manholes have been completely nailed.*" After a while, however, they discovered that they could break open the ventilators and abstract water by means of small vessels. This stage had been reached at the time the Committee made their inspection. Since then the ventilators have been so modified that the villagers cannot make use of them. At present the defence is successful, and we await the next offensive move of the villagers.

12. One recommendation on which the Committee lays considerable stress, is the provision of a large number of "scours." This proposal is dealt with on pages 26 and 27 *infra*. Here I may explain that a scour to a pipe is a branch, which is normally closed, but which may be opened by turning a valve, so that water may be run out of the pipe through the branch.

The object of a scour is two-fold: Firstly, to empty the main pipe for repair, examination, or for making connections. Secondly, to change the water in pipes where it is liable to remain stagnant. To accomplish this two-fold purpose, the writer—following modern practice—provided scours at all low places to empty the pipes, and at all dead-ends to change the water where it is likely to stagnate. Provision was also made for additional scours, to be fixed in places where experience should prove them to be necessary.

I consider that it would be waste of money to go beyond this, until the need is proved.

The water in the Madras distribution system is changed on the average four times every 24 hours, so that scours are not required to change the water except at points where there is a stagnation.

Possibly the Committee thought that the scours could be used to remove silt from the old pipes. Experience proves that they would be useless for this purpose. In a town so flat as Madras, where in nearly every case the free outlet of scours must necessarily be above the pipe, the removal of silt is confined to a very short length on each side of the scour. The removal of silt from the old pipes will probably require scrapers. It is a problem that will have to be faced as soon as the whole of the city water-supply is filtered.

13. Perhaps I may be pardoned if I point out that the works have been constructed with a large saving (estimated at Rs. 4 lakhs) over the cost which would have been incurred had original designs been adhered to, and had the alterations now recommended by the Committee been carried out as part of the works

Inasmuch as the alterations have increased rather than decreased the efficiency of the works, I feel justified in claiming some credit on the score of the economy effected.

14. In conclusion, my detailed plans of the Pumping Station and Elevated Tank were submitted to the Sanitary Engineer (Mr. Hutton) in 1911 for detailed scrutiny. It is, to say the least of it, unfortunate that he did not make his present criticisms then, so that they could have been thrashed out before the works were started, rather than now, after they are finished.

In July 1913, a sample of the sand then being placed in the filters was sent to Mr. Hutton who wrote that "*it will give, I am sure, excellent results. Trouble may be experienced from clogging of the sand in the beds owing to the fineness of the sand.*"

The Committee now says the sand is too coarse!

I have the honour to be

Sir,

Your most obedient servant,

(Signed) J. W. MADELEY.

NOTE BY THE
SPECIAL ENGINEER, CORPORATION OF MADRAS.
ON
MADRAS WATER-WORKS REPORT
BY
MAJOR JUSTICE, I.M.S. AND MR. W. HUTTON.

Origin of report.

1. The report submitted by Major Justice, I.M.S., and Mr. Hutton, respectively Sanitary Commissioner and late Sanitary Engineer to the Government of Madras—has been prepared by order of the Government in consequence of a Resolution passed by the Corporation of Madras, on 5th September 1917, which reads as follows:—

"*That the Government be requested to move the Government of India for deputing Lt.-Col. Clemesha (or in case he is not available to depute Col. Cornwall) at an early date to inspect and report on the Madras Municipal Water-works and the City Water-supply.*"

This Resolution was brought forward by Mr. K. C. Desikachariar, owing to doubt concerning the quality of the water supplied to Madras, arising from certain analyses by the Director of the King Institute, Guindy. The Resolution was welcomed by the executive for, in the absence of a Corporation Bacteriologist and Bacteriological Laboratory, the officers of the Corporation were not in a position to maintain bacteriological control over the water-supply.

In place of either of the gentlemen asked for by the Corporation, the Government appointed a Committee consisting of Surgeon-General Bannerman (President) and the Sanitary Commissioner and the Sanitary Engineer. It is a misfortune that, owing to ill-health, Surgeon-General Bannerman was unable to assist in the preparation of the report.

Preliminary report by the Special Engineer.

2. To facilitate the work of the Committee, the President of the Corporation instructed the writer to prepare a report on the working of the Water-works, more especially the filters. This report, dated 9th October 1917, was sent to the Committee on 11th October 1917. Its principal contents are—

(1) A description of the Water-works.
(2) Details of working and difficulties encountered.
(3) A statement of the defects of the water-supply and the points that require elucidation.

The report is illustrated by numerous plans, diagrams and appendices dealing with the working of the filters, staff employed, and the results of analyses made at the King Institute, Guindy.

As frequent references will be made to this report, it has been printed, and is attached as an annexure to this note (pages 30 to end *infra*).

Other information supplied by the writer from time to time, either to the Committee direct, or through the Corporation President, included the Special Engineer's "Restricted Programme Report," 1916, and his "Madras Water-works Distribution Report," 1911. In addition, a number of data and plans were furnished in compliance with requests received from the Committee.

Order of considering Committee's Report.

3. The most convenient order in which to consider the report submitted by the Committee will be to follow the questions raised in paragraph 22 of the writer's report (page 51 *infra*).

In what follows the questions raised are printed in heavy type, the recommendations of the Committee are printed in italics, and are succeeded in each case by remarks in ordinary type.

Contamination of Red Hills Lake.

4. **Whether the steps at present taken to prevent contamination of the Red Hills Lake are sufficient? If not, what further protection is necessary or desirable?**

The Committee does not state the steps at present taken. These are described in some detail in paragraph 14 of the writer's report (page 40 *infra*). The Committee imply that the measures therein described are not sufficient, for they make the additional recommendations (*a*) to (*d*) given below—

RECOMMENDATION (*a*):—"*That an area of land around the margin of the tank 1,000 feet wide should be acquired and that an inspection path should be framed through this area.*" (Page 43.)

REMARKS:—In the writer's opinion, the margin would be useless, unless it were strongly fenced, and a considerable number of men were employed to patrol it. The only suitable cheap type of fence that the writer can think of, is a belt of prickly pear shrubs some 12 feet wide. This would cost about Rs. 50,000, including an allowance for places where special types of fence would be necessary.

Even if a margin 1,000 feet wide round the lake were acquired, it would still remain necessary to provide dry weather water-supplies to all villages situated within or close to the margin. Without such supplies, no patrol of reasonable strength would be able to keep men and cattle—starving for want of water—from crossing the margin to quench their thirst. Further, the drainage from the villages would still remain. This is the worst part of the contamination. To eliminate it, the drainage would have to be diverted and dealt with in such a manner as not to pollute the lake—a problem not easy of solution. It is probably on account of this difficulty that Sanitary Commissioners in the past have recommended the acquisition of the whole of the "inner" catchment draining to the Red Hills Lake.

The financial aspect is obviously an important factor. As the writer had no means of forming an accurate estimate of the cost of acquiring the land, a letter dated 8th August 1918 was addressed to Mr. Hutton, now Superintending Engineer, V circle, asking for an approximate estimate. In reply to a reminder, a reply has been received stating that even a rough approximate estimate can only be obtained by reference to the revenue authorities, and that this is being obtained. In the meantime as a very rough approximation, to indicate the order of magnitude only, the cost of acquiring the 1,000 feet wide margin constructing a fence, and making a cycle path through it, may be set down at Rs. 12 lakhs, and the provision of dry weather water supplies to villages at Rs. 50,000.

RECOMMENDATION (*b*):—"*That the banks of the supply channel from Cholavaram Tank should be fenced, and also the area between Tiruvellore Road, Red Hills village and the tank margin.*" (Page 43.)

9

REMARKS:—To be of any use, the fencing would have to be patrolled. The cost of fencing is estimated very roughly at Rs. 50,000.

RECOMMENDATION (*c*):—"*The patrolling staff of ten lascars and one overseer should be re-organized, supplied with proper uniform, mustered regularly and their work checked more frequently by superior officers.*" (Page 43.)

REMARKS:—It is not understood what is meant by "re-organized." Except for a uniform, the recommendation coincides with procedure already adopted and the work is checked by superior officers as frequently as is practicable. A uniform was provided until recently. It was stopped for reasons of economy, but the question is again to be brought before the Corporation. The duties of the staff are described in paragraph 14 of the writer's report (*see page 41 infra*).

If the Committee's recommendations are to be effective, a much larger staff would be required. In this connection, the writer would refer to measures 1, 2, 3, 4, and 5 (page 41 *infra*).

RECOMMENDATION (*d*):—"*That the village of Kannadyapalaiyam be removed further to the east of the tank bund and as an alternative temporary measure this village be fenced on three sides to prevent access by the villagers and their cattle to the tank water.*" (Page 43.)

REMARKS:—The estimated cost of this work is—

For removing the village	...	Rs. 15,000
For fencing ...	...	„ 5,000

GENERAL REMARK:—With reference to all these recommendations to stop pollution, it may be remarked that the Committee state that the "*quality of the Red Hills Tank water is on the whole good.*" (Page 42.)

In addition to the cost of the recommendations estimated at Rs. 13,15,000 the staff at the Red Hills would have to be increased to at least five-fold. The question arises as to whether the water, which is stated by the Committee to be already good, would be sufficiently improved by these measures to justify the expense.

Level of draw off from Red Hills Lake.

5. **What is the best level to draw off the water at the Inlet Tower? The present practice, which is believed to be the best, is to draw off from a little below the surface.**

RECOMMENDATION:—*Outlet Tower. In "withdrawing water from the Outlet Tower to the roughing Filter, the inlet pipes should be protected by screens and the upper valve below water level should always be used, any deficiency of supply being supplemented by a partial opening of the middle valve. The bottom valve should only be used when, owing to low level of water in the tank, this is found absolutely necessary.*" (Page 43.)

REMARKS:—The writer does not agree with the Committee that "*the upper valve below water level should always be used.*" When this valve is so close to the surface that it draws in the top layer of water, it should not be used. If it is used, it will draw into the city water supply the impurities that are found in the surface water, including a very offensive scum which is driven towards the valve tower by the west and south-west winds that prevail during the hot weather.

The writer's view is supported by the bacteriological results given in Appendix IV, page 54 of the Committee's report, from which are taken the following figures, showing the number of bacteria at different levels at the Red Hills Lake Outlet Tower :—

Depth from surface.	Total colonies per c.c. on Agar at 37°C.	No. of c.c. in which lactose fermenters present.
At surface.	860	30
1 ft. 2 ins.	765	60 upward.
5 „ 5 „	620	60 „
11 „ 4 „	790	60 „
15 „ 10½ „	940	60

These experiments show that, at the time the samples were taken, the surface water was the worst of all as judged by the lactose fermenters test, and it contained more total colonies than any other sample except that taken from the very bottom of the lake.

The experiments also indicate that the purest water is at a depth of 5½ feet from the surface, which is about the level from which the water is now drawn It thus appears advisable to continue the present practice.

With reference to the recommendation that the inlet pipes should be protected by screens, it is observed that such screens would be nothing but strainers and would require frequent cleaning if they stopped weeds. Screens to exclude this matter from the town water-supply are already provided at screening chamber.

Roughing Filter.

6. Does the Roughing Filter serve any useful purpose or not? If not, would it be better to dispense with it, maintaining the screening chamber and measuring weir? (page 51 *infra*).

RECOMMENDATION :—" *That broken stones should not be used in these filters, but that they should be used simply as tanks acting as small sedimentation and sunning basins.*" (Page 43.)

REMARKS :— By implication the Committee's reply to the first part of the question is in the affirmative and to the second part in the negative. The results obtained by the King Institute in July and September 1917, are at variance with those of the Committee, in that they do not show deterioration of water while passing through the Roughing Filter. It appears that further experiments are required to clear up this difference. The conditions of working the Roughing Filter have to be taken into account.

For some time before the Committee visited the works, half of the Roughing Filter was put out of use in order to try to determine whether it was beneficial or not. But in the absence of bacteriological examinations, a decision could not be arrived at. In view of the Committee's recommendation, the whole of the Roughing Filter is now used as a sunning and sedimentation basin until it is possible to carry out further experiments. Should it be found that the roughing filter has a bad effect, the next question that would arise is whether it would not be well to do away with it altogether and cover in the screens. This would appear to be the logical conclusion from the Committee's report, for in section 5, page 9, the Committee state that " *it was obvious that the growth of moss was*

encouraged by light." However, further experiments are required before this point can be settled.

It may be remarked that the Committee is mistaken in thinking that the Roughing Filter was not cleaned before their visit. As a matter of fact, it had been cleaned and sterilised on a number of occasions, and on one side, as the Committee must have observed during their visit, the stones had been removed. These would have been replaced, and the stones on the other side removed, had it not been known that an investigation was to be made, and it was thought well that the Committee should see half of the filter at its worst, in order to facilitate a decision on the utility of the Roughing Filter—a point on which an expression of opinion had been asked.

Vegetable growth in conduit.

7. Is the vegetable growth in the conduit harmful to the water? If so, what steps should be taken to prevent it?

The Committee does not appear to have investigated this point.

Effectiveness of sand filters.

8. Can the sand filters be worked so as to render the water safe and wholesome?

" *On the whole the Committee are satisfied from the results obtained from the analyses of water at Kilpauk and especially from the Committee's experiment with bed No. 4 that satisfactory results from the filtration of water through sand filters when efficiently controlled are obtainable.*" (Page 38.)

At first sight this appears to be a re-statement of a well established fact, but from the general tenor of the report, it is safe to surmise that the Committee means that the Madras filters can be made to purify the Red Hills water satisfactorily.

This is re-assuring. Unfortunately, the Committee did not carry out continuous experiments over a long period similar to those of Dr. Gibson, and failed to encounter the difficulties described in paragraphs 12 and 20 (pages 39 and 46 *infra*) of the report prepared for them, and illustrated by the diagrams (facing page 38 *infra*) of the results of those experiments.

Crabs, fish, and frogs, make it difficult to maintain the filter skin properly. They are not peculiar to Madras. For instance they also cause trouble in Calcutta. The best method of dealing with them has yet to be determined. The writer has been trying screens. The Committee has nothing further to suggest.

As regards the results obtained, we are no further forward than we were before the Committee was appointed. We knew then from Dr. Gibson's experiments that individual filters can give consistently good results for considerable periods, *e.g.*, Dr. Gibson's experiment on Filter-bed No. 8 gave good results from 3rd March to 12th May 1916, when it was stopped for cleaning (*see* Appendix II, pages 68 to 70).

The isolated experiments of the Committee show the results obtained on the particular dates on which samples were taken. They do not show how the filters were working between those dates, nor do they show how the filters would work under the different conditions that occur at times of the year other than those at which the samples were taken.

Major Clemesha in his recent report on the Bombay water-supply states that "*The bacteriological study of the water should, to be of any use, be continued for at least a year.*" Those who have to maintain a water-works like that of Madras will agree with him. Even in 12 months all the factors bearing on the quality of the water may not be encountered.

Methods of working filters.

9. **(a) What modifications, if any, are required in the methods of working the filters now adopted and set out in Appendix I-B.**

RECOMMENDATIONS :—The recommendations on the working of the filters are somewhat scattered. The principal refer to formation of filtering skin, method of starting the filters, and the filtering head. The chief respects in which these recommendations differ from the rules which were prepared by the writer in 1915, and handed to the Committee (*see* page 56 *infra*) are—

(1) That the sedimentation shall be three days instead of twenty-four hours.

(2) That the filtering head shall not exceed 24 inches.

REMARKS :—With regard to these, the question of sedimentation for 3 days instead of 24 hours requires, in the opinion of the writer, further investigation. A reference to the bacteriological results given in Appendix XIII, page 63 of the report of the Committee will show that on 17th April 1918, the beds worked under the rules laid down by the writer in 1915, without any special supervision, were as good as the results from the bed specially worked under the direction of the Committee.

The figures given for the filtered water from the outlets of the different beds are as follows :—

Bed No.	Total colonies per c.c. of Agar at 37°C.	Lactose fermenters present in how many c.c. ?	REMARKS.
2	205	30	
3	115	None in 60	
4	135	60	
5	200	20	
6	190	60	
7	130	None in 60	Bed No. 4 was worked under the direction of the Committee. The other beds under the rules of 1915.
8	205	15	
9	120	None in 60	
10	140	60	
11	165	60	
12	145	None in 60	No vibrios were found in any of these samples.
14	150	"	

Taking the lactose fermenters as the proper test, and comparing the 11 other beds with No. 4, we find that 5 were better, 3 equal and 3 worse. Thus the bed specially worked according to the instructions of the Committee was very nearly equal to the average of the beds which were worked according to the rules drawn up in 1915 and set out in Appendix (*see* page 56 *infra*).

It is not seen that any case has been made out for an alteration in the rules under which we have been working for some years. As soon as a bacteriologist is available, it will be desirable to carry out continuous experiments

extending over long periods, in order to find out how to get the best possible results from the filters.

The writer strongly deprecates a cast-iron rule restricting the head to 24 inches, as recommended by the Committee, unless it is definitely proved that a greater head results in imperfect purification. Such a limitation of head, if unnecessary, involves more frequent cleanings, greater waste of water, and a larger area of filter-beds than if a greater maximum head is permitted.

Perhaps the recommendation is due to a misapprehension of the working of the Madras filters, for on page 38 the Committee writes—

"*If a filter-bed were completely clogged . . . . . the filtering head would be the difference in level between the surface of the unfiltered water and the floor of the filter. This difference might be seven feet . . . . .*"

This statement shows that the Committee does not understand the working of the Madras filters. In ordinary working, before the filtered water can pass away it has to rise in the outlet chamber until it reaches the weirs of the regulator. As the weirs of the regulator cannot sink lower than 3½ feet above the filter floor, it is obvious that the filtering head in ordinary working could never be "*the difference in level between the unfiltered water and the floor of the filter-bed.*"

As a matter of fact, in ordinary working, the filtered water level cannot be lowered below a point about one foot above the normal sand surface level and the total head which can be applied to the filter cannot exceed 2 feet 10 inches.

This non-appreciation by the Committee of the method of working is confirmed by the three plates illustrating the filter-beds in which the water is shown flowing with a free surface into the main drain, neither the collecting drains nor the main drain being full. This state of affairs is an impossibility with the arrangement of the Madras filters.

Additional filters required.

10. **What additional filtering area is required ?**

RECOMMENDATION :—"*As the present filters are only capable of supplying eleven million gallons daily and as thirteen million gallons are required, we recommend the construction of two additional filter-beds.*" (Page 48.)

REMARKS :—The writer entirely disagrees with the Committee that two additional filters are sufficient. He remains of the opinion that at least seven extra filters are required if the whole supply to the city is to be filtered.

In order to ascertain how the Committee arrived at its opinion, reference may be made to page 34 of the report where the Committee assumes that the *present* population—taken as 523,000—is to be supplied with 25 gallons per head. This would require 13,075,000 gallons per day; 75,000 gallons per day (the supply of 3,000 people) is knocked off, and the quantity to be provided is taken as 13,000,000 gallons per day. The Committee then assumes that 16 filters will supply this quantity.

The writer has to point out that, if the city is to be supplied wholly with filtered water, the filters must be capable of supplying the maximum reasonable demand, which occurs during the hot weather, and unfortunately coincides with the period when the filters clog most rapidly.

The writer contends that it would be most unwise to assume—as the Committee does—that the maximum supply can be reduced to 13,000,000 gallons per day.

The present consumption in hot weather already amounts to 16,000,000 gallons per day, and it is unlikely to be materially reduced, for any reduction in waste that may be effected, is likely to be neutralised by increase in population, and by the extension of water-closets, baths and flush-out latrines, so that, in the writer's opinion, it would be most unwise to provide for a consumption less than the present.

Further the Committee has over-estimated the output from the filter-beds. The reasoning by which they arrive at their conclusion is given on page 34 in the following words :—

"*The Committee are aware that the total output of 14 filter-beds is 14,000,000 gallons and that at least 3 of these beds would be out of use under cleaning, so that the net quantity of filtered water available for the city would only be 11,000,000 gallons daily. . . . . . . They are therefore prepared . . . . . . to recommend the early construction of two more filter-beds so as to obtain a daily supply of 13,000,000 gallons of filtered water.*"

The Committee therefore assumes that with 16 beds they would be able to filter 13,000,000 gallons per day. As a matter of fact, it is very unlikely that they would get this quantity. Assuming their own figure that "*at least 3 out of 14 beds would be out of use for cleaning,*" it may be taken that on many occasions 4 out of 16 beds would be out of use for cleaning. The remaining 12 beds would filter 12,000,000 gallons per day when working at their maximum rate, but they do not work at their maximum rate throughout because at starting two days are required to fill the filter, three days for sedimentation, followed by one day's wasting of imperfectly filtered water, and a further two days of slow filtration. Then before a filter can be cleaned, two days are required to empty it, so that in addition to the time required for cleaning, there are 8 days during which a filter passes no water at all, and two when the rate of filtration is slow. The net result is, that taking all stoppages into account each filter deals with water at an average rate of 660,000 gallons per day. So that for a supply of 13,000,000 gallons per day, 20 filters are required. As the supply already reaches 16,000,000 gallons on many days seven additional filters at least are required, as recommended by the writer, accepted by the Corporation, and sanctioned by Government in G. O. No. 1442 M., dated 31st July 1914. Experience may prove that more are necessary.

Changes in design of filters.

11. Are any alterations in design needed ?

RECOMMENDATION:—The Committee recommends the following alterations in design. (Page 46.)

(1) "*Conversion of the 3-feet margin (of fine sand) by extending under drains and broken stone to side walls.*"

(2) "*Increase to the depth of the filtering sand by 3-inches.*"

(3) "*Increase in the thickness of broken stone under layers by 6-inches.*"

(4) "*Screening and washing of the sand used in the filter-beds.*"

The original standard grade of sand to be used, viz., the filtering sand to pass through a screen of 30 meshes to the lineal inch and be retained on a screen of 50 meshes to the lineal inch."

Removal of sand margin.

REMARKS:—(*a*) The first recommendation has reference to dealing with the black layer of sand which is found in all the beds. This black layer, as it was found in the hot weather of 1917, is described in paragraph 20 of the writer's report (*see* page 47 *infra*). For some reason or other, its distribution had changed at the time the Committee visited the works, and the writer considers that it would be well to carry out the Committee's recommendation for one filter and ascertain the result.

It may be pointed out that the 3 feet sand layer is not the writer's invention—as the Committee appears to think. It is a well recognized method of preventing "*water creep*" down the sides of filter bed walls, and is employed in the London water-works, amongst others. It should certainly not be discarded unless it is shown that it does harm rather than good. No experiments have yet been made to test this point.

It is interesting to note that the analyses made for the Committee by Dr. Simonson, confirm the opinion arrived at by Dr. Kesava Pai (*see* page 48 *infra*), that the black layer in the filter-beds is due to the formation of sulphide of iron owing to the chemical action of sulphur in the water on the small quantity of iron in the sand. This probably explains why the complaints of bad smell from the water at the house services have now ceased, although they were very common before the introduction of the new water-supply. It is certainly preferable to get rid of the sulphur at Kilpauk, even if it involves some smell at the filter beds, if the water at the house tap is thereby freed from an offensive smell. The sulphide of iron in the sand, so far as has been observed at Kilpauk, is reconverted into iron oxide, so that probably the purifying effect of the iron will continue indefinitely. If it does not, it may prove beneficial to add iron to the sand as iron filings or in some other form.

Depth of water over sand.

(*b*) The recommendation to increase the depth of filtering sand and the depth of the stone layers, involves a corresponding reduction of the depth of water over the sand. The writer does not advise such a reduction for it would almost certainly lead to an increase of algal growth, which up to the present has given remarkably little trouble in the Madras filters. That the danger is present is proved by the fact that this growth does take place in the hot weather, and forms a thick skin over some of the filters.

Minimum thickness of filtering sand.

(*c*) A reason given for increasing the thickness of sand is because "*the Committee consider that the filtering sand should not be reduced below 2 feet to obtain good results*" (Page 45). It is quite unusual to insist on such a thickness as a minimum. Quite a usual thickness is one foot. This is the German standard; it is common in England and is the thickness specified in Calcutta. The writer has laid down 15 inches (*see* Rule 10th page, 57 *infra*), and he considers it sufficient. Even if, after experiment, the unusual minimum thickness of 2 feet was found necessary, it would be far better to maintain it by replacing dirty sand by washed sand, than by the method suggested by the Committee, which would favour the growth of algæ.

Thickness of broken stone layers.

(*d*) The same arguments apply to the increase of broken stone under layers. It is not understood why these layers should be made thicker. They serve perfectly their object of supporting the sand which does not percolate into the drains. It is not understood what the Committee mean by saying that "*another important function of this layer is to facilitate the passage of filtered water from the sand layer to the under drains.*" (Page 19.) A layer of coarse sand resting on two layers of broken stone should certainly suffice for this passage.

In this connection it is interesting to note that recently one member of the Committee (Mr. Hutton) argued strongly in favour of stone layers 24 inches thick, which is much thicker than modern practice. This was embodied in what was called the "*Madras Standard Filter*". He now appears to be satisfied with 10 inches. It is not unreasonable to suppose that before long he will still further reduce his standard.

Fineness of sand.

(*e*) With reference to the fineness of the sand, it is interesting to note that when first a sample was sent to Mr. Hutton, he (on 21st July, 1913) wrote to the President, "*The Kilpauk sample is a much finer sand than we have used in the Guindy experiment and will give, I am sure, excellent results. Trouble may be experienced from clogging of the sand in the beds owing to the fineness of the sand.*"

In those days he considered the sand too fine, now he is of opinion that it is too coarse!

Apparently Mr. Hutton has changed his opinion since then.

Sand washer.

(*f*) The recommendation that the Corporation should instal Walker's sand washers, is extraordinary, for the Walker sand-washer is an old type, which the writer would condemn. A much more satisfactory type has been designed, of which one is in use and three are under manufacture. These will be sufficient to deal with the 14 existing filter-beds.

Bacteriological control.

12. What steps should be taken to maintain an adequate bacteriological control?

RECOMMENDATION:—*The Corporation should employ a bacteriological assistant with a suitably fitted up Laboratory at Kilpauk, so that daily investigations can be carried out on the quality of the water.* (Page 41.)

REMARKS:—If the bacteriological quality of the water has any importance at all, it is of the greatest importance that effect should be given to this recommendation as soon as practicable. This question was gone into at some length with the Director of the King Institute, Guindy, from whom it was ascertained that the necessary apparatus could not be obtained at the present time.

Occasional bacteriological analyses are of very little value. To maintain a proper control of water, they should be taken every day.

Samples to be taken.

13. What samples should be taken?

(1) As a matter of routine.

(2) Occasionally.

No reply has been found in the report to this very important question.

Crenothrix polyspora, sulphuretted hydrogen.

14. What should be done to remove the white filamentous growth of "crenothrix polyspora" from the filtered waters? How can the smell of sulphuretted hydrogen be removed?

REMARKS:—No detailed investigation has been made but the Committee states that if effect is given to its recommendations the members *think that in all probability the presence of crenothrix growth and unpleasant smell of sulphuretted hydrogen will disappear.*

This of course may or may not be the case. Further investigation of these difficulties is required.

As regards the smell of sulphuretted hydrogen, it may be remarked that it is preferable to remove the sulphur at the filter-beds rather than in the pipes, where it causes a smell that is highly objectionable to water consumers.

Therefore, except for sentimental reasons, the liberation of sulphuretted hydrogen is probably a blessing in a disguise which is unpleasant to the olfactory sense.

Sterilisation of under-drains.

15. Is the sterilisation of the under drainage system of the filters desirable to prevent post filtration multiplication of bacteria, and also the growth of "crenothrix polyspora?"

This question does not appear to have been investigated by the Committee.

Rate of filtration.

16. What rate of filtration may be adopted?

RECOMMENDATION:—*Maximum rate of 4 inches per hour.* (Page 47.)

REMARKS:—This agrees with the rate given in Rule 2 for the working of the filters (page 56 *infra*), a higher rate is mentioned in Rule 12, but this has not been allowed since the effort to supply the city wholly with filtered water was abandoned.

Maximum head.

17. What is the maximum head that may safely be adopted on the filter-beds?

RECOMMENDATION:—*In no case should the filtering head be allowed to exceed 24 inches.* (Page 47.)

REMARKS:—As already stated, (page 15 *supra*) the writer deprecates limiting the head to so small a figure, unless it is proved that higher heads cannot be safely used.

Exclusion of crabs, frogs, fish, etc.

18. How can crabs, frogs, fish and other harmful organisms be excluded from the filter-beds?

RECOMMENDATION:—*The inlet chamber should be provided with a screen as an additional precaution against the entrance of frogs, crabs, etc.* (Page 45.)

REMARKS:—The Committee's proposal is not new. Screens at the inlet chambers of some of the filters have been in use for some years to ascertain if they will exclude the organisms that do the damage. It is disappointing to the writer that the difficulties of these causes were not further investigated by the Committee, as they form the greatest problem that has to be solved. It is believed that most of the troubles with the filters indicated by the bacteriological analyses and shown on the diagrams, facing page 38 *infra*, are due to these causes.

Means to purify water other than sand filters.

19. If sand filters are not sufficiently reliable, what other steps should be taken to secure to the city a sufficient supply of wholesome water?

REMARKS:—The Committee probably considers that this question does not arise because it has expressed the opinion that the water can be rendered safe by means of slow sand filters. When framing the question, the writer had in mind that, if there were any uncertainty, it would be well to sterilize the water. The readiest agent would probably be chlorine obtained by electrolysis of a solution of brine, as is done at the Buckingham and Carnatic Mills for bleaching purposes. The cost of such a process would be small, as brine is readily obtainable, and there is already at the station a dynamo to generate electricity for electric lighting at night, during the day it could be used to produce chlorine. Sterilisation is superfluous, however, if uniformly satisfactory results can be obtained with sand filters only, but this has not yet been proved.

Cost of recommendations.

20. What would be the cost of carrying out each of the recommendations that may be made in reply to the above queries? As regards—

(a) The cost of installing all the necessary plants and apparatus.

(b) The annual cost of upkeep and maintenance.

REPLY.—The Committee *point out that they have only recommended two additional filters instead of the seven, the construction of which was approved by the Corporation. The other recommendations are in connection with the improvement of details, the cost of which would be relatively small.* They consider however that "*the washing, screening and relaying of the filter-bed materials will ultimately cost a considerable sum.*" (Page 50.)

REMARKS:—It is not understood how the Committee arrived at its conclusion that its recommendations, excluding the two new filters and washing, screening and relaying filtering materials, would cost only a small sum. On the contrary they would cost a large sum as is shown in the introductory letter.

Insufficient capacity of Filtered Water tanks.

21. In addition to the queries, there were certain defects pointed out in the writer's report for the benefit of the Committee. Of these a few will now be dealt with.

The insufficient capacity of the filtered water tanks.

REMARKS:—No reference is found to this defect in the Committee's report. Possibly its importance was not appreciated. Those who have to maintain the water-works feel that an additional tank will be urgently required when the town is again supplied with filtered water only.

Distribution pipes still required.

22. The increase in the number of street pipes and the installation of a waste water detection meter system, as provided in the sanctioned scheme, but deferred for want of funds.

REMARKS:—These points are not dealt with by the Committee beyond the following reference:—

"*The Committee recognise the advantages of adding Deacon's waste Detection Meters to the distribution system of the city.*" (Page 48.)

The Committee does not appear to have considered what additional pipes are required for the distribution system. It may therefore be well to point out that to complete the scheme as designed by the writer, approved by the Corporation, and sanctioned by Government, the following additional pipes are required:—

Diameter.	Length required.
4 inches.	2,70,000 feet.
5 "	15,000 "
6 "	15,000 "
7 "	7,000 "
8 "	10,000 "
9 "	5,000 "

These should be obtained and laid when funds are available.

Waste of water.

23. The large amount of waste and non-domestic use of water which makes it impossible to maintain a high pressure throughout the day.

RECOMMENDATIONS:—A number of recommendations are made, which will be taken in order.

(1) "*The present policy of supplying unlimited quantity of water should be given up.*" (Page 48.)

REMARKS:—As there never has been any such policy, it cannot be given up.

(2) *The policy to be adopted should be that of fixing the quantity of water in gallons per minute to be supplied during stated periods.**

REMARKS:—The Committee deals with this in considerable detail on pages 33 and 34 of its report.

The method proposed is impracticable. The Committee is wrong in its conclusion that *there is at present no organized regulation of the distribution draw off such as they have indicated.* (Page 48.) The regulation of the supply by sluice valves is used to prevent excessive use of water by limiting the flow to any particular area or street. But it cannot be employed to the extent contemplated by the Committee. It is quite impossible in this way to ensure that every person in the city shall obtain an equitable share of water. In the absence of a waste water detection meter system and house meters, which cannot be obtained at the present time, the only method, which has so far been found practicable, is to reduce the pressures in the manner stated in the writer's report (page 52 *infra*). It is the method adopted in Bombay and Calcutta and should be continued in Madras.

House meters.

24. The Committee recommend "*the early introduction of house-service meters.*" "*We contemplate that one-quarter of the house services will be metered in the next few years.*" (Page 48.)

REMARKS:—This recommendation is indefinite inasmuch as it does not indicate whether it is proposed that all house-services should eventually be metered, or if any particular class or classes of house should be metered. The

* These are not the actual words of the Committee, but they convey its meaning.

Corporation has already considered this matter on several occasions. The question is largely one of finance. The number of existing house services is 29,326. If these were all metered, the cost, including meter pits and additional stopcocks, etc., would be Rs. 50 lakhs, and would involve an annual expenditure in staff and repairs and interest on capital amounting to at least 6 lakhs per annum. The annual cost could be recovered by meter rents—though this means an extra tax of Rs. 6 lakhs per annum—but the capital cost is outside the range of practical politics at the present time, when the Corporation has had to cut down to the uttermost its expenditure on new works.

It was on account of the great cost that the writer in his Water Distribution Report, dated September 1911, advocated the classification of services into first-class and second-class house services (*see* pages 89, 79, 80 of the said report). This principle has been accepted by the Corporation and sanctioned by Government. It is now strictly enforced (*see* page 5 of the Water-works Hand-book forming Appendix I-F and bound between pages 64 and 65 *infra*).

In these circumstances, it would appear that the Corporation has already gone beyond the Committee inasmuch as it has decided exactly what class of house shall be metered as soon as meters are available and funds permit.

Waste detection Staff.

25. RECOMMENDATION :—*Special Staff.—We also propose .... a special staff for the proper organization of house-services and meters.* (Page 48.)

REMARKS :—This question of reorganisation is one on which the newly appointed Water-works Assistant Engineer will doubtless put up proposals as the need arises.

There already is a special staff with proper organization for house services and meters. That it does useful work may be seen by a reference to page 18 of the Administration Report for 1917-18 where it is recorded that *the waste detection staff examined 21,000 houses and brought to notice over 3,000 defects in the services.*

The Committee considers that the staff is quite inadequate. The question of its increase is one for which the Assistant Water-works Engineer will doubtless put up proposals when and if needed.

The present is however hardly an auspicious time to make proposals for an increase of staff, for the Corporation finds it difficult to pay its way and is urged by Government to reduce its staff to the uttermost.

Charge for water.

26. RECOMMENDATION :—The Committee recommends *"that the charge for excess water used which is at present 12 annas per 1,000 gallons .. .. should be raised to Re 1 per 1,000 gallons."* (Page 48.)

REMARKS :-The Corporation has already raised the price to Re. 1 per 1,000 gallons. It has gone further and has reduced the free allowance from 160 to 100 gallons per rupee of rent following a recommendation made by the writer in his Restricted Programme Report, dated 22nd July 1916, page 26, that *"the free allowance should be reduced from 160 gallons per rupee of rent to 110 or perhaps 100 gallons per rupee of rent."*

15

Increasing quantity of water available.

27. Another point which the writer brought to the notice of the Committee is—

The question whether the water-supply from existing sources is sufficient, and whether the works as a whole can bring enough water to the City. (Page 52 *infra*).

Answers to these questions are found scattered about the report. On page 35, the Committee say :—*"The Committee would emphasize their opinion that a supply of 25 gallons per head per day is ample for all reasonable demands and it is not the duty of any Corporation to comply with unreasonable requirements."*

With reference to the question of increasing the supply by raising the F.T.L. of the Red Hills Tank in the manner urged by the writer, the Committee states :—*"We deprecate the extension of the Red Hills Tank, if the idea is to continue to supply more water to the present population than they are entitled to receive."* (Page 42.)

The proposal to extend the Red Hills Tank by raising the bund in the manner proposed by the writer is not to supply the present population with more water than they are entitled to receive, but to prevent a water famine and the very serious results that would follow. In his opinion such a famine is a real danger in a dry year, and this view is confirmed by a letter from the Superintending Engineer, V Circle, given on page 80 of the Committee's report for he says that *"had the issues to the Madras Corporation in 1904-5 been the same as 1915-16 the tank would have failed."* This fully confirms the writer's view, and adds force to his argument that the capacity of the Red Hills Lake should be increased without delay, and that the lowest level for issue of irrigation water be also raised at the same time.

ADDITIONAL RECOMMENDATIONS MADE BY THE COMMITTEE.

Scours on pipes at Red Hills.

28 In the foregoing paragraphs, the recommendations made by the Committee have been considered in connection with the points raised by the writer in his report

Certain additional recommendations of the Committee will now be considered

(1) RECOMMENDATION (page 43) :—*"Valve house—Owing to the inefficiency due to their small size of the scour pipes on the 24-inch mains from the lake to the valve house, it is necessary to provide 14-inch scour pipes and as the length of these mains from the valve house to the roughing filter is not scoured at all at present the valve house should be shifted as near as possible to the roughing filters and the new scour pipes provided at the new site."*

REMARKS :—The velocity of water in the 24-inch pipes is twice that in the conduit and it is considered that this velocity is sufficient to ensure any silt being carried to the settling pit into which the 24-inch pipes discharge at the screening chamber. To make doubly sure that this scouring action shall take place, the whole of the water is passed for a short time every morning through each pipe in turn. This ensures a velocity of about 8 feet per second which has a much greater scouring action than the arrangement proposed by the

Committee. It is not considered that the few experiments made by the Committee are sufficient to prove any deterioration of the water in this short length of 62 yards of pipe.

The silt observed by the Committee must have formed in the scour pipes. The writer has examined the inside of both 24-inch pipes and found that they were quite clean.

Roughing Filter.

29. The question of the roughing filters generally has already been dealt with. (Page 12 *supra.*) Various detailed recommendations are also given by the Committee, some of which have already been executed. The remainder may be referred to the Water-works Assistant Engineer for consideration and action as he thinks advisable.

This applies also to a number of recommendations concerning the conduit, *e.g.*, an inspection path which is in course of construction.

Syphons on conduit.

30. "*The three syphons on the conduit should either be duplicated and provided with means for emptying them or the conduit should be reconstructed at these places at its usual gradient and the cross drainages which originally required the construction of syphons on the conduit should themselves be syphoned under the conduit.*" (Page 43.)

REMARKS:—These recommendations are made with a view to minimising the deposit of silt in the present syphons, it being thought that such silt produces bacteriological deterioration of water. Roughly estimated, the works would cost about Rs. 20,000. It is recommended that they should not be carried out unless and until it is proved that there is a real deterioration of water when passing through the syphons. The writer has been inside one syphon and found no silt.

The syphons can be cleaned as required, the question of what intervals should be left between cleanings is one which should be settled by the Assistant Water-works Engineer as the result of experience in working.

Water-supply to Sulurpet and Puttavaram.

31. "*The two villages on the conduit line, Sulurpet and Puttavaram, should be provided with wells supplied from the conduit.*" (Page 44.)

REMARKS:—The proposals for the supply to Sulurpet of water by means of wells as suggested by the Committee were submitted by the Special Works Department before the Committee was appointed. The matter is awaiting disposal by Government.

As regards the supply to Puttavaram Village, the question has not arisen, and the Assistant Water-works Engineer informs me that he is convinced that no water is now being taken from the conduit by the inhabitants of this village.

Extension of Water-Supply area.

32. "*The service connection north-west of the filter-beds at Kilpauk should be extended as far as Manhole No. 54 . . . . . that this area and collection of houses near Manhole No. 54 should be brought within the administration of the Corporation as it is too close to the filter-beds to be allowed to extend as a village site uncontrolled by sanitary authorities.*" (Page 44.)

REMARKS:—The writer does not recommend the extension of the service connection unless the area is brought within the Corporation administration. This latter is a question outside his province.

Screens at end of conduit.

33. "*The provision of double screens at the beginning and at the end of the conduit.*" (Page 44.)

REMARKS:—With the object of excluding frogs, crabs, fish, etc., screens are already provided at the inlet of the Roughing Filters. If further screens are required at the inlet to the conduit, only 100 feet further on, the question arises whether or not it is desirable to do away with the Roughing Filter altogether and connect the conduit directly with the screening chamber. This matter requires careful experimental investigation before anything is decided.

There already are screens at the outlet of the conduit, and experimental screens have been tried at the filter inlets. A suitable type has been evolved, and it is proposed to fix one on each filter inlet.

Pump wells outside engine house.

34. RECOMMENDATION (page 48):—"*The provision of pump wells outside the engine-house so arranged that each pump well can be disconnected and cleaned. The suction pipe of a pump should be extended into one of these pump wells.*"

REMARKS:—The writer disagrees with the recommendation of the Committee. The alteration would cost Rs. 80,000 and is undesirable from an engineering point of view. The usual modern practice is to instal pumping engines directly over suction culverts, as is done at Kilpauk, in order to obtain as direct a suction lift as possible.

This is the usual practice in England, and the writer may point out that in India, the following important pumping stations all have their engines placed directly over the suction culverts:—

At Pulta and Tallah of the Calcutta Water-works eight large pumps, at Rangoon, Benares, Lucknow, Allahabad, Cawnpore and Agra. These pumps all deal with filtered water as is the case at Kilpauk.

In the case of unfiltered water-supplies, it is often necessary to extend the suction outside the engine-house to reach the water, but this is recognised as a disadvantage, and in some cases gives a great deal of trouble when the water becomes low. Such trouble would undoubtedly be caused at Kilpauk if the Committee's recommendation is adopted.

The argument used by the Committee that, where the pipes pass through masonry, cracks invariably occur at the junction of the pipe and the masonry (page 25), is an argument against extending the suction outside the engine-house for they then would have to pass through the walls of the proposed new suction well, whereas as at present, the suction does not pass through any wall.

Steel tank scours.

35. The Committee (pages 26 and 48) suggests that scours should be provided and add that they "*can only suggest that there should be six scours distributed over the flat bottom of the tank with inlets at floor level.*" (Page 26.)

REMARKS :—The need for better means of cleaning the tank has been found in operation. The writer's intention is to construct a steel diaphragm some 4-feet high across the middle of the tank thus dividing it into two halves. Each half will be provided with a scour so that it may be cleaned, while the other half still contains sufficient water to prevent air being drawn into the distribution system. A similar method has been adopted for the very much larger elevated steel tank in Calcutta and has proved perfectly satisfactory. This particular improvement has been held back owing to the necessity of economising in every possible way.

Distribution system rules.

36. The Committee (page 49) makes a number of small recommendations with regard to the organization of the staff, rules, returns, etc. This matter has been receiving the attention of the Assistant Water-works Engineer for some while past. As a result the Corporation has the "*Water-works Hand-book,*" and when he has time to study fully the requirements of the distribution system, doubtless he will issue rules for the instruction and guidance of the maintenance staff.

It would be a mistake to issue rules till the requirements of the system have been ascertained. In this connection it is noteworthy that Calcutta and Colombo have no printed rules, and that those of Bombay are out of print and have not been reprinted. There is such a thing as too many rules and forms.

Scour valves.

37. The recommendation of the Committee is as follows :—

"*In all larger sized pipes numerous scour valves should be fixed. The size of each should be fixed by the rule——diameter of scour branch equals half the diameter of the pipe to be scoured plus 1-inch . . . . . . All scour pipes should have free outlets above risk of contamination.*"

REMARKS :—The Committee states that numerous scours should be fixed. As it was not understood what "numerous" meant, Mr. Hutton was addressed, he has informed the writer that "*it would be advisable in the first instance to adopt ½ a mile apart in fixing scour pipes of suitable diameter subject to alteration to suit local conditions.*"

The cost of fixing scour-outs half a mile apart, on all pipes larger than 4 inches diameter is estimated at Rs. 2,15,000.

As the question of scours is perhaps the most important of the very few new recommendations made by the Committee, it would be well perhaps to quote verbatim what is said by the Water-works Engineer to the Calcutta Corporation as to the practice in that city :—

"*So far as the distribution system is concerned we do not fix scours on any points except at dead-ends and at these points we only fix a standpost with or without hydrant attached to act as a scour.*"

"*The scours have been fixed only on our 6 feet steel main, upon which there are 4-12 inch scours or wash-outs fixed not so much with a view to scour out silt or dirt but more with a view to emptying the main when necessary to effect repairs. The sizes of these scours or wash-outs were fixed with a view to empty the main within a reasonable time*".

"*We find that on the distribution system the standposts some of which are fitted with fire hydrants are quite sufficient to keep the pipes reasonably clean and clear of silt and we do not contemplate making any addition to the scour arrangement now existing.*'

With reference to the use of scours it may be pointed out that they are employed where experience shows that scouring is required. Thus many of the pipes in Rayapuram and St. Thomé are scoured out regularly every week and sometimes twice a week. On occasions a fire-engine is used to draw out the water.

The writer in laying out the water-works has provided scours at all depressions of the larger new pipes, and at dead-ends which cannot be avoided. This is the modern practice, and is found sufficient in filtered water-supplies. In Bombay scours are not provided at all, hydrants being relied on, and in Calcutta scours are only provided in a very few special cases where there are dead-ends. It therefore appears that the Madras provision for the new pipes is already more liberal than that adopted in Bombay and Calcutta, and the adoption of the Committee's recommendation with the high expenditure involved is not justified with our present knowledge. The whole question of the purity of the water-supply in the distribution system will form an interesting study when the Corporation has a bacteriologist of its own. His researches will show where scour-outs are required, if they prove to be necessary.

Connected with the question of scours is another problem to which the Committee does not refer, *i.e.*, the cleaning out of the old pipes, which contain a considerable amount of deposit and also shell fish. It may be found desirable to remove these materials, in which case it is probable that pipe scrapers will have to be used. That scours by themselves will be of little use has been shown on the occasions of bursts when very little silt has been moved, although the velocity of the water was greater than could be provided by scours.

It is however of little use to clean out the pipes so long as unfiltered water is used; this problem may stand over until the city has a wholly filtered water-supply.

Establishment.

38. "*We are confident of the urgent necessity of the Corporation employing a Water-works Engineer to be in charge of the whole system . . . . He should be supplied with a residence within the head-works area.*" (Page 49.)

REMARKS :—The Corporation has already appointed an Engineer to look after the water-works under the general direction of the Corporation Engineer. His pay is considerably lower than that recommended by the Committee, but it is a matter for consideration whether satisfactory service is, or is not, obtained on the pay given.

39. MINOR RECOMMENDATIONS.—In the foregoing paragraphs, the writer has dealt with the principal recommendations of the Committee. There are also a number of minor recommendations which have no material importance, and which may, or may not, be found desirable. Some of them are unnecessary as action has already been taken on somewhat similar lines to that recommended. They may all be referred to the Assistant Water-works Engineer for consideration and action where necessary. Any cost incurred in carrying out these recommendations may be met from the Water-works Maintenance Grant.

18

ANNEXURE

BEING

REPORT ON THE WORKING

OF THE

MADRAS WATER-WORKS

PREPARED IN SEPTEMBER 1917 FOR THE COMMITTEE

BY THE

SPECIAL ENGINEER

CORPORATION OF MADRAS

UNDER INSTRUCTIONS OF

THE PRESIDENT, CORPORATION OF MADRAS.

CORPORATION OF MADRAS.
SPECIAL ENGINEER'S OFFICE,
NAPIER PARK,
MADRAS, *9th October* 1917.

To

THE PRESIDENT,

CORPORATION OF MADRAS.

REPORT ON CERTAIN MATTERS CONNECTED WITH THE MADRAS WATER-SUPPLY.

SIR,

In submitting to you herewith my report on "The working of the Madras Filters and some other matters connected with the water-works (including a brief description of the works)," I have to say that about the middle of September I received instructions from Mr. T. Vijiaraghavachariar, Acting President of the Corporation, to prepare a report on the working of the Madras Filters, to be placed before the expert whom the Corporation, at their meeting, held on 5th September 1917, resolved that Government should be requested to appoint.

2. This work was well in hand before I received information that Government had decided to appoint a Committee "to inspect and report on the water-works and the supply to the city of Madras generally" and to "examine carefully the defects of the present system and suggest remedies where necessary," and it was not until the 2nd instant that I received from you a copy of the minutes of the first meeting of the Committee with a request that I would supply as soon as possible the information which the Committee require.

3. In these circumstances, I thought it best to complete the report as originally planned. I have added a paragraph (21) on the extent to which the works carried out differ from the original design of 1905. The other information that the Committee asks for, is included in Appendices at the end of the report.

A list of contents, plates and statements is given at the beginning of the report to facilitate reference, and it is hoped that by its aid the Committee will have no difficulty in looking up any point with which it deals.

4. The only point on which the Committee require information, and which has not been dealt with fully, either in the report or in the Appendices, is "A report on the analyses of water made from time to time at the King Institute of Preventive Medicine, by whom the samples were taken, by what method they were taken, and at what places." The analyses so far as they relate to the experiments made by the Director of the King Institute on the working of the filters have been given in full in Appendix II, but the miscellaneous analyses have not been copied, because when I consulted you, you considered that the Committee intended that these analyses should be supplied direct from the King Institute.

5. If there is any further information that the Committee may desire, I shall be very pleased to supply it to the best of my ability.

6. If the Committee have no objection, I should like to accompany them when they inspect the works. I should also like to be given an opportunity personally to represent some difficulties the Executive have in carrying out their work.

I have the honour to be,
Sir,
Your most obedient servant,
(Signed) J. W. MADELEY.

PLATE I.

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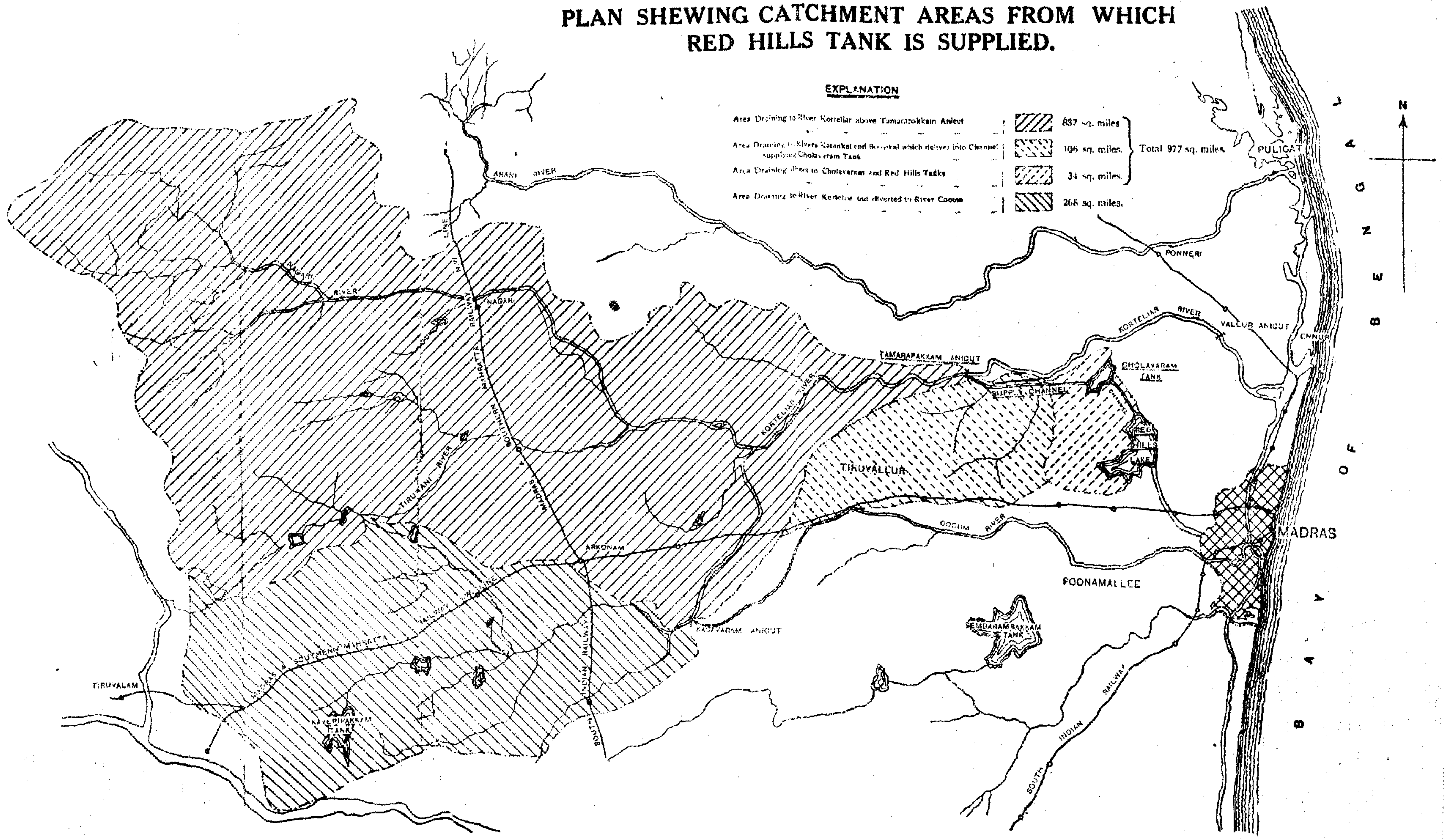
PLAN SHEWING CATCHMENT AREAS FROM WHICH RED HILLS TANK IS SUPPLIED.



Report on the Working of the Madras Filters

and Some interconnected Matters.

(including a brief description of the Water-works)

BY THE

SPECIAL ENGINEER, CORPORATION OF MADRAS.

At a meeting held on 5th September 1917, the Corporation of Madras resolved "That the Government be requested to move the Government of India for deputing Lieut.-Colonel Clemesha (or in case he is not available to depute Colonel Cornwall or other suitable expert), at an early date to inspect and report on the Madras Municipal Water-works and the City Water-supply." Reason for Report.

This report has been written in accordance with the instructions of the President, Corporation of Madras, in order to place the present position as regards the working of the Madras Filters before the expert who may be deputed by Government.

Before describing the filters and their working, it will be necessary to give a brief description of the sources of supply and of the present works, so far as they affect the working of the filters.

2. The Madras City Water-supply is part of a project undertaken with the object of utilising, to the fullest economical extent, the waters of the Corteliar River and its tributaries. This is effected by means of a masonry weir built across the Corteliar River at Tamarapakkam. This weir diverts the river—excluding the greater flood discharges—into a channel feeding the Cholavaram and Red Hills Tanks, which store the flood-water resulting from the monsoon rains, and render it available during the months that the river-bed is dry. Sources of water-supply.

The Cholavaram and Red Hills Tanks also receive a considerable supply from the catchment areas that drain directly to them and to the supply channels. From the lower of these—the Red Hills Tank—the Madras Water-supply is drawn.

The catchment areas of the system are shown on Plate I, they are as follows:—

River Corteliar, Tirutani and Nagari above Tamarapakkam Anicut	1,105	square miles.
Red Hills	23	"
Cholavaram Tank	11	"
Katankal River	62	"
Boosikal River...	44	"
Total...	1,245	"
Deduct—Catchment area of River Corteliar above Kasavaram Anicut	268	"
Net catchment area	977	"

Sources of water-supply (*contd.*).

Besides providing the Madras City supply, the water from both tanks is also used to irrigate a first crop area of 7,500 acres, and a second crop area of about 3,200 acres. The quantity of water thus used for irrigation is estimated to amount in a normal year to about twice the present water-supply to Madras.

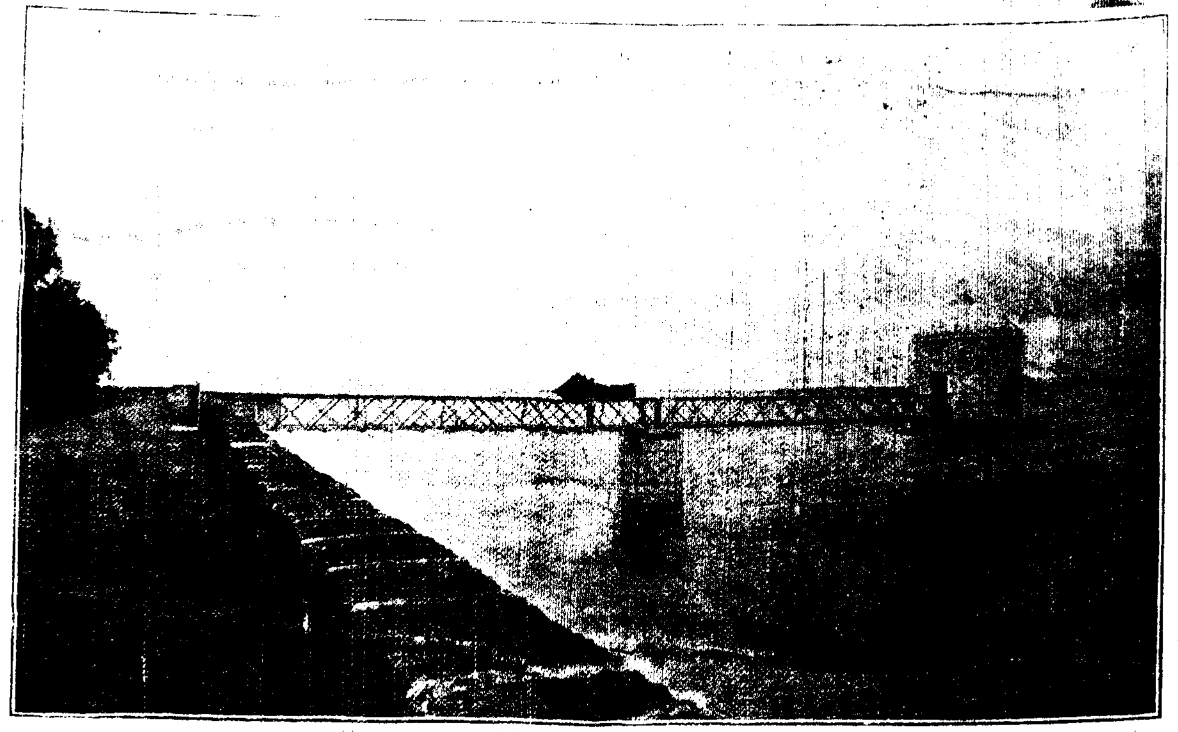
The storage capacity of the two tanks when full, is as follows :—

	Cubic feet.
Red Hills Tank	2,162,000,000
Cholavaram Tank	579,000,000
Total ...	2,741,000,000

The average rainfall over the whole catchment area may be taken as 37 inches per annum.

PLATE III.

INTAKE TOWER.



This tower, built where the lake is deepest, is provided with inlets at different levels through which the water is admitted into the new works.

Water-supply works.

3. The present water-works, which were opened in December 1914, consist of :—

(*a*) An Intake Tower at the Red Hills Lake located at a point where the water is deep.
(*b*) A Screening Chamber and Roughing Filter to remove the grosser impurities.
(*c*) An Underground Conduit 7 miles long built of brickwork and concrete.
(*d*) Fourteen Sand Filters.
(*e*) Three underground covered pure water tanks built of brickwork and concrete : capacity of each, 1½ million gallons.
(*f*) Pumps to impart pressure to the water.
(*g*) An Elevated Steel Balancing Tank : capacity 1½ million gallons.
(*h*) The Cast-iron Pipe Distribution System, partly new and partly old.

The water enters at the Intake Tower and passes through the works in the order given above.

PLATE II.

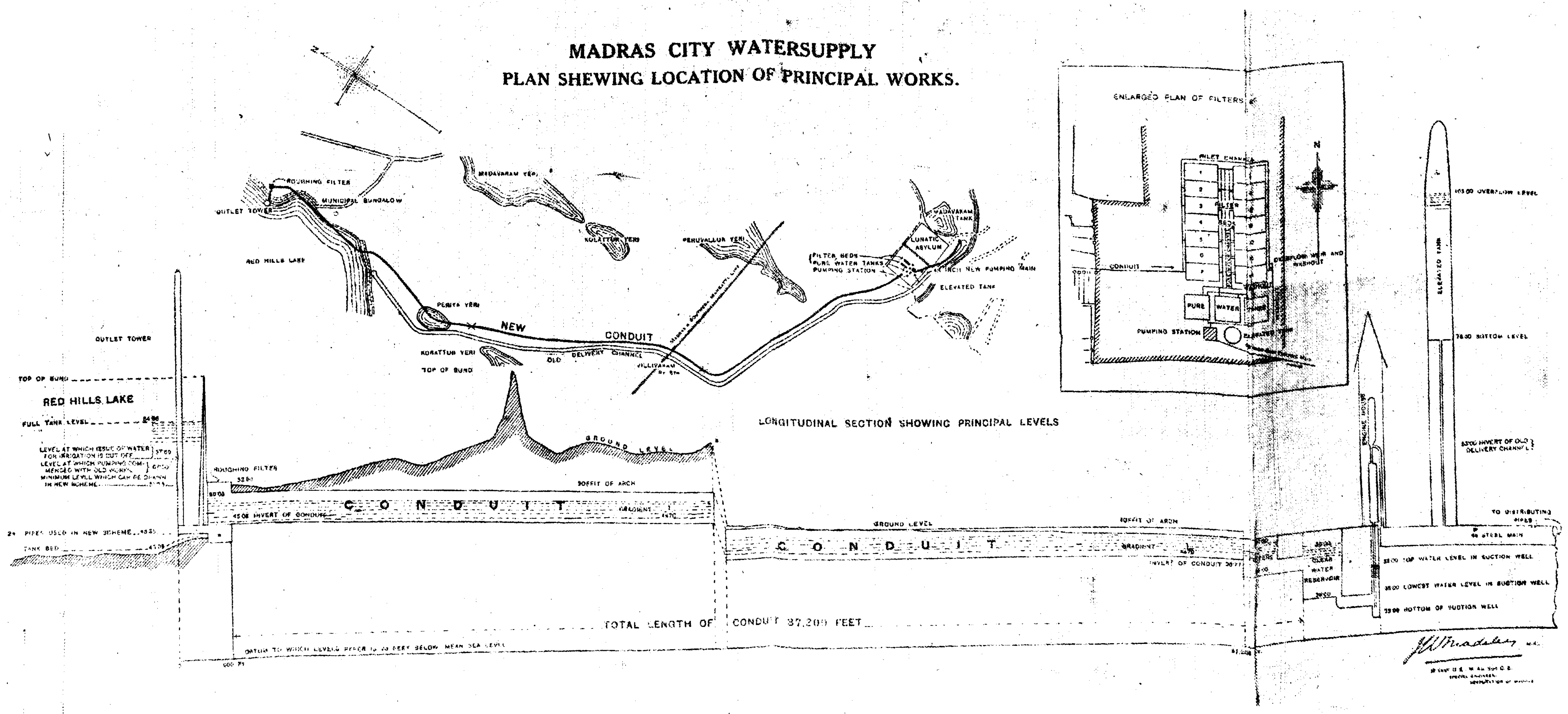


PLATE IV.

ROUGHING FILTER AT RED HILLS.
PLAN
Scale 1 inch = 40 feet.

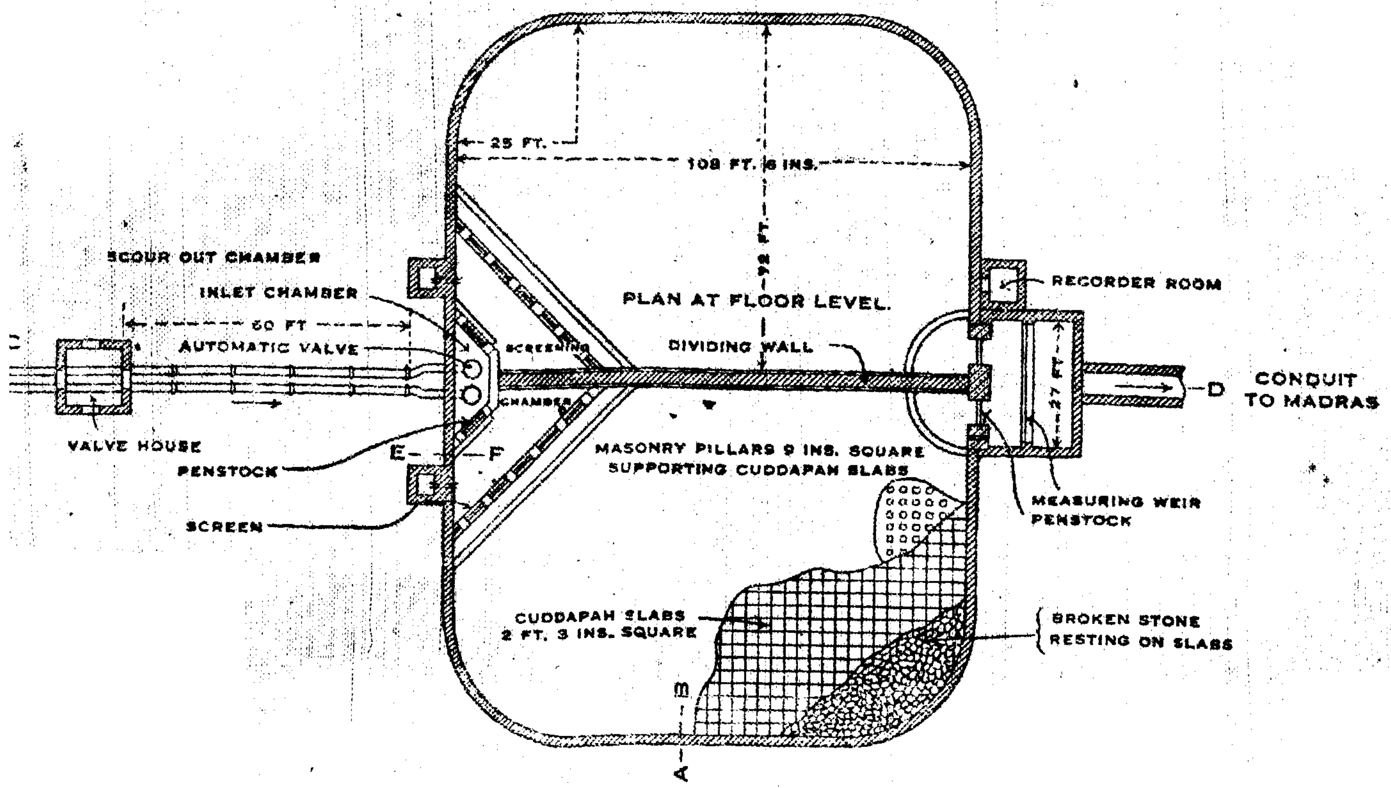


PLATE V.

ROUGHING FILTER.

On the left is the triangular Screening Chamber, with gear for raising and lowering the screens. The water passes through the screens and then enters the roughing filter at floor level; rising through a filtering medium of broken stone, it passes over the measuring weir on the right, into the conduit to Madras. The quantity passing is continuously measured and recorded by a meter placed in the Valve House on the right.

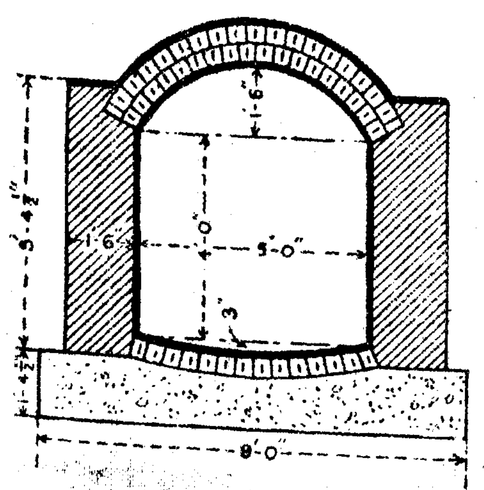
PLATE VI.

TYPICAL CROSS SECTIONS
OF
CONDUIT.

Scale 1 inch = 4 feet.

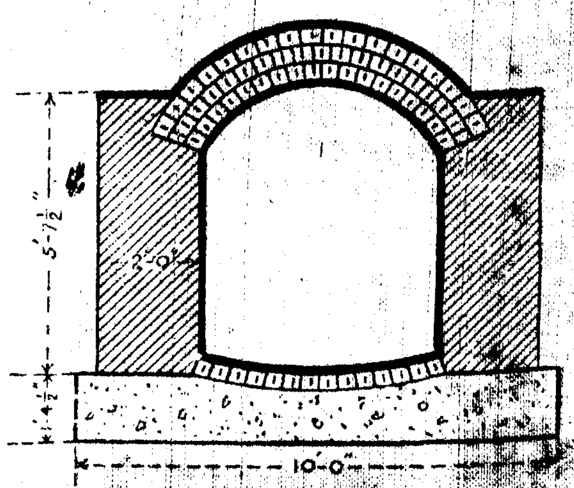
Note.—Internal dimensions are the same for all sections.
All inside surfaces are plastered with cement mortar. Arch and top of walls are plastered with combination mortar.

FIG. 1.



Cross section of conduit in shallow excavation. 11 feet or less to invert.

FIG. 2.



Cross section of conduit in good ground. 11 to 18 feet to invert.

PLATE VII.

TYPICAL SECTION THROUGH UNDERGROUND PURE WATER TANK.

Scale 1 inch = 16 feet.

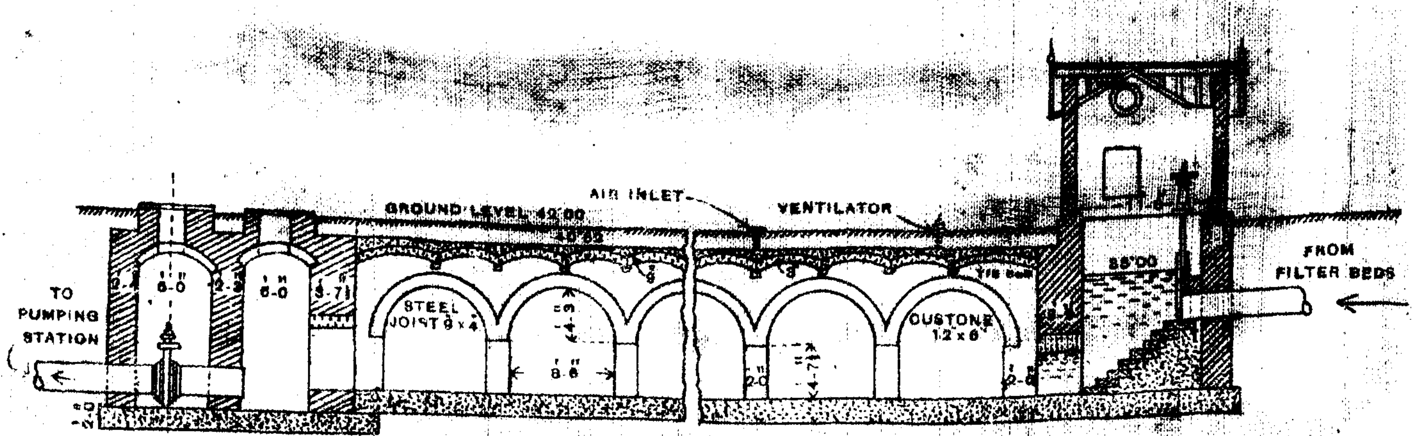


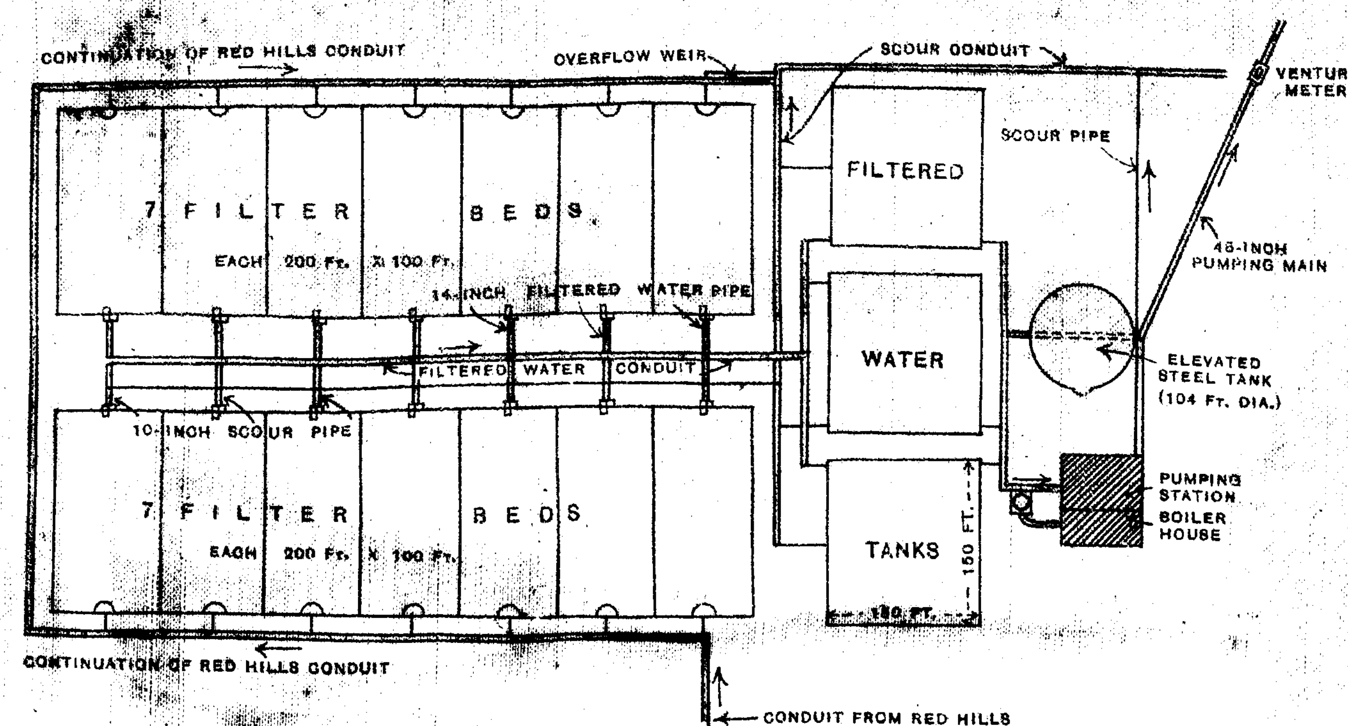
Plate II shows in plan the general arrangement of the works (*a*) to (*g*) mentioned above, and in section the relative levels of the several works. Except for the filter beds, no further description will be given of the works. It is thought that Plates Nos. III, IV, V, VI and VII, which follow, give sufficient information for the purposes for which this report has been prepared. Water supply works—(*contd.*).

4. There are in all 14 filters of the ordinary slow sand type, arranged in two rows of 7 each. The general arrangement of the filters and the pure water tanks is shown on Plate VIII, from which it will be seen that the conduit, which brings the water from the Red Hills, is continued round the 14 filters. The water enters each bed through a 14-inch diameter cast-iron pipe controlled by a valve, so that any filter may be isolated for cleaning or repair. Between the two rows of filters runs the filtered water conduit, to which the filtered water is delivered separately from each bed through an Automatic Outlet designed to keep the rate of filtration constant. The filtered water flows through the filtered water conduit to three underground storage tanks, each 150 feet square with a maximum depth of 11 feet of water. From these tanks the water gravitates to the pumps which send it into the city mains. General description of filter-beds.

PLATE VIII.

Plan showing general arrangement of Filters, Pure Water Tanks, Pumping Station and Elevated Tank at Kilpauk.

SCALE 1 INCH = 200 FEET.



The filters were brought into use on the following dates:—Beds 3, 5, 7, 9, 11 and 13 on 17-12-1914; bed 1 on 9-6-1915; bed 14 on 9-9-1915; bed 2 on 6-11-1915; beds 8 and 12 on 4-2-1916; bed 4 on 4-6-1916; bed 10 on 23-8-1916; bed 6 on 17-11-1916. They have been in continuous operation since, except when out of use for cleaning.

5. A plan and section of a filter-bed is shown in Plate IX facing page 6. It will be seen that each filter is 200 feet long and 100 feet wide. Sunk below the floor is the main drain traversing the centre of the length of the filter from inlet to the outlet. Into this drain discharge collecting drains made of two rows of bricks, the bottom row being laid in lines 4½ inches apart from near the edge of the filter to the main drain. In the top row, the bricks are laid touching each other and across the bottom row, so as to form a series of collecting drains 4½ inches wide and 3 inches deep. Detailed description of filter-beds.

iiled
:ription
lter-beds
(*contd.*)

On the top layer of bricks is 4 inches of broken stone in two layers of different sizes, *viz.*, $\frac{3}{4}$ inch to $\frac{3}{8}$ inch and $\frac{3}{8}$ inch to $\frac{1}{8}$ inch. Above the stone is 2 inches of coarse sand $\frac{1}{8}$ inch to $\frac{1}{30}$ inch. The coarse sand supports a layer of fine sand 2 feet 4 inches thick. This sand is screened to eliminate all material except that which passes through a $\frac{1}{30}$ inch mesh and is retained on a $\frac{1}{50}$ inch mesh, but contains a percentage of finer stuff which it was impracticable to eliminate. The depth of water over the fine sand varies from about 3 feet 6 inches to about 4 feet, according to the level of the water in the conduit.

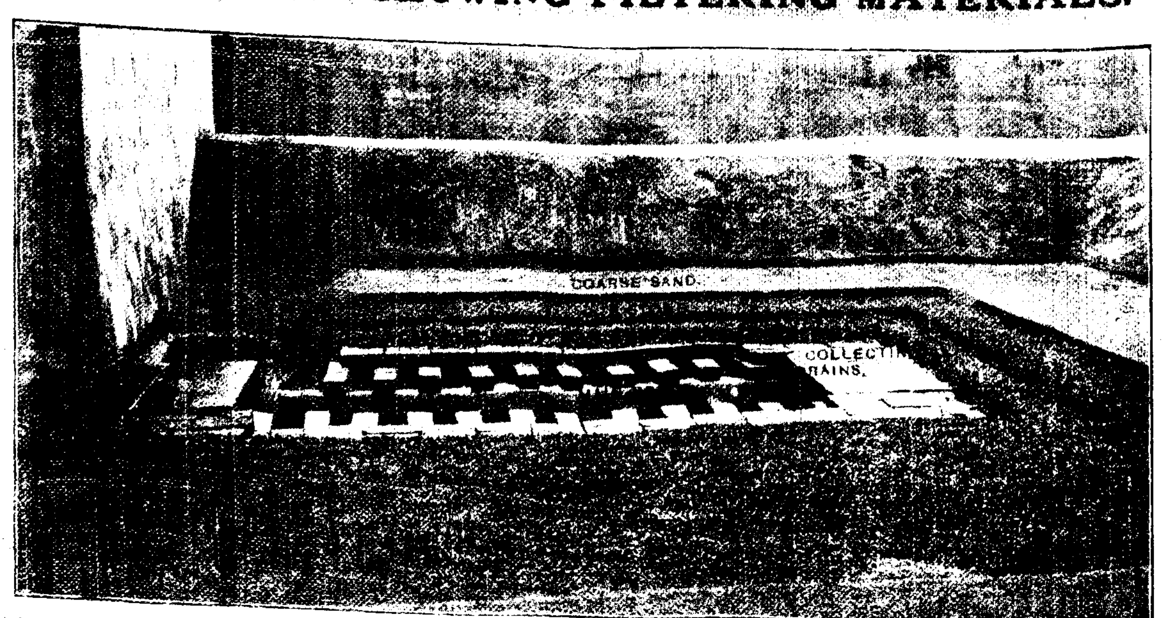
The water enters each filter through a semi-circular Inlet Chamber, the wall of which reaches up above the top of the sand layer, and is designed to prevent any flow which would scour the surface of the bed. After passing downwards through the filtering media, the water reaches the main drain which leads to the Outlet Regulator Chamber, in which is fixed an Outlet Regulator of the floating weir type, so arranged that the depth of water flowing over the discharge weir can be regulated from zero to about 7 inches and can be maintained constant at any point within the working limits of the filtering head and the level of the water in the filter.

Another and somewhat unusual feature of the filters is that the collecting drains and broken stone and coarse sand are stopped 3 feet from the walls, the space being filled with fine sand. This is to prevent short circuiting of the unfiltered water by creeping down the walls. With the same object in view, all the walls are battered, so that any settlement of the sand tends to compress it.

The photograph below (Plate X) shows well the arrangement of filtering materials and drains.

PLATE X

FILTER-BED SHOWING FILTERING MATERIALS.



The fine sand, 28 inches thick, is seen to be supported on 2 inches of coarse sand, which rests on a 2 inch layer of $\frac{3}{8}$ inch stone, under which is 2 inches of $\frac{3}{4}$ inch stone. Below the stone are the brick collecting drains leading to the main drain, which is sunk below the filter floor. The raw water is admitted at the top, is purified by passing through the sand, and leaves the filter by means of the main drain.

of 6. The original scheme contemplated 21 filters, but only 14 were included in the estimates sanctioned by Government, probably because it was considered that, at the time the works were brought into use, the quantity of water required would not be more than could be dealt with by 14 filters.

The writer personally considered it highly desirable to construct all the 21 filter-beds at once, and in November 1913—thirteen months before the opening of the new waterworks—wrote to the President that he was "strongly of opinion that the Corporation

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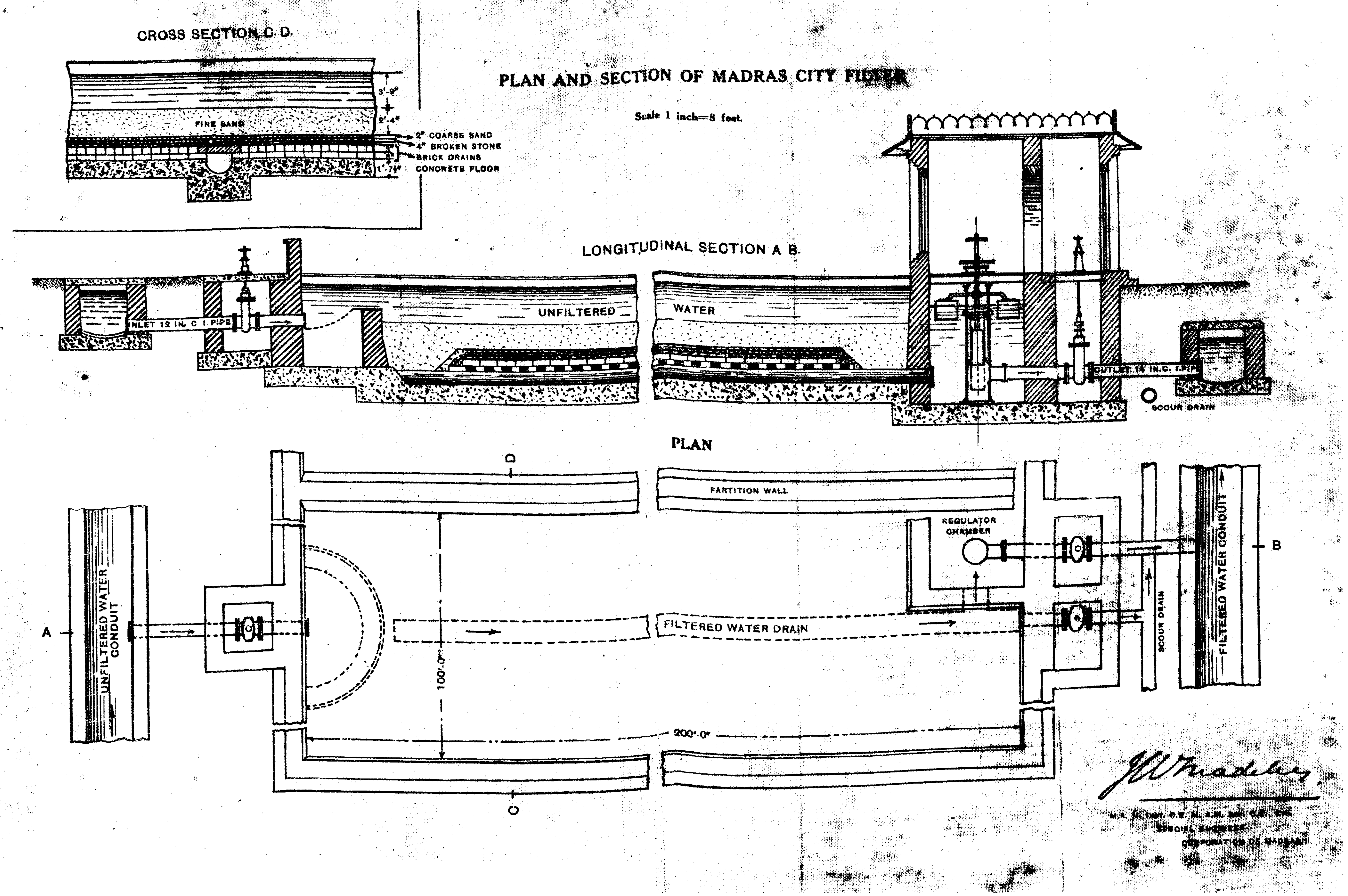
PLATE IX.



should at an early date proceed to construct the remaining seven filters and one pure water tank." Number of filters (*contd.*).

Detailed plans and estimates were subsequently submitted, and in July, 1914, these were sanctioned by Government, subject to the proviso " that the works should not be begun without a further resolution of the Corporation in the matter, and this should not be passed until adequate information is available as to the pace on which the existing filters will work and the consumption per head throughout the city under the new conditions, since it is possible that this may show that these additional filters are not really needed." (G. O. No. 1442 M., dated 31st July 1914.)

Just before the receipt of the G. O., the war had broken out, and it became necessary largely to curtail the new water and drainage works. Amongst the works which it was decided to defer were the additional filter-beds. Unfortunately the ultimate quantity for which the water-works were originally designed has already been closely approached, and the number of filters is insufficient to deal with the water that the city is taking. From the experience gained in working the filters, it appears that 10 rather than 7 additional filters are required, unless some method is devised to remove a large proportion of the suspended matter before the water is allowed on to the filters.

7. Immediately after the water-works were opened, it was proved that the city would require more water than the filters would be able to deal with at the rate of filtration for which they were designed. Twenty-one filters were provided to deal with 16½ million gallons per day, so that the 14 filters, at the same rate, should be able to filter 11 million gallons per day. As a result of experience in working, it is doubtful if they can filter properly more than 10 million gallons per day. The actual quantity taken by the city to begin with was measured to be about 19 million gallons per day, and experiments proved that if the full pressure were maintained for 24 hours, the water taken would amount to 23½ million gallons per day or more. By limiting the pressure, the consumption has been reduced to between 14 and 15 million gallons per day. Quantity of water to be filtered.

8. The Corporation was thus faced with the difficulty of having insufficient filters, and also with the Government order that, before additional construction was undertaken, adequate information should be obtained as to the rate at which the filters could be worked. In these circumstances, it was decided to ascertain if the filters could be worked at a higher rate than that for which they were designed. Rate of filtration.

As already stated, 21 filters were designed to deal with 16½ million gallons per day. Allowing one filter in every 7 to be off for cleaning, this gives a rate of filtration equivalent to 4 inches vertical per hour, which is a very usual standard rate to adopt.

The town is taking between 14 and 15 million gallons per day and as additional filters could not be constructed for several years, it became a question whether the whole of the 14 to 15 million gallons per day could be passed through the 14 filters with advantage. No previous suitable experience with the Madras water being available, the only course was to experiment, and to this end the water was passed through the filters at rates reaching a maximum of 5·7 inches vertical per hour. This rate was in force when at the whole of the filters were brought into use, and for a time it was possible to filter the whole of the water-supply.

After a few months however, the filters which had first been brought into use at the end of 1914, *viz.*, Nos. 3, 5, 7, 9, 11 and 13, began to clog rapidly, and it became necessary to report to the Corporation that it was no longer possible to filter the whole of the supply. An experiment with an intermittent supply was then tried, but it was not a success, and the Corporation decided to mix unfiltered water with the filtered water, so as to make up the required quantity and this is being done at present. The rate of filtration has now been reduced to a maximum of 4 inches vertical per hour.

Method of working the filters.

9. For the working of the filter-beds, detailed rules have been drawn up, which are included in Appendix I. The rules originally drafted by the writer were submitted to the Director, King Institute, in July 1915, and were slightly amended in accordance with suggestions made by him. They are still adhered to so far as is possible, but in the absence of bacteriological control, it is impossible to comply with them fully. Since July 1917, when unfiltered water was freely added to the filtered water in order to increase the supply, the rate of filtration was not exceeded 4 inches vertically per hour.

Bacteriological control of filters.

10. Unfortunately, the Corporation have not at their disposal means of examining the water bacteriologically. The only agency available is the staff at the King Institute, Guindy, but when the Director was first approached by the writer in 1913, he stated that he was unable to undertake regular analyses of water for the Corporation. The Corporation decided to employ their own bacteriologist, and in G.O. No. 1242 M., dated 29th June 1914, "sanction is accorded to the proposal of the Corporation of Madras to employ a Chemist-Bacteriologist. . . ." Unfortunately, the financial stringency due to the war caused this proposal to be postponed indefinitely.

The Director of the King Institute was again approached by the writer with a view to his maintaining bacteriological control. In September 1915, the Director wrote that "owing to the war and the consequent impossibility of obtaining fresh stock of certain materials, I shall not be able to undertake such a large volume of work as would be involved by controlling the efficiency of the Madras Filters."

It was eventually decided in October 1915, that filtered water from two of the beds should be sent regularly to the Guindy Institute for examination, but Corporation deputing an overseer to do the work under the direction of the Director. This was to be considered in the nature of an experiment to find out what results were likely to be obtained with the Madras water. At that time, the results of the investigations on experimental beds at Guindy showed that there were certain factors which had the power of destroying the efficiency of the filters for the time being, and the Director stated that he was unable to say what results could reasonably be expected from sand filters in Madras.

Experiments on filtration.

11. Regular experiments on the filtrates from the Madras Filters began on 8th November 1915, and continued until September 1916, when they were discontinued at the suggestion of Dr. Gibson, Director of the King Institute, who personally superintended the work, because he was going away on leave. The results of these experiments are given in Appendix II.

It will be seen that from 8th November 1915 to 4th February 1916, the filters experimented were Nos. 13 and 14. Subsequently they were Nos. 8 and 12. The change was made because Dr. Gibson desired to compare the working of a covered filter and an open filter under exactly the same conditions. He wished to begin his investigation from the time the filters were first started. To comply with his wishes, an area 100 feet long and 50 feet wide in filter-bed No. 8 was covered with a roof and filled with fresh filtering materials. This was started simultaneously with the open bed No. 12, which was also filled with fresh filtering materials. The two beds were worked on precisely the same lines from 5th February to 29th September 1916. The four diagrams attached show graphically the working of these four filters: each diagram gives for the filter to which it refers:—

(1) Rate of filtration. (2) Filtering head.
(3) Total counts of bacteria in the raw water.
(4) " " in the filtered water.
(5) The No. of c.c. in which lactose fermenters were detected in the raw water.
(6) The same for the filtered water.

PLATE XI.

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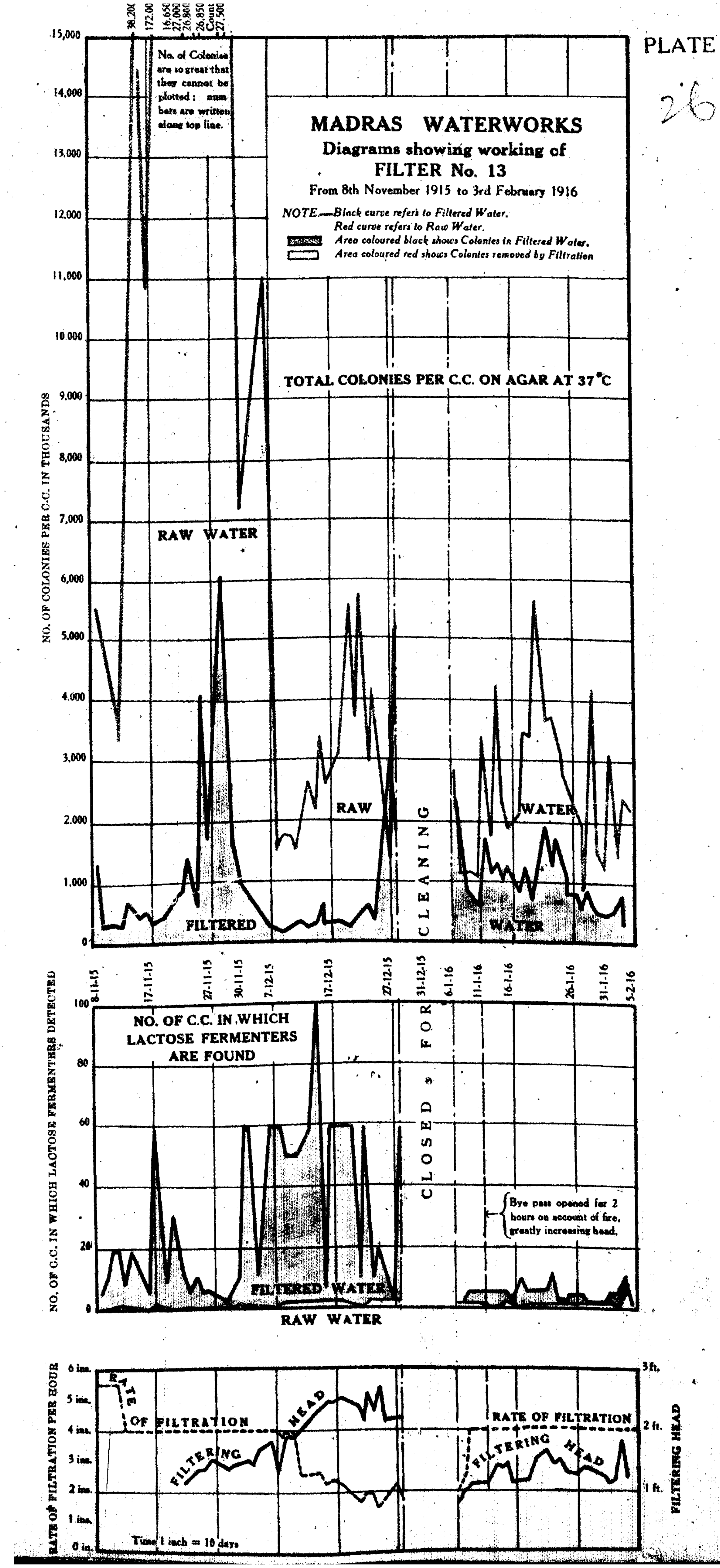

PLATE XII.

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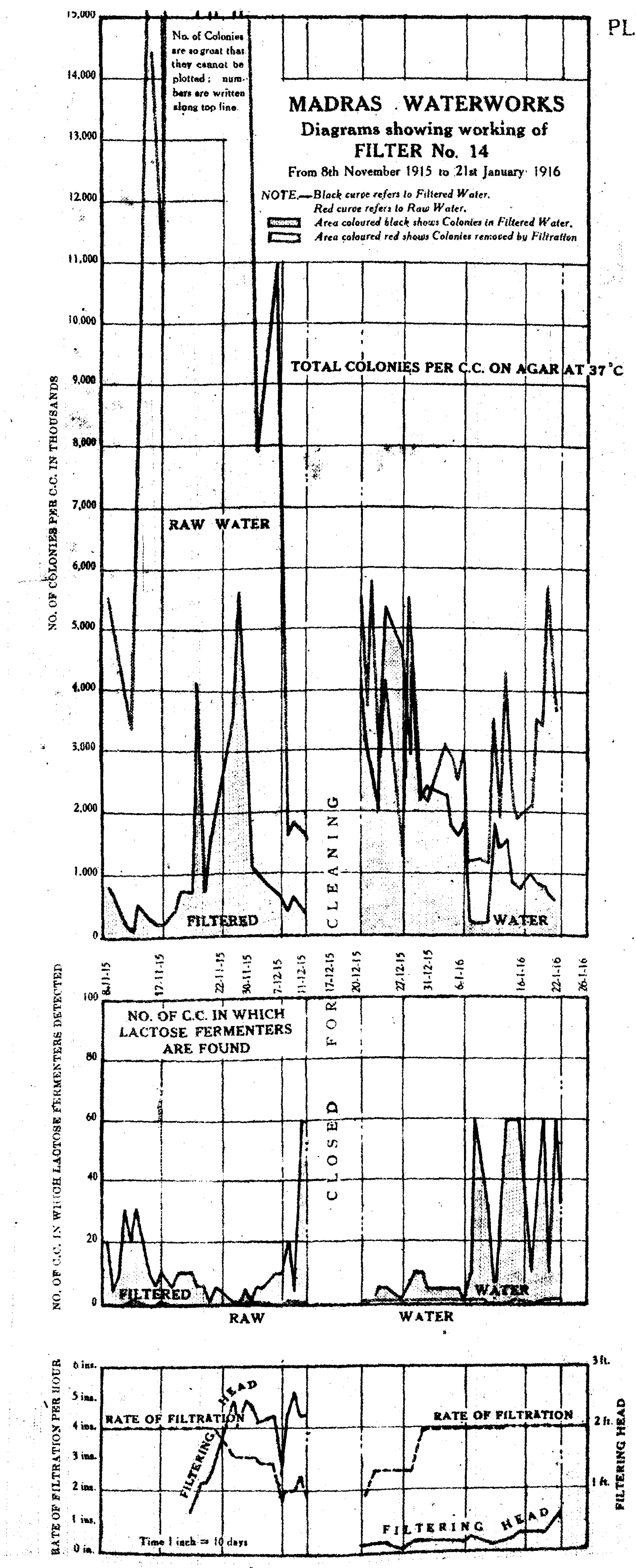

MADRAS WATERWORKS
Diagrams showing working of
FILTER No. 14
From 8th November 1915 to 21st January 1916
NOTE.—Black curve refers to Filtered Water.
Red curve refers to Raw Water.
Area coloured black shows Colonies in Filtered Water.
Area coloured red shows Colonies removed by Filtration
No. of Colonies are so great that they cannot be plotted; numbers are written along top line.
TOTAL COLONIES PER C.C. ON AGAR AT 37°C
RAW WATER
FILTERED
WATER
CLEANING
FOR
CLOSED
NO. OF COLONIES PER C.C. IN THOUSANDS
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
8-11-15
17-11-15
22-11-15
30-11-15
7-12-15
11-12-15
17-12-15
20-12-15
27-12-15
31-12-15
6-1-16
16-1-16
22-1-16
26-1-16
NO. OF C.C. IN WHICH LACTOSE FERMENTERS ARE FOUND
NO. OF C.C. IN WHICH LACTOSE FERMENTERS DETECTED
100
80
60
40
20
0
FILTERED
WATER
RAW
WATER
RATE OF FILTRATION PER HOUR
6 ins.
5 ins.
4 ins.
3 ins.
2 ins.
1 ins.
0 in.
RATE OF FILTRATION
FILTERING HEAD
RATE OF FILTRATION
FILTERING HEAD
Time 1 inch = 10 days
3 ft.
2 ft.
1 ft.
FILTERING HEAD

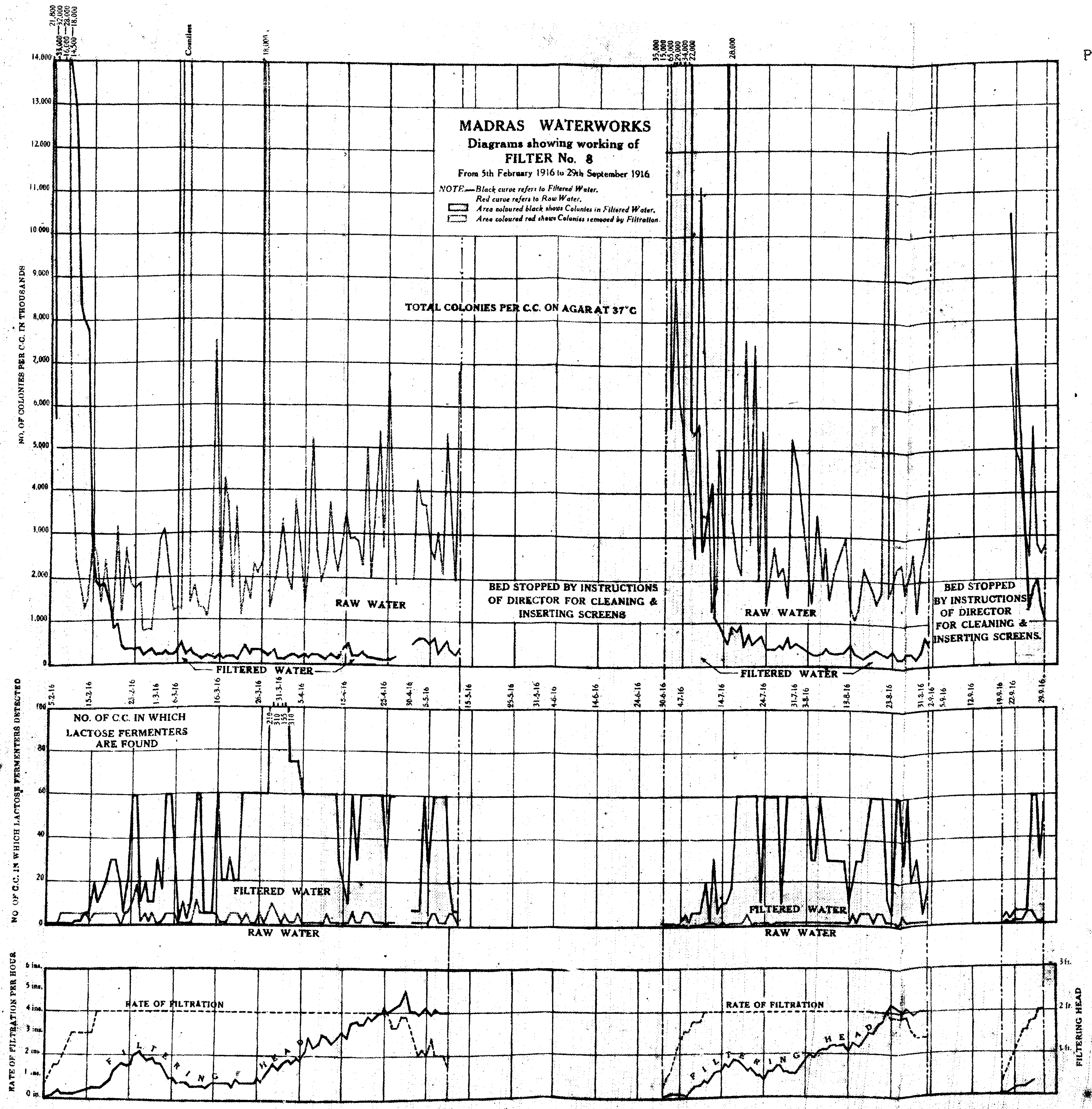
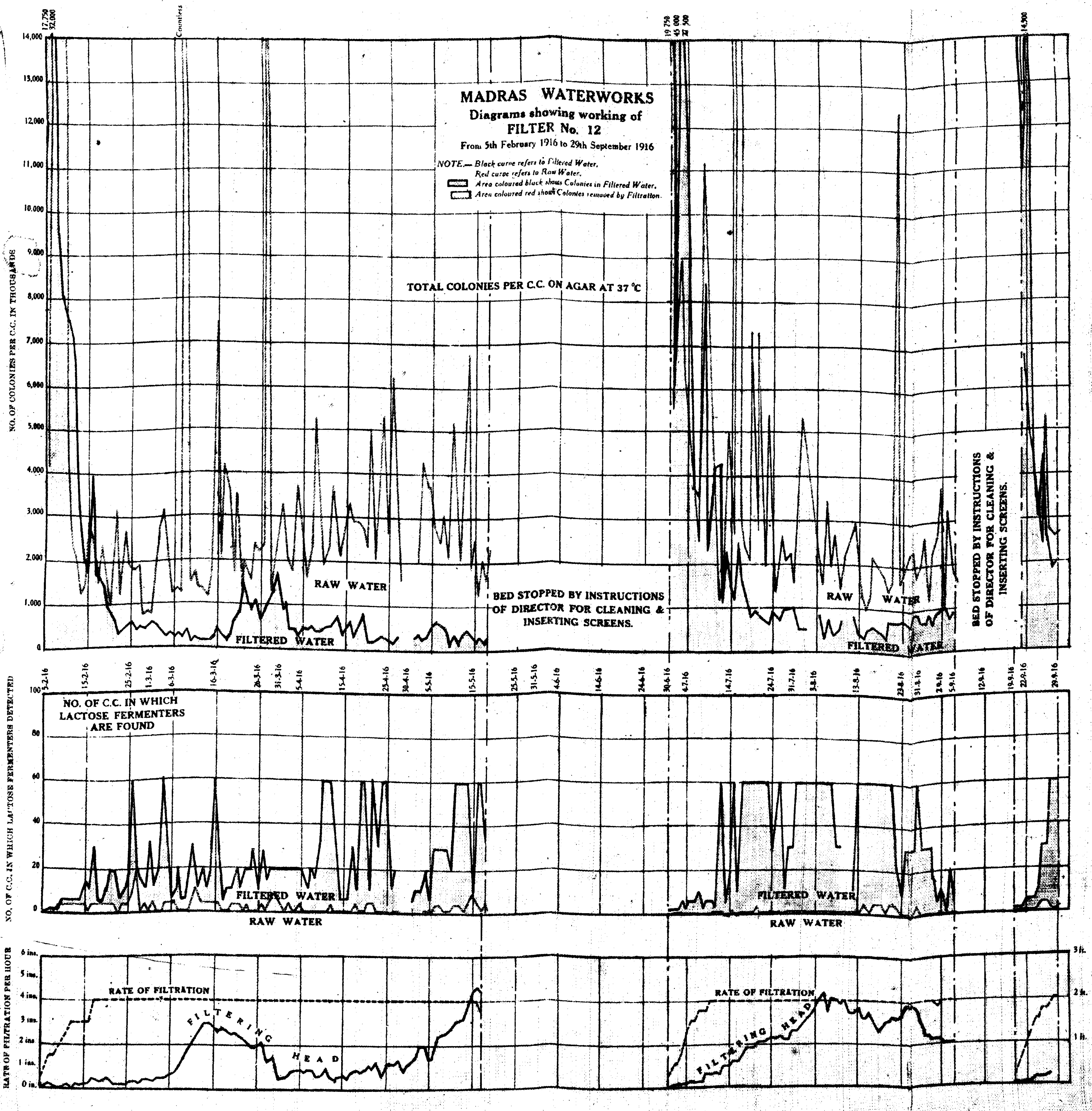

MADRAS WATERWORKS
Diagrams showing working of
FILTER No. 8
From 5th February 1916 to 29th September 1916
NOTE.—Black curve refers to Filtered Water.
Red curve refers to Raw Water.
Area coloured black shows Colonies in Filtered Water.
Area coloured red shows Colonies removed by Filtration.
TOTAL COLONIES PER C.C. ON AGAR AT 37°C
NO. OF COLONIES PER C.C. IN THOUSANDS
RAW WATER
FILTERED WATER
BED STOPPED BY INSTRUCTIONS OF DIRECTOR FOR CLEANING & INSERTING SCREENS
NO. OF C.C. IN WHICH LACTOSE FERMENTERS ARE FOUND
NO. OF C.C. IN WHICH LACTOSE FERMENTERS DETECTED
RATE OF FILTRATION
FILTERING HEAD
RATE OF FILTRATION PER HOUR

PLATE XIV



MADRAS WATERWORKS
Diagrams showing working of
FILTER No. 12
From 5th February 1916 to 29th September 1916
NOTE.— Black curve refers to Filtered Water.
Red curve refers to Raw Water.
Area coloured black shows Colonies in Filtered Water.
Area coloured red shows Colonies removed by Filtration.
TOTAL COLONIES PER C.C. ON AGAR AT 37 °C
NO. OF COLONIES PER C.C. IN THOUSANDS
RAW WATER
FILTERED WATER
BED STOPPED BY INSTRUCTIONS OF DIRECTOR FOR CLEANING & INSERTING SCREENS.
NO. OF C.C. IN WHICH LACTOSE FERMENTERS ARE FOUND
NO. OF C.C. IN WHICH LACTOSE FERMENTERS DETECTED
RATE OF FILTRATION
FILTERING HEAD
RATE OF FILTRATION PER HOUR

Experiments on filtration (*contd.*).

On occasions during these experiments the filtrates from other beds were examined, but as Dr. Gibson pointed out in his letter of 10th January 1916, "no useful information can be derived from the desultory observations carried out on beds 3, 5, 7, 9, 11 and 2," and these figures have been neither given in the tables, nor plotted in the diagrams.

An exception has been made in the case of the filtrate from Bed 14 which was examined daily from 13th to 18th December 1915, when the rate of filtration was $5\frac{11}{16}$ vertical inches per hour. These figures (Appendix II, page 66) are quoted because they indicate what results may be expected with a rate of filtration 42 per cent. above the normal maximum of 4 vertical inches per hour.

Points brought out by experiments.

12. The results of the experiments as given in the tables forming Appendix II, and as illustrated in the diagrams, bring out the following points:—

(1) When the filters are first started with new filtering media, the total counts of bacteria and numbers of lactose fermenters are both greater in the filtered water than in the unfiltered. Efficient filtration did not start for about 16 days in the case of both filters 8 (open) and 12 (covered).

(2) On starting after cleaning a similar period of inefficient filtration is observed.

Note—From observations on the filtering head in other filters, it is thought that further experiments on this point are likely to prove that the efficiency of filtration will be recovered more rapidly when the bed is cleaned only than when fresh sand is added.

(3) The covered and uncovered filters appear to give very similar results.

(4) Bacteriological purification appears to be equally good with a rate of filtration of $5\frac{5}{8}$ linear inches per hour as with a rate of 4 linear inches per hour.

Note.—The experiments which bring out this point are the daily examinations of the filtrates from Bed 13 from 8th to 11th November 1915 (Appendix II, page 65) and Bed 14 from 13th to 18th December 1915 (Appendix II, page 66). These experiments were not prolonged sufficiently to be conclusive. It is understood however that they are confirmed by results obtained from the experimental beds at Guindy.

(5) Individual filters can give consistently good results for considerable periods, *e.g.*, filter 8 from 3rd March to 12th May 1916, when it was stopped for cleaning. Filter 12 from 3rd April to 18th May 1916, when it was stopped for cleaning.

(6) There are periods of unsatisfactory working, generally accompanied by irregularities in the filtering head.

Note.—The unsatisfactory bacteriological purification obtained for certain periods is the most serious difficulty encountered in working the filters. The writer believes it to be caused by crabs and perhaps by frogs, fish and other organisms. There may of course be other causes. There is no doubt that crabs burrow from the surface to considerable depths, and this alone is sufficient to destroy the bacteriological efficiency of a filter.

A remedy would appear to be good screening combined with sterilising the bed before it is brought into use after being thrown out for cleaning, repairs or any other purpose.

It may be pointed out that given adequate bacteriological control, the periods of irregularity would, in actual working, be nothing like so long as they were in the experiments. The reason being that in

Points brought out by experiments (contd.).

actual working, a filter would be stopped as soon as it was found to be giving poor results; it would then be examined, put right, and started slowly with every precaution to ensure the reforming of a good filtering layer. In the experiments on the other hand, the filters were run at the full 4 inches vertical per hour even after they showed poor results, and were allowed to recover themselves as best they could.

If, as the writer supposes, the trouble is mainly due to crabs and other burrowing organisms, it would seem that a filter should be thrown out of use, and steps taken to put it right, immediately it begins to work inefficiently. When it once starts to work badly, it will never recover properly so long as the *poochees* remain to pursue their burrowings.

It is understood that until recently, irregularity of working was experienced in the Guindy experimental beds (it is shown in the paper on the working of these beds, which Mr. Hutton presented to the All-India Sanitary Conference in January 1914), and that in this case the cure has been found in storage.

At Guindy there is an eight days' storage capacity. An equal storage for Madras, allowing freeboard for wave action, would mean tanks of 150,000,000 gallons total capacity. As there is no head available, the tanks would have to be of the continuous flow type, unless costly pumping were adopted. Such storage is believed to be quite beyond the means of the Madras Corporation.

Furthermore, storage might prove not to provide a proper remedy, for the Red Hills water is different from the water used at Guindy to such an extent that it cannot be assumed that a measure that proves satisfactory for the one, will necessarily prove equally beneficial for the other.

General character of water at Red Hills.

13. Paragraphs 11 and 12 refer to the systematic experiments made by the Director of the King Institute, Guindy, on the results obtained by filtering water according to his directions through certain filters.

In addition, a number of examinations of Madras water have been made from time to time. The detailed results of the routine examinations made before the opening of the new works do not appear to have been communicated to the Corporation, but are probably available at the King Institute. The general result seems to indicate that the water is usually fairly good, but contains an objectionable amount of organic matter. The water brought into Red Hills Lake by the channels is not so good bacterially as that in the Red Hills Lake, but the lake water frequently contains more organic matter. The surface water in the lake contains fewer bacteria than the water near the bottom. The water deteriorates in the distribution system.

A typical microscopical examination reveals "sediment voluminous in quantity, contains abundant infusors, cyclops, rotifers, vortichella and greenish filaments of vegetable origin."

Measures taken to prevent pollution of water.

14. This is a convenient point to indicate what measures are taken to prevent the pollution of the Water-supply at its source and on its way to Madras.

A. At Red Hills Lake.

The Red Hills Lake may be considered the source of supply, so far as the Madras Corporation is concerned. This lake is controlled generally by the Government Public Works Department, but the Corporation maintains an overseer and staff of lascars to regulate the supply to the city, and to prevent contamination as far as possible.

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Measures taken to prevent pollution of water (contd.)

A. At Red Hills Lake. —(contd.)

To prevent contamination there are ten lascars who are posted every morning at different villages and grazing grounds. Their duties are to prevent cattle grazing on a prohibited fringe of the lake, and to prevent cattle and men entering the lake for any purpose. The lascars are on duty for eight hours each day from about 7 A. M. In addition, the overseer, with a band of the same lascars, visits different parts of the shore at night time—once or twice a week.

Cattle found grazing are impounded, whereby the owners are fined to the extent of the pound fee. Persons caught fishing are prosecuted and on conviction are usually fined As. 8 to Rs. 2. The following figures refer to the last $2\frac{1}{2}$ years.

Number of cattle impounded ...	3,763	(*April* 1915 *to September* 1917.)
Number of convictions for fishing ...	152	
Charges for fishing not yet heard ...	21	

It is probable that the grosser and more obvious pollution is checked to some extent by the overseer and his men, but ten lascars on duty for eight hours a day cannot possibly prevent the pollution of a shore some 20 miles in length throughout the 24 hours of the day.

As long as villages, destitute of dry weather water supplies, are allowed close to the lake shore, so long must there be pollution by both man and beast in the hot weather. Whether further steps should be taken to prevent pollution depends on the importance attached to the pollution.

The heroic course to stop pollution would be the removal of the villages within a stated margin from the water. This, however, would be very costly.

Other, and much less expensive measures, which would reduce the pollution are:—

(1) To provide dry weather water supplies to all villages and grazing grounds, bungalows and quarters round the lake which do not now possess them, *e.g.*, by wells and tanks which might, where necessary, be provided with pipes from the lake.

(2) To provide causeways where paths between villages cross arms of the lake.

(3) To remove free grazing grounds from the proximity of the lake.

(4) To improve the watching by dividing the lake into four or more sectors, each to be watched by a staff of lascars under an overseer, quarters being provided in each sector for the staff watching that sector.

(5) To provide the overseer with a motor boat, cycle, or horse by which he could rapidly go round the lake and ascertain if the lascars were at their posts.

Special Precautions.—Special precautions are taken when considered necessary. For example, in July and August this year, when there was a festival at Periapalayam, a special patrol of six lascars was appointed to prevent pollution of the water by pilgrims who halted near the lake on their way to and from Periapalayam.

The overseer and his assistant have orders to take special care that the patrol carries out its duties, and are told that they will be held personally responsible for any pollution that may be due to the pilgrims.

It is believed that these special measures are effective in preventing serious pollution.

Measures taken to prevent pollution of water (*contd.*).

B. Conduit. The closed conduit is provided every 1,000 feet or so with manholes to give access for inspection and repairs, and also to provide air vents. The manholes are closed with hinged iron covers fitting into iron frames built into the masonry. The doors are locked to the frames. As a precaution the conduit is regularly patrolled.

Until twelve months ago, the Corporation maintained water in the old open channel, and the villagers along its route were able to take water from it. During the last twelve months the channel has usually been dry, and the inhabitants took to breaking open the conduit manholes by lifting the covers and frames bodily with crowbars, and obtaining water by lowering chatties. To overcome this, bars have been built across the manholes and the covers firmly bolted down to them, only a few covers, well removed from villages, are now capable of being opened.

Evidence of the efficacy of these measures is provided by the following extract from a memorial, dated 20th August 1917, addressed to Government by the villagers of Surapet:—

"The manholes which were hitherto kept open have been now closed under the orders of the Municipality and they would nowhere to go for water and it would be impossible to take water even stealthily as manholes have been completely nailed,"

But though, by these means, the pollution of water in the conduit has been rendered more difficult, the usefulness of the manholes has been impaired, and it has become difficult, to inspect the inside of the conduit.

For Ayanavaram village the Corporation has provided a water-supply from the city pipe system, and for Surapet, as a temporary measure, water has been let down the old open channel as far as the Surapet tank.

General bacterial history of water passing through water-works.

15. Sufficient records are not available to compile an accurate bacterial history of the water passing through the works.

Generally speaking, it is found that, starting from the Red Hills Lake the bacteria—both total colonies and lactose fermenters—increase rapidly during the four hours or so that the water remains in the conduit, so that on reaching the filters, the numbers may have multiplied tenfold, twentyfold or even more.

The filters, when working properly, remove over 90 per cent. of the bacteria, but during the eight hours or so that the water remains in the dark underground tanks, where unfiltered and filtered water are mixed together, the bacteria again multiply rapidly.

After pumping into the Distribution System, there appears to be some increase in the total counts, but not in the lactose fermenters.

As records showing a continuous bacterial history of the water are not available, the history will be considered in sections as follows:—

(1) Red Hills Tank to Filters.
(2) Passing through Filters.
(3) Filters to Engine-house and post filtration multiplication of bacteria.
(4) Engine-house to Service Taps.

History of water—Red Hills Lake to filters.

16. The following table indicates the great increase in the number of bacteria that takes place as the water passes through the seven miles of covered conduit from the Red Hills Lake to the filters. The increase appears to be independent of the season of the year. It seems to be a natural growth, and not to be due to pollution. It is similar to the growth that takes place in the mixed, filtered and unfiltered water while in the underground storage tanks.

History of water—Red Hills Lake to filters (*contd.*).

Results of Examinations of Water made at the King Institute.

Source.	Total Colonies per c.c. on Agar at 37°C.	Lactose fermenters present in how many c.c.	Vibrios present or not.
12th July 1917.			
Outlet of Roughing Filter	300	Absent in 60 c.c.	Present
Manhole on Conduit	7,500	10 c.c	"
21st July 1917.			
Red Hills Lake 100 yards from Tower ...	480	20 c.c.	"
Red Hills Lake at Tower	960	7½	"
Manhole 10 on Conduit	4,200	5	"
25th September 1917.			
Red Hills Lake at Tower	850	5	Absent.
Roughing Filter Outlet	800	5	"
Manhole half-way along Conduit ...	1,400	1	"
Inlet Filter-bed	1,150	1	"

In addition to the bacterial history indicated by the figures quoted above, there is a visible increase in suspended matter in the water during its passage through the conduit. This appears to be due to a vegetable growth on the walls of the conduit, which breaks away and is carried along with the flowing water. There are two forms of growth—one which produces a continuous slimy coating over the walls and invert of the conduit, the other grows in patches brown in colour and moss-like in texture. A sample of the moss-like growth was sent to Dr. Gibson who reported on 23rd November 1915, that "The material found floating in the water of the conduit is a growing plant, the nature of which is under investigation. It consists of stout jointed filaments somewhat like spirogyra, but containing no chlorophyll."

The quantity of suspended matter varies from time to time, but whether it is seasonal or not has yet to be determined. So far as observations go, it appears to be greatest in the hot weather.

Results of passing water through the filters.

17. There are a large number of figures showing that, when the filters are working properly, the filtered water is much purer bacterially than the unfiltered, whether measured by total colonies or by the presence of lactose fermenters. Even when the filters are not working properly, there is considerable purification, except when the filters are first started.

The experiments made by Dr. Gibson furnish most of the data available for considering the bacterial effect of the filtration on the quality of the water. They have been dealt with in paragraphs 11 and 12, so need not be considered here.

An inspection of samples of the water before and after filtration shows at once that a large amount of suspended matter has been removed. Indeed to the naked eye it appears that all the suspended matter has been removed.

Results of passing water through the filters (*contd.*).

(For an account of features observed in the working of the Madras Filters, *see* paragraph 20, where are described the filtering layer, the formation of iron sulphide in the sand, the growth of crenothrix in the filtered water, and the destruction of the filtering layer by burrowing crabs).

Filters to Engine-house—Post filtration multiplication of bacteria.

18. Certain results of Dr. Gibson's experiments led him to conclude that there was post filtration multiplication of bacteria in the filter under-drains.

A. Filtered Water.—Except these experiments, no data are available to show the bacterial history of the filtered water after filtration, because in all the examinations that have been made the filtered water has been mixed with unfiltered water.

There is a strong probability that however carefully the water is stored, there will be a multiplication of bacteria both in the filter under-drains and in the storage tanks. This multiplication has been found to occur both in Europe and America. As it is favoured by high temperature it is likely to be more rapid in Madras.

B. Mixed, Filtered and Unfiltered Water.—A number of examinations have been made which show that in the mixed, filtered and unfiltered water there is a rapid increase in bacteria.

The following tables give some results and the writer's estimate of the approximate time elapsed from filtration to the time that the sample was taken :—

MIXED, FILTERED AND UNFILTERED WATER.

Results of King Institute Examinations for week ending 22nd August 1917.

Date of taking sample.	Nature of water.	Hours elapsed since filtration.	Source.	Total Colonies per c.c. on Agar at 37° C.	No. of c.c. in which lactose fermenters present.	Vibrios Test.
15-8-17	Raw ...	...	Inlet to Bed 3 ...	14,000	0·01	Positive.
,,	Filtered ...	2½	Outlet ,, ...	1,200	15	Negative.
16-8-17	Mixed ...	2¾	Manhole on filtered water conduit ...	4,000	5	Positive.
17-8-17	Raw ...	..	Inlet to Bed 3 ...	9,000	5	,,
,,	Filtered ...	2½	Outlet ,, ...	500	60	,,
18-8-17	Mixed ...	2¾	Manhole on filtered water conduit ...	2,700	0·1	,,
20-8-17	Raw ...	...	Inlet to Bed 3 ...	9,000	0·1	,,
,,	Filtered ...	2½	Outlet ,, ..	450	60	,,
22-8-17	Mixed ...	2¾	Manhole on filtered water conduit ...	1,850	5	,,

These figures show that shortly after mixing the bacterial properties of the water are intermediate between the filtered and unfiltered waters.

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Filters to Engine-house—Post filtration multiplication of bacteria (*contd.*).

The following table shows the effect of further storage on the bacterial content of the mixed water :—

MIXED, FILTERED AND UNFILTERED WATER.

Results of King Institute Examinations 18th to 20th September 1917.

Date of taking sample.	Nature of water.	Hours elapsed since filtration.	Source.	Total Colonies per c.c. on Agar at 37° C.	No. of c.c. in which lactose fermenters present.	Vibrios Test.
18-9-17	Raw ...	...	Inlet to Bed 5 ...	1,100	10	Positive.
,,	Filtered ...	2½	Outlet ,, ...	370	20	,,
,,	Mixed ...	12	Engine-house ...	1,630	1	,,
,,	,, ...	?	East Reservoir 1 ft. below surface ...	1,450	5	,,
,,	,, ...	?	East Reservoir 6¾ ft. below surface ...	980	5	,,
19-9-17	Raw ...	...	Inlet to Bed 5 ...	1,920	5	Negative.
,,	Filtered ...	2½	Outlet ,,	680	10	Positive.
,,	Mixed ...	12	Engine-house ...	3,300	1	,,
,,	,, ...	?	Central Reservoir 1 ft. below surface.	4,710	5	,,
,,	,, ...	?	Central Reservoir 6¾ ft. below surface ...	6,250	1	,,
20-9-17	Raw ...	...	Inlet to Bed 5 ...	1,420	10	,,
,,	Filtered ...	2½	Outlet ,, ...	490	30	,,
,,	Mixed ...	12	Engine-house ...	3,210	1	,,
,,	,, ...	4	West Reservoir 1 ft. below surface ...	1,760	10	,,
,,	,, ...	6	West Reservoir 7 ft. below surface ...	2,630	5	,,

The figures in the above table show that there is a rapid increase of bacteria in the mixed water in the underground storage tanks. This is not surprising seeing that in the Red Hills—Kilpauk Conduit, where the water is flowing at some two miles per hour, there is an increase ranging up to twentyfold or more in four hours.

There is nothing to indicate to what extent the bacteria would multiply. In any case, the figures refer to mixed, filtered and unfiltered water, and afford no guide to what would take place in wholly filtered water.

From Engine-house to service taps.

19. The following table carries the bacterial history to the service taps. The taps selected are close to leading mains so as to avoid dead ends and other conditions that might produce a local effect, not typical of the water as a whole.

From Engine-house to service taps (*contd.*).

Source.	Approximate distance from Kilpauk in feet	Total Colonies per c.c. on Agar at 37. C.	No. of c.c. in which lactose fermenters present.
26th September 1917—Northern Supply Main (No. 1).			
Pump Suction Culvert	0	1,900	1
Fountain Kelly's Road by Purasawakam High Road	4,000	2,200	5
Tap 138 Mint Street, Georgetown ...	16,800	2,190	3
Fountain $\frac{3}{47}$ Tiruvottiyur High Road, Tondiarpet	36,500	3,400	1
28th September 1917—Southern Supply Mains (Nos. 4 and 7).			
Pump Suction Culvert	0	1,650	1
Kolandai Gramani Fountain, Purasawakam	7,500	1,350	1
Fountain Wallajah Road by Triplicane High Road	14,600	2,650	0·1
Tap Police Station Ice House Road by Triplicane High Road	24,800	1,610	5
Fountain Mundakanniamman Koil by Cutcherry Road, Mylapore ...	27,700	2,400	1

In all these samples vibrios were absent in 100 c.c.

From these figures it appears that there is some increase in total counts in the distribution system, and that the increase is greater the further the water has to travel. On the other hand, it is noteworthy that out of seven samples, three show a decrease in lactose fermenters, and only one an increase.

Features observed in the working of the Madras filters.

20. *FILTERING LAYER.*—In the Madras Filters, the "filtering layer" consists of two distinct portions which both affect the rate of flow through the filter. It is almost certain that both also influence the purification of the filtrate. They are :—

(1) The ***sedimentary skin*** which forms on the surface of the sand.

(2) The *gelatinous layer* which consists of the top layer of sand, in which the grains are surrounded by a jelly-like substance.

Of these terms, the first is considered more truly descriptive and certainly more euphonious than the German "Schmutzdecke" frequently employed. There does not appear to be any accepted term for the second, though "slimy layer" is sometimes used.

The *sedimentary skin* appears to consist of the material which is carried by the water in suspension—sediment and vegetable growth all matted together. The thickness and appearance of the sedimentary layer apparently depend on the amount of suspended matter carried by the raw water. At times it forms a felt-like skin which, on drying, curls up in sheets of considerable tenacity roughly hexagonal in shape and about 3 square feet in area. This is well shown in the following photograph (Plate XV).

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Features observed in the working of the Madras filters (*contd.*).

Normally there is a well defined skin, not so thick or tenacious as the last mentioned, which, on drying, curls up in sheets about ¾ square foot in area. It possesses some tenacity and is distinctly separate from the sand. Occasionally, apparently when the water contains comparatively little organic matter, the sedimentary skin is thin, and on drying separates into quite small patches which are not readily detached from the surface sand.

PLATE XV.

So far as has been observed, there is normally no growth of algæ in the sedimentary skin, though on occasions when the depth of water over the sand has been reduced for some days, a growth has rapidly taken place. This appears to indicate that the depth of water over the sand—3½ to 4 feet—is sufficient to inhabit the growth of algæ in open filters in Madras. The experience at Guindy, where there appears to be algæl growth with 2 feet of water over the sand, indicates that the depth in the Madras filters cannot be reduced safely.

The *gelatinous layer* is usually well marked for a depth of 1½ inches below the surface of the sand, and sometimes can be seen by the eye to extend to a depth of 9 inches or so. The sand grains in this layer are surrounded by a jelly-like substance, which gives the sand a certain tenacity, so that it can be kneaded with the fingers, as if it were mixed with clay.

As already stated, it is believed that both the sedimentary skin and the gelatinous layer play a part in the purification of the water.

When a filter first clogs, it is usually due to the formation of a dense sedimentary skin, and when the skin is removed, the filter will continue to work for a considerable period. This may often be repeated with advantage several times before removing and washing the gelatinous layer.

The thickness of the gelatinous layer which can be most advantageously removed has not yet been determined, but so far 1 to 1½ inches appears to be sufficient. This agrees with the experience with the Guindy experimental filters, for the writer was told by the overseer in charge that at each cleaning he removed a layer of sand 1 inch thick in the case of the open filter, and 3 inches thick in the case of the covered filter.

BLACK LAYER.—When a filter is stopped after working for some time, a black layer of sand is found. Commencing usually immediately below the surface, the black sand extends to a depth which depends on the length of time that the filter has worked

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Features observed in the working of the Madras filters (*contd.*).

without thorough aeration. Usually the thickness is about 2 inches, but it may be as much as 15 inches. When the water is drawn off a filter and the sand exposed to the air, the black colour rapidly disappears.

Dr. Kesava Pai kindly examined the black layer in place, and took a sample to Guindy where he examined it. He found that "sand contains a fairly large amount of iron mixed up with it" and that when the black sand was "boiled with dilute sulphuric acid" (it) "gave abundance of sulphuretted hydrogen." His conclusion is that "The black material found in the sand is probably sulphide of iron."

The *smell of sulphuretted hydrogen* that is found in the neighbourhood of the filter outlets and the filtered water tanks is a feature which produces a disagreeable impression on the large number of persons who visit the waterworks. The worst smell is at the filtered water reservoirs, but a sample of water from the pipe supplying the central reservoir, taken by Dr. Kesava Pai on a day when the smell was unusually strong, failed to reveal any trace of H_2S. Of a sample taken from a filter outlet at the same time, Dr. Kesava Pai reports that a "trace of sulphuretted hydrogen was found to be present." Thus it would appear that the sulphur in the decomposing organic matter in the sedimentary skin forms H_2S some of which is carried in the water but is given off first as the water passing over the filter outlet weir falls down the outlet pipe, and finally as it enters the filtered water reservoir.

This is borne out by the facts that no smell of sulphuretted hydrogen can be detected at the pumping station, and that the complaints of bad smells from dead ends of the distribution system, which were numerous formerly, have now practically ceased.

It is believed that there is no harm in the sulphuretted hydrogen, and it is certainly better that it should be liberated in the open at the filter-beds, than in the consumer's room through his tap.

At the same time, it creates a sentiment in the public mind against the works, and for that reason it would be a good thing if it could be stopped without incurring much expense.

A white growth which Dr. Gibson has identified as *crenothrix polyspora*, appears in the water after filtration. It clings, in long white trailing filaments, to the walls of the filter outlet chambers, to the regulating weirs and to the sides of the filtered water conduit, and occasionally it is found on the walls of the outlet chambers of the filtered water tanks.

During the six months of the hot weather, the growth assumes formidable proportions, and despite constant removal, and the use of fine mesh screens on the outlet weirs, it has been impossible to keep the crenothrix entirely out of the distribution pipes. In 1915, when it first made its appearance, numerous complaints were received from consumers of white particles appearing in the water drawn from their taps. In the two subsequent years, the efforts made to exclude the growth have been so far successful that very few complaints have been received. As crenothrix does not appear to be present in the raw water, it must be a post filtration growth, and in 1916 a vigorous effort was made to eradicate it by emptying the filters and passing permanganate solution up the outlet drain and into the under-drainage system. This treatment was continued whenever a filter was out of use for cleaning. Unfortunately after 1915 permanganate rose in price to a figure which placed its purchase outside the range of the annual filter maintenance allotment.

The measures mentioned brought the crenothrix growth to manageable proportions, but it still appears more in some filter outlets than others. In consequence of the very serious choking of the pipes which would take place if the crenothrix obtained a

Features observed in the working of the Madras filters. (*contd.*).

footing in the distribution system, it is systematically destroyed whenever it makes its appearance. During the hot weather the filamentous growths have to be removed daily from the filter outlet chambers and from the pipes leading to the filtered water tanks.

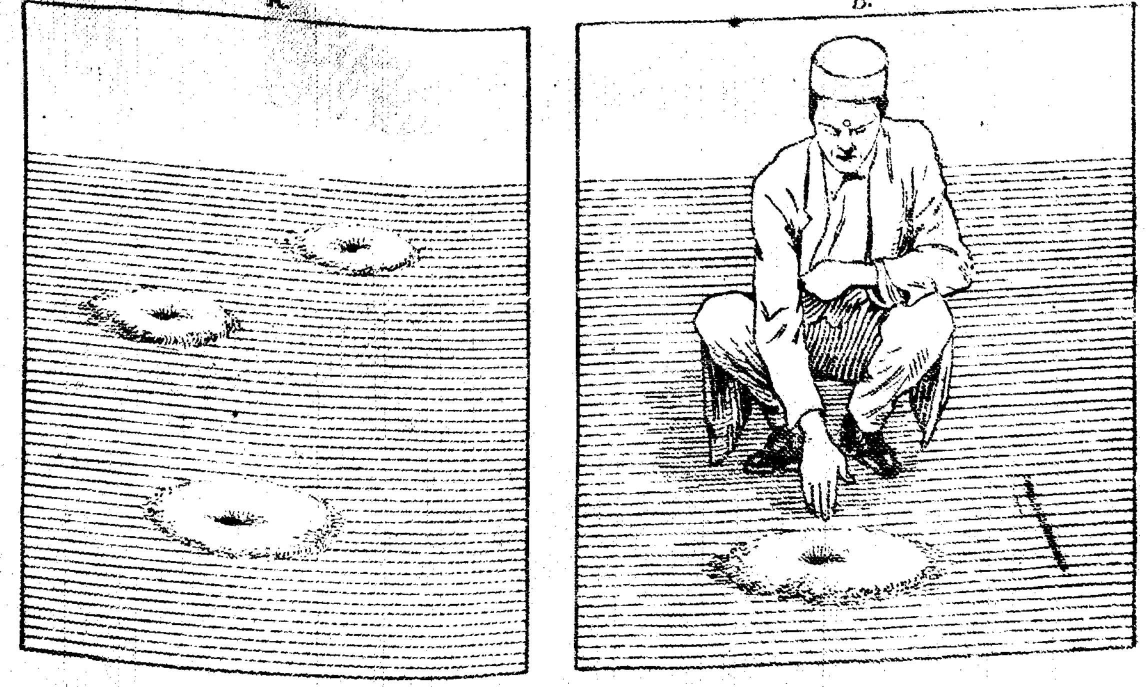
In view of the importance of eradicating it entirely, and of the post filtration multiplication of bacteria, to which reference has already been made in paragraph 18, it would seem highly desirable to resume the sterilisation of the under-drainage system when the filters are cleaned.

Burrowing crabs and other poochees.—The most serious difficulty encountered in the working of the filters is caused by crabs and other *poochees* which destroy the filtering layer by burrowing from the surface to depths of 2 feet or more. The Director of the King Institute has suggested catching all the living organisms. This has been regularly done as far as practicable, but has not proved effective, probably some of the *poochees* live buried in the sand, and others find their way into the filters with the unfiltered water.

Crabs undoubtedly make holes sufficient to impair the filtering layer (both sedimentary skin and gelatinous layer). The two photographs (Plate XVI) show crab holes in Filter No. 1 when it was emptied on 26th September 1917. Photograph A shows a group of three and photograph B an unusually large one. These holes are more marked than usual, but they indicate the nature of the holes.

PLATE XVI.

A. B.



The light band running across the photograph is a linen tape divided into inches.

Other *poochees*—frogs, tadpoles, fish and occasionally prawns have been observed—may have an equally bad effect, or at any rate may rupture the sedimentary layer.

The remedy would appear to be efficient screening of the water before entering the filters and sterilising the filtering materials and under-drains before the filters are brought into use after being thrown out for cleaning or other purposes.

Extent to which works carried out differ from the original design of 1905.

21. Generally speaking, the main principles of the works as originally designed in 1905 have been adhered to so far as relates to the design of the Roughing Filter, Conduit, Filter-Beds, and Clear Water Tanks. The remaining works referred to in the report forming Appendix III, namely, the Engine-house, Engines and Boilers and Elevated Tank, were not designed in detail in 1905 and differ entirely from the suggestions made in the report. Although the general principles have not been altered, the

Extent to which works carried out differ from the original design of 1905 (contd.)

details, and in some cases the materials of construction have been considerably altered. The more important modifications will be described beginning at the head and proceeding downwards.

Inlet Tower, Balcony and Bridge.—Re-designed.

Roughing Filter has been re-designed so as to provide upward filtration instead of lateral filtration. A screen wall has also been provided surrounding the roughing filter and screening chamber, in order to exclude animals which might obtain access thereto. This is additional work.

Conduit.—Nearly all the steel pipes proposed have been replaced by masonry conduit. The mortar generally used has been "combination mortar" made of a composition decided on as the result of an elaborate set of experiments. The lime-cement mortar originally proposed was not found suitable for wet ground. The thickness of the walls of the conduit, and the materials of which they were built, were modified from time to time to suit the nature of the ground. The weir between the filter-beds and the conduit was omitted as it was considered unnecessary. A by-pass has been introduced from the conduit to the filtered water tanks since it was found that 14 filters were insufficient to provide the water required by the city.

Filters and Pumping Station—General Arrangement.—The general arrangement of the filters and pumping station has been reversed, and by this alteration considerable economy has been secured.

Filter-beds.—The filter beds have been modified in the following respects:—

(1) *The depth of broken stone and gravel layer*—has been reduced from 1 foot 6 inches to 4 inches.

(2) *The height of water* above the sand has been increased from 2 feet to between 3 feet 6 inches and 4 feet.

These alterations are economical and they are also considered beneficial.

The shallower the depth of the broken stone, the less the opportunity for post filtration multiplication of bacteria in the drainage layers. The greater the depth of water over the sand, the less the chance of growth of algæ, and it is noteworthy that no growths of algæ have yet been detected.

(3) *The side walls* of the filters below sand level have been battered, and the drainage layers, including the broken stone and the brick drains have been stopped 3 feet from the walls, the space between the ends of the drains and the walls being filled with fine sand.

The object of these alterations is to reduce the chance of unfiltered water creeping down the sides. The batter of the walls makes any settlement of the sand tend to compress it, and keeping the drainage layers some distance from the walls further reduces the likelihood of water reaching the drains without passing through the filtering sand.

(4) The thickness of the floor has been reduced from 2 feet to 18 inches as the nature of the ground led to the conclusion that this thickness is sufficient.

(5) A screening wall has been erected round the filter-beds to exclude animals, which would otherwise be likely to obtain access to them. This is additional to the work provided for in the original scheme.

(6) Expansion joints were provided in the top layer of the filter bed floors to prevent them cracking.

Engine-house, Pumping Station and Distribution System.—As has already been stated, these are totally new designs. They are described in the Special Engineer's Madras City Water Distribution Report of 1911 and fully illustrated by the plans accompanying that report.

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Extent to which works carried out differ from the original design of 1905 (contd.)

Pumping Main.—The thickness of pipes was increased from ... inch as originally proposed to $\frac{7}{16}$ inch.

Distribution System.—The distribution system sanctioned by Government is fully described and illustrated in the Special Engineer's Distribution Report of 1911. The work has been carried out generally in accordance with that scheme, but, owing to financial stringency, a considerable number of distribution pipes have been omitted, and the installation of a waste water detection meter system has been deferred. Further, a number of small pipes 2 to 3 inches in diameter, which would not otherwise have been used, have been laid in order to make the supply as good as possible. The omissions are entirely due to the want of funds. They cause defects in the system, which should be remedied as soon as funds can be obtained.

Defects of water-supply and points that require elucidation.

22. In closing this report, it seems desirable to bring forward points that appear to those in charge of the water-works to require elucidation, as it is not likely that such an authoritative Committee will be available again for a long time to come. The points on which the executive desire information are as follows:—

(1) Whether the steps at present taken to prevent contamination of the Red Hills Lake are sufficient? (*See* paragraph 14). If not, what further protection is necessary or desirable?

(2) What is the best level to draw off the water at the Inlet Tower? The present practice, which is believed to be the best, is to draw off from a little below the surface.

(3) Does the Roughing Filter serve any useful purpose or not? If not, would it be better to dispense with it, maintaining the Screening Chamber and Measuring Weir?

(4) Is the vegetable growth in the conduit harmful to the water? If so, what steps should be taken to prevent it?

Note.—A similar growth takes place in the Roughing Filter.

(5) Can the sand filters be worked so as to render the water safe and wholesome? If so:—

(*a*) What modifications, if any, are required in the methods now adopted and set out in Appendix I-B.

(*b*) What additional filtering area is required?

(*c*) Are any alterations in design needed?

(*d*) What steps should be taken to maintain an adequate bacteriological control?

(*e*) What samples should be taken:—

(1) As a matter of routine?

(2) Occasionally?

(*f*) What should be done to remove the white filamentous growth (*crenothix polyspora*) from the filtered water?

(*g*) How can the smell of sulphuretted hydrogen be removed?

(*h*) Is the sterilisation of the under-drainage system of the filters desirable to prevent post filtration multiplication of bacteria, and also the growth of *crenothix polyspora*?

(*i*) What rate of filtration may be adopted?

(*k*) What is the maximum head that might safely be adopted on the filter beds?

(1) How can crabs, frogs, fish and other harmful organisms be excluded from the filter-beds?

Defects of water-supply and points that require elucidation (*contd.*)

(6) If sand filters are not sufficiently reliable, what other steps should be taken to secure to the city a sufficient supply of wholesome water?

(7) What would be the cost of carrying out each of the recommendations that may be made in reply to the above queries as regards—

(*a*) The cost of installation of all the necessary plant and apparatus?

(*b*) The annual cost of upkeep and maintenance?

In addition to the above queries, there are some important points which have to be decided and which may perhaps be considered under the head of "defects of the system," which it is noticed have come within the reference to the Committee. The defects that are definitely known are—

(1) The insufficiency of the filters to deal with the water that the city is consuming.

(2) The working of the filters, which is not yet sufficiently consistent.

(3) The insufficient capacity of the filtered water tanks.

(4) The need of a low level elevated tank to provide more storage in case of breakdown of the pumps or conduit, more especially the former, and also to secure economy by reducing the head against which the pumps have to work during the hours at which pressure is reduced in the distribution system.

(5) The increase in the number of street pipes, and the installation of a waste water detection meter system, as provided for in the sanctioned scheme, but deferred for want of funds.

(6) The large amount of waste and non-domestic use of water which makes it impossible to maintain a high pressure throughout the day.

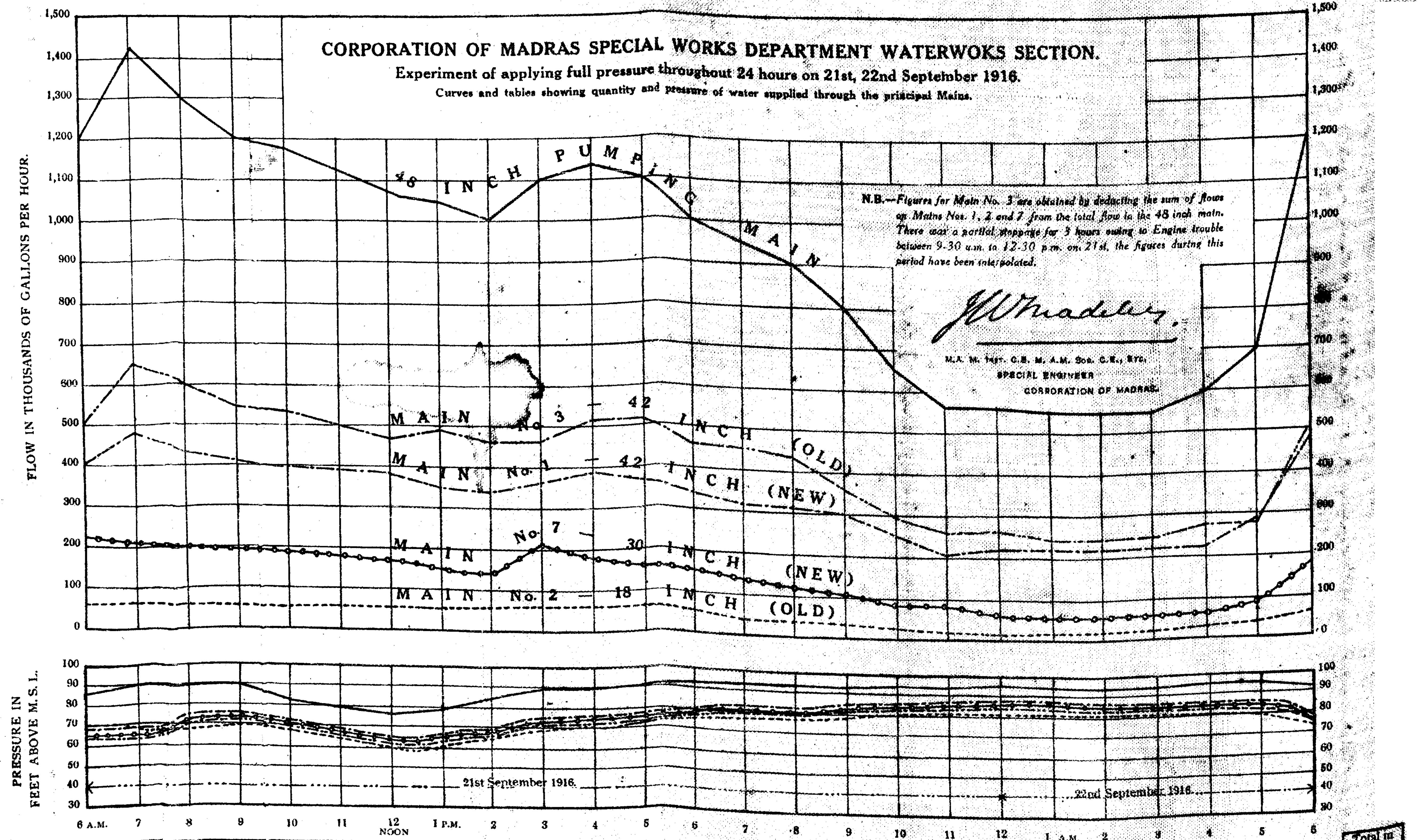
(7) The large leakage from street pipes, house services and fittings. Perhaps the greatest loss of water is from the iron service pipes which have a short life in Madras soil.

In addition to these defects, there is the question whether the water-supply from the existing sources is sufficient * and whether the works as a whole can bring enough water into the city. These are large questions which depend upon what supply is considered necessary for the inhabitants of Madras. If it is still agreed that the previously approved provision of 25 gallons per head per day is sufficient, then the works are not defective in the quantity of water that they can provide. If, as some say, every person in Madras should be provided with as much water as he wishes to take, then the works are defective in the quantity of water that they can provide. Intimately connected with this question are the prevention of waste and misuse of water which are very serious to those who have to manage the waterworks. In order to ensure that the water shall be equitably distributed, it has been found necessary to curtail the supply during many hours of the day, so that the high pressure, which will ensure that water will reach everybody, may be maintained during the hours of maximum consumption. The pressures in feet above ground level now maintained at the heads of trunk mains are as follows :—

6 A.M. to 9 A.M.	... ...	45 feet.
9 A.M. to 10 A.M.	... ...	35 „
10 A.M. to 6 P.M.	... ...	25 „
6 P.M. to 6 A.M.	... ...	10 „

* For some years a discussion has been in progress between the Corporation and Government on the maximum supply that can be obtained from present sources during dry years and on the question of raising the F.T.L. and lowest level for the issue of water for irrigation. These questions appear to be approaching solution.

PLATE XVII.



RATE OF FLOW IN THOUSANDS OF GALLS. PER HOUR.

	6 A.M.	7	8	9	10	11	12 NOON	1 P.M.	2	3	4	5	6
MAIN No. 1	410	482	432	408	400	389	379	350	349	360	357	370	338
MAIN No. 2	62	69	57	54	55	55	55	53	56	60	60	60	59
MAIN No. 3	503	651	609	547	538	506	471	495	456	470	513	510	459
MAIN No. 7	225	218	202	191	182	175	170	152	148	210	180	160	150
PUMPING MAIN	1,200	1,420	1,300	1,200	1,175	1,125	1,075	1,050	1,000	1,100	1,140	1,100	1,000

	7	8	9	10	11	12 MIDNIGHT	1 A.M.	2	3	4	5	6	Total in Thousands of Galls.
MAIN No. 1	317	314	300	250	206	220	220	210	219	225	290	475	8,308
MAIN No. 2	45	32	29	24	21	20	21	21	22	31	38	56	1,109
MAIN No. 3	463	488	365	296	253	260	245	246	248	275	277	491	10,575
MAIN No. 7	135	120	105	80	80	60	64	64	60	60	95	178	3,472
PUMPING MAIN	960	900	800	650	560	560	546	550	550	600	700	1,200	23,455

PRESSURE AT KILPAUK SHAFT IN FEET ABOVE M. S. LEVEL.

	6 A.M.	7	8	9	10	11	12 NOON	1 P.M.	2	3	4	5	6
MAIN No. 1	70	69	73	75	78	68	65	66	69	75	75	77	79
MAIN No. 2	71	68	68	71	68	65	60	61	67	70	72	74	76
MAIN No. 3	65	64	78	75	76	68	65	65	70	74	75	76	78
MAIN No. 7	66	66	73	75	73	65	65	71	71	74	75	76	79
PUMPING MAIN	92	90	88	90	82	78	75	78	84	88	88	90	92

	7	8	9	10	11	12 MIDNIGHT	1 A.M.	2	3	4	5	6
MAIN No. 1	82	82	84	85	86	86	86	85	85	[illegible]	85	78
MAIN No. 2	76	77	79	80	81	81	81	81	81	[illegible]	70	73
MAIN No. 3	80	80	83	83	84	84	84	84	84	84	82	76
MAIN No. 7	82	82	83	84	85	85	85	85	85	84	84	77
PUMPING MAIN	93	93	93	94	94	95	94	94	94	95	95	93

From an experiment that was made of the water consumed under full pressure for 24 hours, it was found that the consumption reached* 23½ million gallons, equivalent to some 45 gallons per head per day. This large consumption is due to waste and leakage and misuse of water, and is a repetition of what is found in every large Indian town of the plains. Indeed it is believed that no large city in India has been able to give private water services freely and at the same time to maintain a regular high pressure supply throughout the 24 hours. Certainly neither Bombay nor Calcutta has been able to do so. It would be a fine achievement should the Corporation of Madras be the first Municipal body to provide a continuous high pressure water-supply to a large Indian city of the plains. It is an achievement that should be capable of accomplishment, if all concerned will co-operate. *Defects of water-supply and points that require elucidation (contd.).*

23. This report has necessarily dealt mainly with the defects of the system, because these are the subjects referred to the Committee for whom the report has been prepared. *Benefits obtained from new water-works and their effect on the health of city.*

Perhaps it is permissible to point out that there is another side. Except for the filter-beds, the new works were designed to supply 16½ million gallons per day. They have proved capable of supplying more. Indeed during the high pressure experiment they supplied 23½ million gallons in 24 hours.

It is thought that the requirements of the city are reasonably met. This view is supported by the fact that very few complaints are received of insufficient water. The few petitions that come to hand are mostly for new pipes where there are none, and a few for larger pipes where the old pipes are choked. Unfortunately, only a small number of these requests can be complied with, owing to the great restriction of pipe-laying rendered necessary by the financial stringency caused by the war.

The small number of complaints received is in great contrast to the state of affairs before the new works were opened. Then a stream of complaints was continually pouring into the Corporation offices—a stream that resumed its flow during the ten days that the supply was cut off for some hours each day in an endeavour to restrict the consumption to the quantity of water that could be filtered, and which again ceased when continuous supply was restored.

As regards quality, whatever defects there may be, the very great danger of serious pollution in the open channel has been removed. Under the old system, a large staff was engaged every day in cutting and removing weeds from the channel, for which purpose they were immersed in the water. In the hot-weather—despite patrols—men, women, and also cattle were frequently to be seen in the channel, assuaging their thirst and cooling their bodies. This source of contamination has been removed by the underground conduit, which has replaced the open channel.

The best test of a water-supply is its effect on the health of the people. To apply this test, the following figures compiled from the Health Officer's Returns are quoted :—

Year.	No. of deaths in the year.	Death-rate per 1,000.	Remarks.
1901—10	22,485	44·0	Average for decade.
1914	24,174	46·6	Last year of old water-supply.
1915	18,683	38·0	First two years of new water-supply.
1916	17,872	34·4	

* A diagram showing the results of this experiment, faces this page (Plate XVII).

Benefits obtained from new water-works and their effect on the health of city (*contd.*).

Up to the end of September, the death-rate for 1917 is 2 per 1,000 above the death-rate for the corresponding period in 1916. This may, in a large measure, be accounted for by the remarkable increase in birth-rate that has taken place in the same period, because this has increased the number of infants, and with the high mortality that exists among infants, the greater the proportion of infants, the greater the death-rate.

However that may be, the death-rate for the period of 2¾ years since the new water-works were opened is decidedly below that of any equal period within recent years, and very much below the average for the previous decade.

It may be argued that total death-rates are no true guide to the effect of the water-supply on the health of the community and that the death-rates from water-borne diseases only should be studied. To meet this point, the writer has obtained from the Health Officer the average number of deaths and death-rates from cholera and also from dysentery and diarrhœa for the ten years before and for the 2¾ years since the opening of the new works. They are as follows :—

	Decade 1905—14 average per year.	1914 last year of old water-works.	1915-16 first 2 years of new supply average per year.	1917 first 9 months.
No. of Deaths.				
Cholera	926	1,757	32	75
Diarrhœa and Dysentery ...	4,910	5,508	3,936	3,222
Total ...	5,836	7,265	3,968	3,297
Death-rates.	Per thousand per annum.			
Cholera	1·79	3·4	0·06	0·2
Diarrhœa and Dysentery ...	9·52	10·6	7·10	8·0
Total ...	11·31	14·00	7·16	8·2

The writer understands from the Health Officer that since the opening of the new water-works, there has been no case of cholera traceable to the water-supply.

The comparative absence of cholera from Madras during 1917, when it was raging in the communities round is remarkable. Nearly all, if not all, cases in the city were imported or due to imported cases.

The above figures confirm the total death-rate figures, and prove that there has been a decided reduction in deaths due to water-borne diseases, since the new water-works were opened.

These considerations lead to the conclusion that despite the defects that have been dealt with in this report, the new water-works have been a real benefit to the city.

(Signed) J. W. MADELEY,
Special Engineer,
Corporation of Madras.

NAPIER PARK, MADRAS,
6th October 1917.

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Appendix I.

A.—Data regarding Working of Filter-beds.

Number of filter.	Date when brought into use.	Duration of working up to 30th September 1917.	Amount of water in millions of gallons passed through between 1st June 1915 and 30th September 1917.	Rate of Filtration.
1	9th June 1915.	732 days	764·14	The filters were started at a slow speed and gradually worked up to a maximum of 5⅝ linear inches per hour which was continued so long as there was sufficient head. As the filters clogged, the rate of filtration decreased to about 2½ linear inches. This does not apply to the beds experimented on by Dr. Gibson and which were worked according to his instructions. Full details are given in Appendix II. Since 12th July 1917, the maximum of 4 linear inches per hour has not been exceeded.
2	6th Nov. 1915.	585 „	603·17	
3	17th Dec. 1914.	782 „	733·88	
4	4th June 1916.	411 „	452·31	
5	17th Dec. 1914.	798 „	651·82	
6	17th Nov. 1916.	251 „	302·53	
7	17th Dec. 1914.	806 „	567·56	
8	4th Feb. 1916.	501 „	336·04	
9	17th Dec. 1914.	810 „	654·08	
10	23rd Aug. 1916.	359 „	373·87	
11	17th Dec. 1914.	805 „	664·67	
12	4th Feb. 1916.	473 „	448·02	
13	17th Dec. 1914.	768 „	496·77	
14	9th Sept. 1915.	662 „	409·14	

No regular analyses were made of water from each filter except filters 8, 12, 13 and 14 the filtrates from which were examined systematically for a time. The results are given in Appendix II.

Appendix I—(*contd.*).

B.—Revised Rules for Working Filters.

N.B.—These rules have been worked to as far as possible, but in the absence of bacteriological control it has been impossible to comply with them fully.

(Signed) J. W. MADELEY.

25th September 1917.

Filling filters.

1. Close inlet and outlet valves and open valve for filling filter from below with pure water, so that the water surface rises at a uniform rate of 2 inches vertical per hour till there is a depth of 6 inches of water over the sand.

Then close the filtered water valve and open inlet valve slightly so as to fill the filter slowly till the depth of water over the sand is 18 inches. The filter may then be filled more quickly, but great care must be taken to avoid disturbing the sand surface by admitting the water too fast (above 5 inches vertical per hour).

Filter to rest.

2. When the filter is full, close the inlet valve and allow the water to stand for at least 24 hours, or such longer period as tests of the transparency of water may prove to be necessary. Then open the scour valve, so that the water sinks at the rate of ½-inch vertical per hour. Having made this adjustment, open inlet valve wide to keep level in the filter constant. After 4 hours increase the rate of filtration to 1-inch and then gradually to 1½ inches, 2-inches and 3-inches. Run the filter at 3 inches for three days, and if after that, there are no lactose fermenters in 100 c.c., allow 4 inches.

Running filtered water to waste.

3. Run water to waste until an efficient filtering skin is formed as proved by bacteriological examination.

Working filter.

4. When an efficient filtering skin has formed, close scour valve, open outlet valve, and adjust the automatic outlet, so that the rate of filtration continues the same. Continue at the rate of 3-inches vertical per hour for a total of three days. Then slowly increase the rate to 4 inches vertical per hour, great care being taken that there is no sudden increase in head. When the bacteriological tests have proved that a first-class filtered water is being obtained at the rate of 4 inches vertical per hour, the rate may be increased gradually to 5 inches vertical per hour and maintained at that rate so long as bacteriological tests prove that there is no loss in the efficiency of filtration.

Work filter-bed until, with the head available, it is no longer possible to get a greater filtration than 3 inches vertical per hour.

Cleaning filter.

5. Close inlet valve and run water through the outlet valve as low as possible. Then open the scour valve and drain the filter completely.

Close scour valve and clean filter-bed by one of the two following methods :—

(*a*) Allow filtering skin to dry by exposure to the sun and remove filtering skin, which will curl up in small patches.

(*b*) Remove filtering skin while moist.

Experience will show which of these methods is most effective and economical. Care should be taken to remove the minimum amount of sand, which should be less than ½ inch. The sand should be smoothed flat, care being taken not to disturb the compact surface.

Precautions when cleaning.

6. Every care should be taken not to foul or disturb the sand surface. For this reason the coolies must wash themselves and their implements, and where necessary planks should be provided for them to walk on. The most effectual and economical way of removing filtering skin must be determined by experiment. Mamooties and wooden rakes should be tried.

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Appendix I.—(*contd.*).

Disturbing surface film.

~~7. When a filter clogs rapidly instead of cleaning it, the surface film may be disturbed in the following manner :—~~

~~Close Outlet. Leave filter standing for 6 hours to allow water to fill spaces in sand, stones and drains. Draw off water to a few inches below sand surface.~~

~~Rake over with an iron plate sufficiently serrated to break up the film.~~

~~Restart filter as described below.~~

~~The effect of the filtrate analyses of thus disturbing the surface film must be carefully noted before it is finally adopted as a standard method of treating a filter which clogs rapidly.~~

This disturbing of the surface film was abandoned after trials had proved it to be unsatisfactory.—J. W. M. (25-9-17).

Disposal of removed filtering skin.

8. The filtering skin removed in the manner above described will be conveyed to a water tight platform, and the organic matter washed out of it as soon as possible. The washed sand will then be stacked for use when it is required to refill one of the filters.

Note.—The cost of this washing must be determined and if it is found to exceed the cost of fresh sand, then the removed filtering skin should be used for filling hollows or other purposes for which it may be suitable, and fresh sand used for replenishing the filter.

It was found very costly to wash the sedimentary skin which is accordingly disposed of otherwise.—J. W. M. (25-9-17).

Re-starting filters.

9. After cleaning, the sand should, if possible, be exposed to the action of the atmosphere. The filters should be re-started after cleaning in exactly the way already described for starting filters.

Minimum thickness of filtering sand.

10. The cleaning as above described may be continued until the fine sand is reduced to a thickness of 15 inches, unless analyses have proved the filter to have lost its efficiency before.

Renewing filtering materials.

11. When the fine filtering sand has been reduced to 15 inches in thickness, or analyses show that the sand should be removed, then the filter should be emptied and the sand as far as it is discoloured, should be removed and washed. The filter should then be refilled with clean sand to the same depth as for new filters.

Rate of filtration.

12. The rate of filtration should not exceed 5 inches vertical per hour, and must be controlled in accordance with the results of bacteriological examination.

Examination of water.

13. The water from each filter should be examined daily to see that it is clear and free from taste and should be compared with the raw water.

Arrangements should be made for regular bacteriological examination. It is desirable that the filtrate from each filter should be examined daily. Should there be any sudden increase in the number of bacteria, the bed should be put out of action and an examination should be made to discover and remove the cause.

Reports.

14. Reports on the working of the filters showing the quantity of water filtered, number of cleanings, and anything calling for special remark, should be sent in bi-monthly, and a general summary of the year's working should be submitted in the first week in April for inclusion in the Annual Administration Report of the Madras Corporation.

(Signed) J. W. MADELEY.

26th October 1915.

Appendix I—(*contd.*).

C.—Quantity of Filtered and Unfiltered Water supplied from time to time.

Period.	Filtered water-supply.	Unfiltered water-supply.	Filtered and unfiltered water consumption.
June and July 1915	609,148,764	433,328,236	1,042 477,000
August and September 1915 ...	381,103,320	495,306,680	866,410,000
October and November 1915 ...	608,553,707	165,546,293	774,100,000
December, 1915 and January 1916 ...	271,302 842	537,369,158	808,672,000
February and March 1916 ...	291,145,068	561,495,932	852,641,000
April and May 1916	612,274,571	270,338,429	882,613,000
June and July 1916	683,540.000	144,819,000	828,359,000
August and September 1916 ...	566,600,000	274,798,000	841,398,000
October and November 1916 ...	711,920,000	103 406,000	815,326,000
December 1916 and January 1917 ...	807,460,000	....	807,460,000
February and March 1917 ...	593,620,000	212,952,000	806,572,000
April and May 1917 ...	598,920,000	285,150,000	884,070,000
June and July 1917	483,850,000	265,669,000	749,519,000
August and September 1917 ...	238,868,665	583,387,335	822,256,000
Total ...	7,458,306,937	4,323,566,063	11,781,873,000

Up to July 1917, the unfiltered water was drawn from above the sand in one or more of six filters which were provided with 14-inch cast-iron pipes leading to the outlet regulator chambers.

Since July 1917, the unfiltered water has been taken through the by-pass from the conduit to the clear water tanks.

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Appendix I—(*contd.*).

D.—Water Consumption in gallons for the City of Madras.

Period.	Total consumption for week.	Average per head per day.	REMARKS.
Week ending 1915			
June 7	111,900,000	30·92	The figures for the average consumption per head per day are calculated on the assumption that there are 517,000 water consumers.
14	128,900,000	35·61	
21	122,600,000	33·87	
28	109,620,000	30·29	
July 5	113,167,000	31·27	
12	111,700,000	30·86	
19	101,100,000	27·93	
26	102,100,000	28·21	The figures give weekly averages, the maximum daily average generally exceeds the weekly average by an appreciable amount.
Aug. 2	104,600,000	28·90	
9	106,700,000	29·48	
16	103,400,000	28·57	
23	109,100,000	30·14	
30	95,600,000	26·41	
Sept. 6	95,600,000	26·41	
13	102,400,000	28·21	
20	93,000,000	25·69	To maintain the pressures given in the report, it is necessary to provide for a consumption of 30 gallons per head per day.
27	92,400,000	25·53	
Oct. 4	91,700,000	25·33	
11	94,200,000	26·03	
18	98,600,000	27·24	
25	90,300,000	24·95	
Nov. 1	90,575,000	25·03	
8	93,225,000	25·76	
15	86,100,000	23·79	
22	84,700,000	23·37	
29	83,700,000	23·12	
Dec. 6	86,300,000	23·84	
13	88,400,000	24·42	If full pressure is maintained throughout the 24 hours, it is estimated from experiments that the consumption would be about 50 gallons per head per day.
20	89,300,000	24·67	
27	87,600,000	24·19	
1916 Jan. 3	88,300,000	24·39	
10	93,900,000	25·94	

Period.	Total consumption for week.	Average per head per day.	REMARKS.
Week ending 1916			
Jan. 17	93,000,000	25·69	
24	97,100,000	26·83	
31	96,900,000	26·77	
Feb. 7	97,100,000	26·80	The original scheme provided a supply of 25 gallons per head per day, ultimately, and a smaller supply when the works were first opened.
14	96,600,000	26·69	
21	96,500,000	26·66	
28	98,500,000	27·21	
Mar. 6	100,000,000	27·63	
13	100,100,000	27·65	
20	99,600,000	27·52	The excess consumption is largely due to waste, leakage and use for gardens and other non-domestic purposes.
27	104,700,000	28·93	
Apr. 3	104,200,000	28·79	
10	101,700,000	28·10	
17	100,200,000	27·68	
24	98,000,000	27·07	
May 1	100,485,000	27·76	It is open to question whether the consumption in Madras could be restricted to 25 gallons per head per day under a continuous high pressure supply.
8	102,700,000	28·37	
15	100,100,000	27·65	
22	103,300,000	28·54	
29	101,700,000	28·10	
June 5	96,600,000	26·68	
12	99,100,000	27·38	
19	92,700,000	25·61	
26	93,400,000	25·80	
July 3	92,000,000	25·42	
10	92,400,000	25·53	
17	98,800,000	27·30	
24	99,300,000	27·44	
31	91,660,000	25·33	
Aug. 7	95,200,000	26·30	
14	98,420,000	27·19	
21	90,900,000	25·12	

Appendix I—(*contd.*).

D.—Water consumption in gallons for the City of Madras—(*contd.*).

Period.	Total consumption for week	Average per head per day.	REMARKS.	Period.	Total consumption for week.	Average per head per day.	REMARKS.
Week ending 1916 Aug. 28	96,350,000	26·62		Week ending 1917 Mar. 19	101,200,000	27·96	
Sept. 4	99,100,000	27·38	*See* previous page	26	100,700,000	27·83	*See* previous page
11	96,200,000	26·58		Apr. 2	99,300,000	27·44	
18	94,700,000	26·17		9	99,800,000	27·58	
25	108,200,000	29·90		16	101,470,000	28·04	
Oct. 2	106,300,000	29·37		23	102,600,000	28·35	
9	99,300,000	27·44		30	100,100,000	27·66	
16	97,500,000	26·94		May 7	102,000,000	28·13	
23	88,000,000	24·32		14	101,700,000	28·10	
30	94,600,000	26·14		21	102,200,000	28·24	
Nov. 6	97,500,000	26·94		28	103,700,000	28·65	
13	102,300,000	28·21		June 4	98,300,000	27·16	
20	88,200,000	22·98		11	78,100,000	21·58	
27	84,200,000	23·26		18	82,000,000	22·66	
Dec. 4	89,500,000	24·73		25	77,700,000	21·47	
11	86,900,000	24·01		July 2	75,400,000	20·83	
18	90,300,000	24·95		9	74,900,000	20·70	
25	90,600,000	25·03		16	88,700,000	24·51	
1917 Jan. 1	89,800,000	24·81		23	104,130,000	28·77	
8	91,800,000	25·36		30	97,800,000	27·02	
15	95,400,000	26·36		Aug. 6	102,400,000	28·29	
22	91,200,000	25·20		13	102,800,000	28·40	
29	94,200,000	26·03		20	98,700,000	27·27	
Feb. 5	93,600,000	25·86		27	96,200,000	26·58	
12	93,400,000	25·80		Sept. 3	89,700,000	24·78	
19	96,200,000	26·50		10	95,300,000	26·33	
26	96,600,000	26·69		17	93,100,000	25·73	
Mar. 5	97,200,000	25·20		24	95,400,000	26·36	
12	100,300,000	27·71		Oct. 1	90,900,000	25·11	

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Appendix I—(*contd.*).

E.—Staff employed on the Water-works and their duties.

(1) RED HILLS LAKE.

Staff as per margin.

1 Overseer.
1 Asst. Overseer.
2 Syrangs.
1 Watchman.
18 Lascars.
1 Peon.
1 Gardener.
1 Sweeper.
2 Scavengers.

1. The overseer and his assistant shall conserve the lake and its surroundings with reference to the prohibitions against fouling the lake, prescribed by Section 319 of the Act. He shall detail lascars to watch the lake from being contaminated by the inhabitants of the surrounding villages, and shall report all offences under Section 319 and conduct prosecutions when ordered by the President. He shall patrol the lake at night at least twice a week. He shall take special care to watch the lake during stormy and wet weather, and shall warn the Engineer and the Public Works Department overseer if he considers that there is any danger of damage.

2. He shall keep the valves, screens, weir meter, etc., at the Inlet Tower, Screening Chamber and Roughing Filters in proper working order, and shall regulate the discharge over the weir in accordance with the instructions from the overseer at Kilpauk Filter-beds.

3. He shall clean the Roughing Filters once in six months, and oftener if required.

4. He shall see that the lake boats are kept in order and good repair, and shall report on all matters affecting the conservancy and safety of the lake, and all works attached thereto.

5. The assistant overseer shall share with the overseer the above duties and shall carry out such duties under his direction.

Note.—The peon, gardener, sweeper and scavengers are employed at the Corporation bungalow and at the quarters of the overseer and his assistant.

(2) FILTER-BEDS.

Staff as per margin.

1 Overseer.
1 Asst. Overseer.
3 Turncocks.
8 Lascars.
4 Gardeners.

The following is a copy of the rules under which the Filter-bed staff is working. For further duties *see* Rules for Working Filter-beds (Appendix I, B) and "Procedure in case of fire" [Appendix I, D (4).]

The following is a brief statement of the main duties of the Filter-beds overseers :—

1. The filter-beds shall be cleaned in accordance with the instructions already issued by the Special Engineer. The chief points are—

A.—The checking of the rate of filtration which shall be done once in 3 hours at least for every filter or oftener if necessary.

B.—Personal supervision of the cleaning and filling operations. The sedimentary skin shall be completely and carefully removed with as little sand as possible.

C.—Starting of the filters after cleaning.

D.—Keeping the filter regulators, gauges and valves in working order by periodical cleaning and oiling.

E.—Keeping the filters and regulator rooms clean and tidy. All flies, etc., on the water surfaces shall be removed, and no flies, etc., shall be allowed to enter into the clear water conduit. No stagnant water shall be allowed to stand in pools or in the scour out chambers.

2. A high level of water shall be maintained in the filter-beds, and the overseers shall take necessary steps by telephoning to Red Hills to prevent shortage of water.

3. Maintaining the filter log books in a clean condition with the records brought up to date. On no account shall the overseers note the filtration heads, etc., on pieces of paper with the intention of transferring the figures to the log books afterwards. The figures shall be entered directly into the log books at the hours noted in them.

4. The site and surroundings of the filter-beds, pumping station and elevated water tank shall be swept and maintained in a clean condition.

5. The overseers shall see that the water level in the clear water tanks, etc., is sufficient not only to meet the needs of the town supply, but also emergencies such as fire, etc.

6. The garden shall be properly looked after. The plants shall be watered daily, and no cattle allowed in the compound.

7. The clear water tanks shall be cleaned once in six months or oftener if required.

8. In case of fire, one overseer shall be at the filter-beds attending to the water-supply while the other overseer shall proceed without delay to the shaft to regulate the valves on the trunk mains and concentrate supply to the district affected.

9. All machinery and plant shall be kept clean and in working order.

10. As the filter-beds and connected works require close and constant attention, no definite hours of work are prescribed, either the overseer or his assistant or both shall be at the site of the works at all times of day and night. The overseers shall stay out and personally supervise and conduct the operations. No responsible work shall be done by the lascars, except in the presence of the overseer or his assistant.

11. He shall maintain the following pressures in the four trunk mains at Kilpauk shaft.

6 A. M.	to	9 A. M.	45	feet above ground level.
9 ,,	,,	10 ,,	35	,, ,,
10 ,,	,,	6 P. M.	25	,, ,,
6 P. M.	,,	6 A. M.	10	,, ,,

12. The Filter-beds overseer, or in his absence the assistant overseer, will inspect the conduit on the second Wednesday of every month. His inspection shall be carefully done. He will open every alternate manhole and look through the conduit to the manholes on either side using lights if required. He will note carefully condition of conduit, as regards its structure, vegetable and other growths on the walls, etc., if any. These notes along with any other matters calling for attention should be embodied in a report and submitted to the office not later than the Friday succeeding the inspection.

13. Weekly and monthly returns shall be submitted promptly and without delay on the due dates.

14. The overseer and his assistants shall distribute the work among themselves in the best manner possible subject to the approval of the Engineer.

(3) PUMPING STATION.

Staff as per margin.

1 Superintendent.
3 Drivers.
1 Foreman Fitter.
3 Firemen.
9 Cleaners.
1 Fitter Cooly.
1 Blacksmith.
1 Asst. Blacksmith.
1 Store-keeper.

The Superintendent's duties are to keep the pumping station in first-class order, and to pump sufficient water to ensure the pressures in the trunk mains as ordered from time to time and to maintain sufficient water in the elevated tank to meet fire call and other emergencies.

He is also responsible for the good order of the elevated tank and the steel Pumping Main.

Note.—The Superintendent is a responsible man, and the details of working the plant are left largely to his discretion. He is paid a *bonus* if he secures sufficient economy in working.

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(4) PROCEDURE IN CASE OF FIRE.

In any case in which the Corporation fire engines are called out, the driver on duty before starting will ring up No. 202 Pumping Station, Kilpauk, and state if possible the division in which the fire has occurred: if this is impossible, the locality. The Engineer on duty at Kilpauk will increase the pressure in the locality where the fire has occurred.

Procedure at Kilpauk Pumping Station when a telephone message is received stating the occurrence of a fire in the city.

1. The driver on duty who receives the message will particularly ask in which division or locality the fire has occurred, and he will immediately report it to the Superintendent and the overseer.

2. Immediately on receipt of the message, the overseer with two lascars will proceed as quickly as possible to the shaft where he will first see that the 36-inch valve is open, and then fully open the valve on the main which supplies the district or locality in which the fire has occurred. Simultaneously, an additional pumping engine will be made ready to start.

3. The driver on duty will enter the message and the time it was received in the engine log.

4. As soon as possible without delaying the execution of the above instructions, the Superintendent will telephone to the Water-works Engineer stating what he knows about the fire and await further instructions.

(Signed) J. W. MADELEY,
Special Engineer, Corporation of Madras.

(5) DISTRIBUTION SYSTEM.

Staff as per margin.

3 Foremen.
12 Overseers.
10 Fitters.
20 Asst. Fitters.
20 Turncocks.
100 Lascars.
10 Brick-layers.
10 Brick-layer Coolies.

1. To maintain all water-supply works and fittings including meters, house services, etc., in good working order and cleanliness.

2. To examine all water-works fittings, hydrants, valves on main pipes, air-valves, meters, etc., and see that repairs required in the pipe system stand-pipes, house-services, fountains, etc., are promptly executed, and that all fountains, cattle troughs, standpipes, etc., are kept tidy and lime washed periodically.

3. To supervise personally the construction of all water-supply works carried out by departmental agency or by contractors or licensed plumbers and maintain up-to-date lists and maps of valves, hydrants, street mains, etc.

4. To investigate and report for action all cases of waste and misuse of water, besides themselves taking immediate steps to put a stop to such waste and misuse.

5. To set right all leaky taps, pipes and fittings and renew packing to valves and clean the dirt boxes of meters, test hydrants and keep them in order.

6. To attend to all works such as leaks, bursts, etc., which require immediate attention, and carry out necessary and urgent repairs without delay, and report such action to the Engineer for confirmation.

7. Investigate and report for action all irregularities and unauthorised work in house connections.

8. To investigate and report on all applications submitted by plumbers for house service work, and personally to supervise work on all such estimates as are sanctioned by the President.

9. To take meter readings every month, and repair and maintain all meters in working order.

10. To report all mains that require cleaning, and submit estimates for same and clean such as are ordered to be done.

11. To report on and submit estimates for laying new street mains, and do the laying of such mains as are ordered.

12. To report on and submit estimates for metering places where water is wasted, misused, or used for non-domestic purposes, and fix such meters as are ordered.

13. To distribute water equitably to all consumers, and check waste and misuse by adjusting valves and stopcocks.

14. To attend promptly to fire calls and help the fire brigade by concentrating the supply to affected area.

15. To report any case where the Municipal Act or By-laws and Rules are not complied with.

Note.—Each overseer is provided with a copy of the Water-works Hand Book—(*see* Appendix I,-F, between pages 64 and 65).

(6) WASTE DETECTION.

Staff as per margin.

3 Overseers.
6 Lascars.

It is too small to check the waste and improper use of water in so large a city as Madras.

The overseer shall inspect regularly and carefully every house or compound provided with a water service and shall note in the registers supplied the following particulars regarding each service:—

A.—Street name and Door No.
B.—Size of service pipe.
C.—Number of taps and pumps, W.C.S. baths and other fittings.
D.—Condition of service.
E.—Whether water is used for domestic or non-domestic purposes.
F.—If pressure was found to be excessive whether it was reduced by regulating the stopcocks or valves.

2. Each overseer shall take the division or divisions assigned to him for investigation and shall proceed street by street in order in the division inspecting every house, and noting particulars required carefully and fully. He shall bring to notice for necessary action all cases of waste, misuse or abuse of water.

3. He shall report for action all cases of leaky or defective fittings, taps, etc.

4. He shall, if possible, inspect every house in his range at least once in 6 months. On all inspections, subsequent to the first inspection, he shall compare the condition of every house with his register of last previous inspection, and shall note any fresh defects or irregularities.

5. Whenever he finds the pressure excessive in any street, locality or house he shall report to the Engineer who will decide whether or not to reduce pressure by regulating valves on mains, and stopcocks on house services. All regulations of pressure by means of valves on mains shall be reported separately to the office, in addition to defects and irregularities which shall be submitted to the office once a week with the registers.

APPENDIX II.

Results of Experiments on Working of Madras Filters.

Note.—The filters were worked and the samples taken in accordance with the instructions of the Director of the King Institute who also conducted the bacteriological examinations.

The samples of unfiltered water were taken from the filter inlets except in a few cases in which they were taken from the supply conduit close to the filters.

The samples of filtered water were taken from the filter outlet chambers.

Date of taking samples.	Unfiltered Water.		Filtered Water from Bed No. 13.						Filtered Water from Bed No. 14.					
	Total colonies per c.c. on Agar at 37°C.	Lactose fermenters in how many c.c.	Total colonies per c.c. on Agar at 37°C.	Lactose fermenters in how many c.c.	Percentage of colonies removed by filtration.	Filtering head. ft.	ins.	Rate of filtration in linear inches per hour.	Total colonies per c.c. on Agar at 37°C.	Lactose fermenters in how many c.c.	Percentage of colonies removed by filtration.	Filtering head. ft.	ins.	Rate of filtration in linear inches per hour.
1915 Nov. 8	5,500	0·1	1,300	5	76	Not measured.		5⅝	820	20	85	Not measured.		4
9	Not taken.		260	10	...			5⅝	710	5	...			4
10	"		290	20	...			5⅝	463	10	...			4
11	"		290	20	...			5⅝	210	30	...			4
12	3,400	1	280	5	92			4	110	20	97			4
13	Not taken.		630	20	...			4	540	30	..			4
15	38,200	0·01	450	10	99			4	290	10	99·2			4
16	Not taken.		495	5	...			4	220	5	...			4
17	11,000	1	295	60	97			4	218	10	98			4
19	1,72,000	0·1	390	10	99·8			4	415	5	99·8			4
20	Not taken.		540	30	...			4	720	10	...			4
22	"		840	10	...	1	1¾	4	670	10	...	0	7	4
23	16,650	0·01	1,400	5	91	1	3	4	4,100	5	75	0	8½	4
24	Not taken.		570	10	...	1	4	4	660	5	...	1	1	4
25	27,000	0·01	4,100	5	85	1	4¼	4	1,600	1	94	1	1	4
26	26,800	0·01	1,700	5	93·3	1	5¾	4	1,960	5	93·7	1	4½	4
29	26,850	0·01	6,050	1	77	1	4½	4	3,450	1	87	2	4½	3
30	Countless.	0·01	2,480	5	100	1	5½	4	5,620	1	100	2	1¼	3
Dec. 1	27,500	1	1,550	10	94	1	5¾	4	2,900	5	89	2	4½	3
2	7,200	1	950	60	87	1	6⅜	4	1,100	1	85	2	4	3
3	8,500	1	750	60	91	1	5¼	4	950	5	89	2	⅛	2¾
4	Not taken.		600	10	...	1	8	4	890	5	...	2	¾	2¾

APPENDIX II—(*contd.*). **Results of Experiments on Working of Madras Filters.**—(*contd.*).

Date of taking samples	Unfiltered Water: Total colonies per c.c. on Agar at 37°C.	Unfiltered Water: Lactose fermenters in how many c.c.	Bed No. 13: Total colonies per c.c. on Agar at 37°C.	Bed No. 13: Lactose fermenters in how many c.c.	Bed No. 13: Percentage of colonies removed by filtration.	Bed No. 13: Filtering head ft.	Bed No. 13: Filtering head ins.	Bed No. 13: Rate of filtration in linear inches per hour.	Bed No. 14: Total colonies per c.c. on Agar at 37°C.	Bed No. 14: Lactose fermenters in how many c.c.	Bed No. 14: Percentage of colonies removed by filtration.	Bed No. 14: Filtering head ft.	Bed No. 14: Filtering head ins.	Bed No. 14: Rate of filtration in linear inches per hour.
1915														
Dec. 6	11,000	0·1	360	60	97	1	10	4	650	10	94	2	$2\frac{3}{4}$	$2\frac{3}{4}$
7	3,400	0·1	280	60	93	1	4	4	590	10	83	1	4	$1\frac{3}{4}$
8	1,625	1	200	Not present in 60	88	1	$10\frac{1}{4}$	$3\frac{3}{4}$	345	20	79	2	$2\frac{1}{2}$	2
9	1,800	1	240	50	87	1	$10\frac{3}{4}$	4	560	5	69	2	$6\frac{1}{4}$	2
10	1,720	1	280	50	84	1	$10\frac{1}{2}$	4	430	60	75	2	$2\frac{1}{2}$	$2\frac{5}{16}$
11	1,600	1	320	50	80	1	$11\frac{3}{4}$	$2\frac{5}{8}$	360	Not present in 60	78	2	$2\frac{1}{2}$	$1\frac{3}{4}$
13	2,650	1	220	Not present in 60	92	2	$3\frac{1}{8}$	$2\frac{5}{8}$	310	60	88	1	0	$5\frac{11}{16}$ F. B. No. 1.
14	2,200	1	260	100	88	2	4	$2\frac{5}{8}$	270	60	88	1	1	,,
15	3,400	1	570	5	83	2	5	$2\frac{3}{8}$	230	60	93	1	$1\frac{3}{4}$	,,
16	2,600	1	280	60	89	2	$5\frac{1}{2}$	$2\frac{3}{8}$	210	Not present in 60	92	1	2	,,
18	3,050	1	320	60	90	2	$6\frac{3}{4}$	$2\frac{1}{4}$	250	75	91	1	3	,,
									F. B. No. 14. Restarted after cleaning on 17-12-15.					
20	5,500	0·1	210	60	96	2	5	$1\frac{3}{4}$	4,750	1	14	0	1	$1\frac{3}{8}$
21	3,750	0·1	320	10	91	2	2	$1\frac{3}{8}$	3,100	1	17	0	1	2
22	5,760	1	430	Not present in 60	93	2	$7\frac{1}{4}$	2	2,700	1	53	0	$1\frac{1}{8}$	$2\frac{5}{8}$
23	2,940	1	510	10	82	2	$4\frac{1}{2}$	2	1,950	5	31	0	$1\frac{3}{4}$	$2\frac{5}{8}$
24	4,150	1	305	20	93	2	$8\frac{1}{2}$	$1\frac{3}{4}$	5,300	5	...	0	$1\frac{1}{2}$	$2\frac{5}{8}$
27	1,300	1	3,025	1		2	2	$2\frac{3}{8}$	4,600	1	...	0	$\frac{3}{4}$	$2\frac{5}{8}$
28	5.500	1	1,750	60	68	2	$2\frac{1}{2}$	$1\frac{3}{4}$	2,950	5	46	0	$1\frac{1}{2}$	$2\frac{5}{8}$
29	4,500	1	**Bed stopped for cleaning.**						4,500	10	...	0	$1\frac{1}{2}$	$3\frac{5}{16}$
30	2,300	1							2,180	10	5	0	$1\frac{1}{2}$	4
31	2,100	1							2,400	5	...	0	2	4
1916														
Jan. 3	3,100	1							2,240	5	28	0	2	4
4	2,900	1							1,750	5	39	0	2	4
5	2,480	1							1,540	5	29	0	2	4
6	2,860	1	2,400	1	16	0	$7\frac{1}{2}$	2	1,760	1	38	0	$1\frac{3}{4}$	4
7	1,140	1	1,650	1	...	1	0	$2\frac{5}{8}$	580	10	49	0	3	4
8	1,200	1	810	5	32	1	1	4	550	60	54	0	$2\frac{1}{4}$	4

APPENDIX II—(*contd.*). **Results of Experiments on Working of Madras Filters**—(*contd.*).

Date of taking samples.	Unfiltered Water: Total colonies per c.c. on Agar at 37C.	Unfiltered Water: Lactose fermenters in how many c.c.	Bed No 8: Total colonies per c.c. on Agar at 37°C.	Bed No 8: Lactose fermenters in how many c.c.	Bed No 8: Percentage of colonies removed by filtration.	Bed No 8: Filtering head ft.	Bed No 8: Filtering head ins.	Bed No 8: Rate of filtration in linear inches per hour.	Bed No. 12: Total colonies per c.c. on Agar at 37°C.	Bed No. 12: Lactose fermenters in how many c.c.	Bed No. 12: Percentage of colonies removed by filtration.	Bed No. 12: Filtering head ft.	Bed No. 12: Filtering head ins.	Bed No. 12: Rate of filtration in linear inches per hour.
1916														
Jan. 10	1,150	1	600	5	48	1	$1\frac{1}{2}$	4	560	30	51	0	$1\frac{1}{2}$	4
11	3,500	0·1	1,650	5	53	1	2	4	1,800	0·1	49	0	1	4
12	1,850	0·1	1,120	5	39	1	$4\frac{1}{2}$	4	1,400	30	24	0	$1\frac{1}{2}$	4
13	4,200	0·1	1,310	5	89	1	$4\frac{1}{4}$	4	1,480	60	65	0	$1\frac{3}{4}$	4
14	2,300	1	1,100	5	52	1	5	4	820	60	64	0	$2\frac{1}{2}$	4
15	1,920	1	1,240	1	35	1	$1\frac{3}{4}$	4	718	60	63	0	4	4
17	2,100	0·1	810	10	61	1	$2\frac{1}{2}$	4	980	10	53	0	4	4
18	3,500	0·1	1,300	5	63	1	$2\frac{3}{4}$	4	870	30	75	0	4	4
19	3,400	1	700	5	79	1	6	4	810	60	76	0	3	4
20	5,700	1	1,300	5	77	1	$6\frac{3}{4}$	4	620	10	89	0	4	4
21	3,600	1	1,900	5	47	1	$7\frac{1}{2}$	4	530	60	85	0	6	4
22	3,700	1	1,280	10	65	1	$4\frac{3}{4}$	4	580	30	84	0	$6\frac{1}{2}$	4
23	3,300	1	1,710	1	48	1	6	4	No samples from Bed No. 14 were examined during this period					
24	2,750	1	1,350	1	51	1	$3\frac{1}{2}$	4						
25	2,600	1	820	5	68	1	$2\frac{3}{4}$	4						
26	2,200	1	810	5	63	1	3	4						
27	2,000	1	583	5	71	1	$3\frac{1}{2}$	4						
28	950	1	867	1	8	1	3	4						
29	4,200	0·1	666	1	84	1	$2\frac{3}{4}$	4						
30	1,480	1	528	1	64	1	$2\frac{1}{2}$	4						
31	1,200	1	490	5	59	1	1	4						
Feb. 1	3,150	1	500	5	84	1	$1\frac{1}{2}$	4						
2	1,450	0·1	800	5	31	1	$10\frac{3}{4}$	4						
3	2,400	5	413	10	83	1	$1\frac{3}{4}$	4						

APPENDIX II—(*contd.*). **Results of Experiments on Working of Madras Filters**—(*contd.*).

Date of taking samples.	Unfiltered Water. Total colonies per c.c. on Agar at 37°C.	Unfiltered Water. Lactose fermenters in how many c.c.	Filtered Water from Bed No. 8. Total colonies per c.c. on Agar at 37°C.	Bed No. 8. Lactose fermenters in how many c.c.	Bed No. 8. Percentage of colonies removed by filtration.	Bed No. 8. Filtering head. ft.	Bed No. 8. Filtering head. ins.	Bed No. 8. Rate of filtration in linear inches per hour.	Filtered Water from Bed No. 12. Total colonies per c.c. on Agar at 37°C.	Bed No. 12. Lactose fermenters in how many c.c.	Bed No. 12. Percentage of colonies removed by filtration.	Bed No. 12. Filtering head. ft.	Bed No. 12. Filtering head. ins.	Bed No. 12. Rate of filtration in linear inches per hour.
1916														
Feb. 5	4,150	1	21,800	0·01	...	0	$\frac{1}{8}$	$\frac{1}{2}$	11,300	0·01	...	0	$\frac{1}{4}$	$\frac{1}{2}$
6	Countless	1	5,700	0·01	100	0	$\frac{1}{4}$	1	17,750	0·1	100	0	1	1
7	33,000	1	32,000	0·01	3	0	$\frac{3}{4}$	$1\frac{1}{2}$	32,000	1	3	0	$\frac{3}{4}$	$1\frac{1}{2}$
8	16,000	5	28,000	0·1	...	0	$2\frac{1}{2}$	$1\frac{1}{2}$	9,500	1	40	0	$\frac{1}{2}$	$1\frac{1}{2}$
9	14,500	5	18,750	0·1	...	0	1	2	8,000	1	44	0	$\frac{1}{8}$	2
10	4,000	5	13,750	0·01	...	0	1	$2\frac{1}{2}$	7,500	5	...	0	$\frac{3}{4}$	$2\frac{1}{2}$
11	2,500	5	12,500	0·1	...	0	$1\frac{1}{4}$	3	7,140	5	...	0	$1\frac{1}{4}$	3
12	2,100	5	8,500	1	...	0	$1\frac{1}{4}$	3	6,500	5	...	0	$\frac{5}{8}$	3
13	1,300	5	8,000	1	...	0	$1\frac{1}{2}$	3	3,100	5	...	0	$1\frac{1}{2}$	3
14	1,500	5	7,750	5	...	0	2	3	2,050	5	...	0	1	3
15	2,900	1	2,500	5	18	0	$2\frac{1}{8}$	3	1,750	15	39	0	$1\frac{1}{4}$	3
16	2,500	5	1,950	20	22	0	3	3	3,950	10	...	0	2	3
17	1,550	5	1,750	10	...	0	$3\frac{3}{8}$	4	1,767	30	...	0	$2\frac{3}{4}$	4
18	2,500	5	1,800	15	28	0	$3\frac{1}{4}$	4	1,600	5	36	0	$2\frac{1}{2}$	4
19	1,500	5	500	20	...	0	4	4	1,200	5	20	0	$2\frac{1}{4}$	4
20	975	5	800	30	17	0	$4\frac{1}{2}$	4	900	10	7	0	$2\frac{1}{2}$	4
21	3,200	5	900	30	71	0	$7\frac{1}{4}$	4	675	20	78	0	$2\frac{1}{2}$	4
22	1,200	0·1	400	20	66	0	$8\frac{5}{8}$	4	300	20	75	0	$1\frac{7}{8}$	4
23	2,750	5	275	5	90	0	$9\frac{1}{4}$	4	425	5	84	0	$1\frac{3}{8}$	4
24	1,875	5	255	20	86	0	$9\frac{1}{4}$	4	550	10	70	0	1	4
25	1,725	10	280	Not present in 60.	83	0	$8\frac{3}{4}$	4	610	20	64	0	$1\frac{3}{8}$	4
26	1,900	20	290	Not present in 60.	84	1	$0\frac{1}{4}$	4	425	Not present in 60.	77	0	2	4
27	750	1	210	10	72	1	1	4	500	20	33	0	$2\frac{1}{8}$	4
28	800	5	260	20	67	0	$11\frac{1}{2}$	4	480	15	40	0	$1\frac{3}{4}$	4
29	800	1	310	10	61	0	$11\frac{1}{4}$	4	505	70	36	0	$2\frac{1}{2}$	4
Mar. 1	1,800	5	200	10	88	0	$11\frac{1}{2}$	4	550	30	69	0	$2\frac{3}{4}$	4
2	2,875	0·1	230	30	18	0	$9\frac{3}{4}$	4	480	10	83	0	$2\frac{1}{2}$	4
3	3,150	1	250	15	92	0	$9\frac{1}{2}$	4	360	20	88	0	3	4
4	2,250	5	190	Not present in 60	92	0	8	4	250	60	88	0	3	4

Date of taking samples.	Unfiltered Water. Total colonies per c.c. on Agar at 37°C.	Unfiltered Water. Lactose fermenters in how many c.c.	Filtered Water from Bed No. 8. Total colonies per c.c. on Agar at 37°C.	Bed No. 8. Lactose fermenters in how many c.c.	Bed No. 8. Percentage of colonies removed by filtration.	Bed No. 8. Filtering head. ft.	Bed No. 8. Filtering head. ins.	Bed No. 8. Rate of filtration in linear inches per hour.	Filtered Water from Bed No. 12. Total colonies per c.c. on Agar at 37°C.	Bed No. 12. Lactose fermenters in how many c.c.	Bed No. 12. Percentage of colonies removed by filtration.	Bed No. 12. Filtering head. ft.	Bed No. 12. Filtering head. ins.	Bed No. 12. Rate of filtration in linear inches per hour.
1916														
Mar. 5	1,150	5	175	60	84	0	6	4	295	30	74	0	$3\frac{1}{4}$	4
6	1,300	5	230	30	82	0	$6\frac{1}{4}$	4	225	5	82	0	$4\frac{1}{8}$	4
7	1,250	1	520	1	68	0	$4\frac{3}{4}$	4	320	10	74	0	$4\frac{1}{2}$	4
8	Countless	1	195	10	100	0	$5\frac{7}{8}$	4	190	20	100	0	$6\frac{1}{4}$	4
9	1,400	1	330	1	76	0	$5\frac{1}{8}$	4	400	5	71	0	$7\frac{5}{8}$	4
10	1,800	1	175	10	90	0	$4\frac{1}{8}$	4	150	5	91	0	$10\frac{5}{8}$	4
11	1,300	12	150	Not present in 60	88	0	$4\frac{3}{8}$	4	250	30	80	1	0	4
12	1,300	5	100	60	92	0	$4\frac{1}{4}$	4	130	10	90	1	$2\frac{1}{4}$	4
13	1,100	5	160	5	85	0	$4\frac{1}{4}$	4	165	20	85	1	$3\frac{3}{4}$	4
14	1,875	5	120	5	93	0	$3\frac{3}{4}$	4	180	10	90	1	6	4
15	7,500	5	110	5	98	0	4	4	260	20	98	1	6	4
16	1,500	5	170	Not present in 60	88	0	$4\frac{1}{2}$	4	460	Not present in 60	69	1	5	4
17	4,300	0·1	80	20	96	0	$4\frac{1}{2}$	4	270	20	93	1	$3\frac{1}{4}$	4
18	3,450	0·1	112	20	95	0	$4\frac{1}{2}$	4	230	5	93	1	$4\frac{1}{4}$	4
19	1,700	5	138	30	91	0	$4\frac{1}{2}$	4	310	10	81	1	4	4
20	3,600	5	120	20	96	0	$3\frac{1}{4}$	4	650	10	81	1	3	4
21	1,100	5	250	20	77	0	$5\frac{1}{8}$	4	800	20	27	1	$3\frac{5}{8}$	4
22	2,000	1	390	Not present in 60	80	0	4	4	1,500	10	25	1	2	4
23	1,800	5	170	60	88	0	$4\frac{1}{4}$	4	1,008	20	32	1	$1\frac{1}{8}$	4
24	2,300	1	230	Not present in 60	90	0	4	4	900	20	60	1	$\frac{5}{8}$	4
25	2,100	1	210	Not present in 60	90	0	$4\frac{1}{4}$	4	1,100	30	47	0	11	4
26	2,350	5	200	Not present in 60	91	0	$5\frac{1}{8}$	4	600	10	74	0	$11\frac{1}{2}$	4
27	18,000	1	110	Not present in 60	99	0	4	4	860	30	95	1	$\frac{3}{4}$	4
28	1,800	5	260	Not present in 60	80	0	$6\frac{1}{2}$	4	1 050	15	19	0	$7\frac{1}{2}$	4
29	2,000	10	300	210	85	0	$7\frac{3}{4}$	4	1,300	20	35	0	8	4
30	2,400	5	140	310	94	0	9	4	1,700	20	39	0	$8\frac{1}{2}$	4
31	3,300	1	130	155	96	0	$8\frac{1}{4}$	4	900	20	80	0	3	4
April 1	2,000	5	180	Not present in 310	91	0	$9\frac{3}{4}$	4	1,020	20	49	0	$3\frac{7}{8}$	4
2	1,700	1	200	75	88	0	$10\frac{3}{4}$	4	500	20	70	0	$3\frac{1}{8}$	4
3	3,800	1	190	75	90	0	$9\frac{3}{4}$	4	480	20	87	0	$4\frac{3}{8}$	4
4	2,800	5	100	75	96	0	$11\frac{1}{4}$	4	340	20	87	0	$5\frac{1}{8}$	4
5	1,600	1	175	60	89	0	$10\frac{3}{4}$	4	500	20	68	0	5	4
6	2,350	1	150	60	93	1	$1\frac{5}{8}$	4	450	10	81	0	$4\frac{3}{4}$	4
7	5,300	1	200	60	96	1	$5\frac{1}{4}$	4	480	20	90	0	4	4
8	2,600	1	205	60	92	1	2	4	440	15	83	0	4	4
9	1,900	1	150	60	92	1	$3\frac{3}{8}$	4	450	30	76	0	$3\frac{1}{2}$	4
10	2,300	1	120	60	94	1	$5\frac{1}{2}$	4	500	60	78	0	$4\frac{1}{8}$	4
11	3,700	5	180	Not present in 60	95	1	4	4	530	60	85	0	$6\frac{1}{2}$	4
12	2,650	1	230	60	91	1	$3\frac{1}{4}$	4	550	60	79	0	$3\frac{1}{2}$	4
13	2,100	1	200	60	90	1	4	4	710	30	66	0	3	4
14	2,700	1	220	30	92	1	5	4	350	5	87	0	4	4
15	3,300	1	310	20	91	1	6	4	450	5	86	0	$4\frac{1}{4}$	4

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APPENDIX II—*(contd.).*

Results of Experiments on Working of Madras Filters—*(contd.).*

Date of taking samples	Unfiltered Water. Total colonies per c.c. on Agar at 37°C.	Unfiltered Water. Lactose fermenters in how many c.c.	Filtered Water from Bed No. 8. Total colonies per c.c. on Agar at 37°C.	Bed No. 8. Lactose fermenters in how many c.c.	Bed No. 8. Percentage of colonies removed by filtration.	Bed No. 8. Filtering head. ft.	Bed No. 8. Filtering head. ins.	Bed No. 8. Rate of filtration in linear inches per hour.	Filtered Water from Bed No. 12. Total colonies per c.c. on Agar at 37°C.	Bed No. 12. Lactose fermenters in how many c.c.	Bed No. 12. Percentage of colonies removed by filtration.	Bed No. 12. Filtering head. ft.	Bed No. 12. Filtering head. ins.	Bed No. 12. Rate of filtration in linear inches per hour.
1916														
April 16	2,900	1	470	10	84	1	5	4	590	5	80	0	3	4
17	2,950	5	170	60	94	1	8½	4	260	30	91	0	4½	4
18	2,800	1	185	30	93	1	9¼	4	500	10	82	0	6½	4
19	2,250	1	300	60	87	1	8¼	4	750	60	66	0	5⅓	4
20	5,100	5	200	60	96	1	8¾	4	175	60	96	0	5¾	4
21	2,000	5	160	Not present in 60	92	1	10¾	4	185	10	91	0	7	4
22	4,300	1	140	Not present in 60	97	1	9½	4	240	Not present in 60	94	0	6½	4
23	5,400	1	120	60	98	1	11	4	270	30	95	0	7	4
24	2,700	1	70	60	97	1	11½	4	240	60	91	0	3½	4
25	6,700	0·1	75	30	99	2	¾	4	205	60	97	0	6	4
26	3,500	1	75	60	98	2	0	3·77	150	10	66	0	6½	4
27	1,850	1	110	Not present in 60	94	2	½	3·31	250	20	86	0	6½	4
28	...	...	...	...	...	2	1	3·31	...	...	...	0	8¼	4
29	...	...	...	...	...	2	2	3·77	...	...	...	0	4¾	4
30	...	...	...	...	...	2	6	3·77	...	...	...	0	6½	4
May 1	2,000	1	410	5	80	2	¼	3·31	200	5	90	0	7½	4
2	4,300	1	540	5	87	2	0	2·79	300	10	93	0	9	4
3	3,700	1	600	5	84	1	11¼	2·00	240	10	94	0	11¾	4
4	3,650	1	585	Not present in 60	84	2	0	2·32	284	20	92	1	0	4
5	2,700	1	430	20	84	2	¾	2·00	500	5	81	0	8	4
6	2,400	5	600	60	75	1	11	2·79	650	30	73	0	8	4
7	3,100	5	240	Not present in 60	92	2	½	2·00	600	30	84	1	2	4
8	2,100	1	350	60	83	2	0	2·00	525	30	75	1	3	4
9	5,300	1	530	60	90	2	0	2·00	200	30	96	1	3½	4
10	3,700	5	335	20	91	2	0	1·63	350	20	91	1	4½	4
11	2,000	5	250	5	88		...	...	150	Not present in 60	93	1	6	4
12	6,800	1	345	5	95		...	...	330	60	95	1	7	4
13	1,800	5	Stopped.		...		...	...	450	60	75	1	7¾	4
14	2,550	10	...	...	...		...	...	340	Not present in 60	87	1	10¼	4
May 15	1,200	5	...	...	...		...	...	215	1	88	2	2½	4
16	2,100	1	...	...	...		...	...	275	Not present in 60	87	2	3½	4
17	1,600	5	...	...	...		...	...	185	60	88	2	2½	3¼
18	2,200	1	...	...	...		...	...	290	30	87		...	...
			Bed stopped by instructions of Director for cleaning and inserting screens.											
June 30	35,000	0·1	Countless.	0·1	...		¼	½	19,750	1	...		¼	½
July 1	5,500	1	15,700	0·1	...		½	1	6,750	1	...		¼	1
2	9,000	1	65,000	1	...		1¼	1½	45,000	1	...		½	1·30
3	6,160	0·1	29,000	1	...		1⅕	2	27,500	5	...		½	2
4	5,300	0·01	34,000	1	...		1	2½	11,650	1	...		1	2½
5	4,500	0·1	22,500	5	...		1	3	7,200	5	...		1¼	3
6	3,400	0·1	5,500	1	...		¾	3	3,800	5	...		1¼	3
7	2,500	0·1	5,250	5	...		1½	3½	3,500	10	...		1½	3½
8	11,200	0·01	5,500	5	61		2¾	3⅓	8,400	1	28		2	3½
9	5,500	0·1	2,650	5	62		3	3½	2,350	5	57		4	3½
10	3,800	0·1	3,500	20	8		4	4	4,050	5	...		4	4
11	1,200	0·1	4,200	1	...		4	4	4,200	1	...		4½	4
12	1,600	1	1,100	80	31		5¼	4	1,130	Not present in 60.	29		4	4
13	6,000	0·1	950	5	81		6½	4	2,300	5	54		6	4
14	2,700	1	700	10	29		7	4	1,500	20	44		6	4
15	28,000	0·1	525	10	98		9	4	1,200	60	96		7	4
16	3,200	1	900	15	72		8	4	2,500	10	22		7	4
17	2,400	1	775	Not present in 60.	68		10¼	4	1,650	Not present in 60.	31		8¾	4
18	2,100	1	950	Not present in 60.	55		9¾	4	1,275	Not present in 60.	39		11	4
19	7,600	1	425	Not present in 60.	94		8	4	825	Not present in 60.	89		11	4
20	2,800	5	725	Not present in 60.	74		7	4	925	60	67		11	4
21	7,500	0·1	475	Not present in 60.	94		8	4	775	Not present in 60.	90	1	0	4
22	2,000	1	600	Not present in 60.	70		6	4	700	Not present in 60.	66	1	½	4
23	5,400	1	650	10	88		6	4	600	Not present in 60.	89	1	1	4
24	1,500	1	375	60	75		5	4	850	30	43	1	1½	4
25	No samples analysed as per Director's orders.					0	7½	4	...	...	...	1	1½	4
26	2,700	0·1	375	Not present in 60.	86	0	7	4	700	60	74	1	2	4
27	2,100	1	465	Not present in 60.	78	0	8	4	940	10	55	1	1	4
28	2,300	1	375	10	84	0	8	4	985	30	57	1	1	4
29	1,600	1	730	60	56	0	6½	4	1,000*	30	39	1	3	4
30	5,300	1	440	60	91	0	7	4	520	Not present in 60	90	1	3	4
31	4,700	1	480	60	69	0	6¼	4	515	60	89	1	5	4
Aug. 1	No samples analysed as per Senior Assistant's order.					0	6½	4	...	...	...	1	7	4
2	No samples analysed as per Senior Assistant's order.					0	8	4	...	...	...	1	8	4
3	No samples analysed as per Senior Assistant's order.					0	10	4	...	...	...	1	11	4

Date of taking samples.	Unfiltered Water. Total colonies per c.c. on Agar at 37°C.	Unfiltered Water. Lactose fermenters in how many c.c.	Filtered Water from Bed No. 8. Total colonies per c.c. on Agar at 37°C.	Bed No. 8. Lactose fermenters in how many c.c.	Bed No. 8. Percentage of colonies removed by filtration.	Bed No. 8. Filtering head. ft.	Bed No. 8. Filtering head. ins.	Bed No. 8. Rate of filtration in linear inches per hour.	Filtered Water from Bed No. 12. Total colonies per c.c. on Agar at 37°C.	Bed No. 12. Lactose fermenters in how many c.c.	Bed No. 12. Percentage of colonies removed by filtration.	Bed No. 12. Filtering head. ft.	Bed No. 12. Filtering head. ins.	Bed No. 12. Rate of filtration in linear inches per hour.
1916														
Aug. 4	1,500	1	265	30	82	1	0	4	775	60	48	2	0	4
5	3,500	1	270	30	92	0	11	4	275	60	92	2	2	4
6	2,000	1	300	60	85	1	½	4	630	60	68	1	9	4
7	2,700	1	380	60	86	1	1	4	430	60	84	2	0	4
8	1,400	1	295	30	79	1	1	4	490	30	65	2	0	4
9	2,250	1	250	30	89	1	2	4	700	30	69	1	11	4
10			No samples.			1	2	4	...	...	...	2	0	4
11						1	1½	4	...	...	...	1	9	4
12	3,000	1	330	30	89	1	2	4	875	10	71	1	8	4
13	1,400	1	540	10	61	1	1	4	400	60	71	1	9	4
14	950	5	265	20	72	1	3	4	320	Not present in 60	66	1	7	4
15	1,300	1	200	30	85	1	2	4	485		68	1	7	4
16	2,300	5	180	30	92	1	3	4	565		75	1	8	4
17			No samples.			1	5	4	...		...	1	5	4
18	1,800	5	320	60	82	1	6	4	460		74	1	3	4
19	1,400	1	380	Not present in 60	72	1	6	4	315		75	1	4	4
20	1,750	5	360	60	79	1	8	4	690		61	1	5½	4
21	12,500	5	295	60	98	1	9	4	700		94	1	6	4
22	1,600	1	230	12	86	2	0	4	690	20	57	1	6	4
23	2,000	1	405	5	80	2	2	3·71	760	10	62	1	7	4
24	2,300	1	194	60	92	2	1	3·71	725	30	68	1	11	4
25	2,400	0·1	200	60	92	2	¼	3·71	670	30	72	1	11	4
			closed.											
26	1,700	5	320	30	81	2	0	3·71	875	30	49	1	10	4
27	2,100	1	310	Not present in 60	85	2	1	3·71	895	60	57	1	9	4
28	2,700	1	315	20	88	2	0	3·00	750	30	72	1	4	4
29	1,250	1	205	30	84	1	11½	2·75	695	30	44	1	2	4
30	2,300	1	365	20	84	2	0	2·75	875	30	62	1	2	4
31	2,750	1	700	5	76	2	0	2·75	600	15	78	1	1	4

Date of taking samples.	Unfiltered Water. Total colonies	Unfiltered Water. Lactose fermenters	Bed No. 8. Total colonies	Bed No. 8. Lactose fermenters	Bed No. 8. Percentage removed	Bed No. 8. ft.	Bed No. 8. ins.	Bed No. 8. Rate	Bed No. 12. Total colonies	Bed No. 12. Lactose fermenters	Bed No. 12. Percentage removed	Bed No. 12. ft.	Bed No. 12. ins.	Bed No. 12. Rate
1916														
Sept. 1	3,800	1	500	15	87	2	0	2·75	850	5	76	1	1	3·71
2	1,000	1	Stopped.						985	10	2	1	1	4
3	3,800	1							1,015	1	69	1	0	4
4	1,875	1							760	20	60	1	0	4
5	1,600	1							875	5	45	1	0	4
											Stopped.			
			Re-started on 19th September 1916.											
19	Spreading colonies.	0·1	Spreading colonies.	1	...		½	½	Spreading colonies.	1	...		½	½
20		1		5	...		¼	1		1	...		½	1
21	6,850	0·1	10,500	1	...		¼	1½	11,000	1	...		¼	1½
22	5,000	1	7,100	5	...		1	2	14,500	5	...		½	2
23	4,500	1	5,300	5	...		1½	2½	10,500	5	...		½	2¼
24	3,100	1	3,000	5	3		1¼	3	4,500	5	...		2	3
25	2,500	5	1,300	5	48		2	3	3,050	10	...		2	3
26	5,500	5	1,700	60	69		2¼	3½	4,300	30	22		2	3½
27	2,800	1	2,000	60	29		3¼	3½	2,500	30	11		2¼	3¼
28	2,600	0·1	1,300	30	50		...	4	1,900	None in 60	27		...	4
29	2,750	1	1,000	60	64		...	4	2,000	60	27		...	4

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APPENDIX IV.

Rules regarding House-service Connections.

1. With reference to Sections 193 and 194 of the Municipal Act III of 1904, in connection with a supply of water to houses for domestic and other purposes, the work within private lands or buildings shall be done by plumbers who have been found duly qualified, and who will be licensed annually after signing an agreement, and paying a fee of Rs. 10 within the first month of each official year.

2. Each licensed plumber before the issue of the license shall be required to deposit with the Municipality, the sum of Rs. 200 as a security for the due and proper fulfilment of a plumber's duties.

3. No person other than these plumbers will be allowed to execute any work in connection with water-supply to houses, etc.

4. If one or more plumbers form themselves into a company, any penalty exacted under these rules shall affect all plumbers belonging to such company.

5. A list of licensed plumbers shall be kept in the Municipal office and at the office of the Assistant Engineers.

6. These plumbers will be empowered to carry out all private service pipe work, including new service pipes, extensions, alterations and repairs subject to the following rules, and to any reasonable orders given by the officers of the Works Department from time to time.

7. When a new service pipe is required, the plumber selected by the applicant will present at the office of the Assistant Engineer, a form of agreement signed by the owner and occupier of the premises requiring the connection, and with such agreements an estimate in W.D. Form No. 48 in duplicate of the work to be done.

8. In such estimate shall be included the cost of the work on the roadways and streets, etc., between the Commissioners' main and the premises, including the tapping of the main, excavation in roadway, etc.; for such work, rates will be furnished by the Commissioners, and this work will be done by the Municipal officers.

9. When the estimate has been sanctioned, the plumber, after receiving advice of the same, shall pay into the Revenue Department of the Commissioners the cost of the work referred to in the last paragraph *plus* an amount equal to ten per cent. (or such other percentages as may be fixed from time to time by the President) on the amount of the estimate, which percentage shall form portion of his estimate.

10. The plumber shall deposit all the material necessary for the work; after receipt of notice in W.D. Form No. 49 of such deposit the Corporation will within 24 hours inspect the material and if the material is of the proper kind, the connection will be promptly proceeded with. After the Corporation have laid the necessary connection an advice will be sent to the plumber that his work may be proceeded with.

11. Extensions, alterations and repairs shall be executed under similar procedure in regard to the submission of estimate, payment of fees and execution of work. No new work, extension, alteration or repair shall be done, except after the completion of the procedure required by the foregoing rules.

12. All plumbers shall keep a book to be provided by the Corporation in which shall be entered all details of works of every description whatsoever done by them, in connection with any private service pipe. Such book shall be the property of the Corporation and shall be sent to the Corporation on the 15th of each month.

13. All repairs required under the Municipal Act by the President or authorized officers shall be done by such plumber as may be selected, the cost of such repairs will be recovered for the plumbers under the powers vested in the President by Act III of 1904.

APPENDIX IV.—(*contd.*).

Rules regarding House-service Connections.—(*contd.*).

14. All materials used, or to be used and all work done shall be subject to the supervision, approval or rejection by the duly authorized officers of the Works Department of the Corporation.

15. All cocks, taps and pipes shall be of a pattern or patterns which shall be kept at the overseers' offices and at the Corporation office.

16. No cock, tap, valve, sluice or other such fitting shall be used hereafter until approved of and stamped at the Corporation Workshop with the Corporation stamp for which a fee of As. 2 per article will be charged. This shall be arranged for by the Works Department, *vide* W.D. Form No. 50.

17. Whenever a plumber requires water to be shut off from, or let on to any premises, he shall apply in W.D. Form No. 51 or 52 to the Divisional overseer. No plumber shall interfere with any street stopcock or stop valve, all such stopcocks or stop valves being entirely under the control of the Commissioners.

18. The President may at any time fine, suspend or cancel with forfeiture of security, the license granted to any plumber found guilty of breaking or evading any by-law or other regulation of the Commissioners, or any of the foregoing rules, or who shall be guilty of any breach of the Municipal Act, or who fails to comply with any reasonable order given him by a duly authorized officer of the Works Department or whose work in the opinion of the President is not satisfactory.

19. Any plumber, whose license has been suspended or cancelled, shall return his license to the President within 24 hours after such suspension or cancelment.

20. Any person who, without a license from the President or any plumber who, during suspension or after cancelment of his license, interferes with any work in connection with the water-supply will be prosecuted under Sections 206 and 207 of Act III of 1904.

Applications for house connections.—All estimates for laying house connections shall be prepared in W.D. Form No. 48 by a plumber and submitted to the Engineer. They are scrutinized in the office and the Engineer sanctions all connections of one tap and if the work is for more than one tap or for fixing of pumps, the sanction of the President is obtained. After sanction the plumber shall be advised to pay into the Revenue Department all supervision and departmental charges and after payment the estimates are registered in a register (W.D. Form No. 53) with date of payment of the Municipal portion of the charges and forwarded to the plumber for carrying out the work who will do the work in accordance with the rules quoted in the above paragraph.