No. CXXXIX.

DRAINAGE OF MADRAS.
(2nd Paper.)

Abridged from a Report on a Project for the Drainage of the Town of Madras. By Capt. Hector Tullock, R.E.

Description of the Project.—It is proposed to drain Madras from the south to the north—to separate the sewage from the rain-water—to carry the former by sewers of small capacity to one central spot, north of, but near, the Madras Railway, and in the neighbourhood of the village of Coorookoopett—to lift it there by steam pumps—and, according as Government may decide, either to discharge it by an outfall sewer into the sea at a point two miles north of the Railway, or to utilize it on some thousands of acres of waste land lying to the north-west of Madras.

In order to render the description of the Project clear, I shall, for the present, defer the consideration of the proposition to utilize the sewage for agricultural purposes, and treat the subject of drainage as if it were necessary to take the sewage away from Madras altogether.

The first point to settle in every project for drainage is the locality of the ultimate outfall for the sewage. Everything hinges on this. At present the sewage of the town, as before mentioned, is discharged partly into the Cooum, partly into the canal, and partly into the sea; and these are all the outfalls available for Madras.

It is unnecessary for me to dwell on the present disgusting state of the Cooum or on that of the canal. To say that they are mere cesspools, from which the sewage cannot possibly escape, is to bring the subject
with sufficient clearness even to the minds of those who have never visited Madras. It should be an indispensable condition of every project for draining the town, that the Coochum and the canal should not be converted into sewage reservoirs. Until this is acted upon, all attempts to render Madras healthy must necessarily be only partially successful.

The only outfall, then, left for consideration, is the sea. The abominable stench from the mouth of the sewer at the north-east angle of the Fort, which drains a portion of Black Town only, is convincing evidence that it is not sufficient merely to discharge the sewage into the sea. No description can convey to the minds of those who have never lived within the influence of the smell from this sewer, its overpowering offensiveness while the outlet is open. The Fort would hardly be habitable from October to February, or while the north-east winds prevail, if this outlet were kept open during the whole day. Fortunately, the sewer is large enough to hold all the sewage which flows into it, for a day or two, so that it is unnecessary to open the mouth except for about a couple of hours during the night. This is done, too, at a time when the wind is blowing from the west, in order that the smell may be driven out to sea.

In some instances in England, no nuisance arises from the outfalls of sewers being placed on the coast and opposite to towns. But this is due to causes which do not prevail in Madras. In England, the tides rise and fall considerably. In London, the difference between low and high tide is 20 feet—in Liverpool, it is 32 feet—in the Bristol Channel, as much as 47 feet. The velocity of the ebb stream, or that which conveys the sewage away from the coast is, under these circumstances, very great. But in Madras, the tides rise and fall three feet only, and the water is exceedingly shallow. The consequence is, that the velocity of the ebb stream is trifling, and the sewage keeps floating by the coast instead of being carried out to sea at once. The prevailing currents, too, for 10 months in the year, follow the line of the coast, i.e., run north and south. Sewage, therefore, discharged opposite the Fort, flows directly in front of Black Town or Triplicane, the two most important, because the most densely populated, neighbourhoods of Madras.

The nuisance at present from the drain near the Fort is as nothing compared with the nuisance which would ensue, if the main outfall for the drainage of the entire town were situated in the same locality. Under the present imperfect arrangements for drainage, the quantity of sewage which
ultimately reaches the sea is small, and it is sufficient if the mouth of the main discharging sewer is opened occasionally. But under a complete system of water-tight sewers, and street and house pipe-drains, the quantity of sewage would be considerable, and it would be impossible to pond it up for many hours together without incurring great expense. The line of coast, too, for a quarter of a mile or so on either side of the outfall, would be so covered with filth of every description, that the sea breeze, instead of being, what it now is, a great source of health to the inhabitants of Madras, would be deprived of all those pleasant associations which we at present connect with it. No outfall so situated as to contaminate our sea breeze should be permitted.

If this is granted, it follows that no sewage should be discharged on the sea-board of Madras Proper, i.e., within the limits of the inhabited strip of coast land from Royapoooram in the north to St. Thomè in the south. The question, therefore, so far as the outfall only is concerned, resolves itself now into this, "Shall the sewage be carried into the sea north, or south, of Madras?"

In order to decide this satisfactorily, several points should be considered. "Is the town, with regard to its physical features, more favorably situated for a southern or for a northern outfall?" "What is the direction of the prevailing winds?" "What that of the prevailing sea current?" "What particular advantages does a northern or a southern outfall offer in itself?"

The most important of these considerations is, without doubt, that which relates to the general configuration of the ground on which the town stands. Now, it has already been explained that, practically, there is no natural line of drainage for Madras, considered as a whole. But if this point admits of dispute, then the only line of drainage, which it is possible to call such, is the valley along which the canal runs. And, certainly, although the greater part of Black Town and all Royapoooram drain into the sea, yet the portion of Madras lying to the north of the Cooum, may, in some respects, be considered as two slopes of ground inclining towards the Canal. The fact, too, of the districts south of the Cooum being generally on a higher level than the valley itself, may strengthen this view—viz., that there is a natural drainage line. But this very fact shows that the southern portion of Madras, if it is the higher, must be drained towards the north, i.e., if the valley of the canal is taken as the drainage course.
And the northern portion cannot be drained to the south, because, in that case, the outfall into the sea must be situated somewhere between Triplicane and Black Town, which, it has already been shown, would be highly objectionable, because the sea breeze would be contaminated. The only course left to adopt them, is, to drain the whole of Madras to the north. And this is exactly what is proposed to be done. So far then as the question is affected by considerations of the natural position of the town, the advantage of the northern outfall is clear and decided.

Now, with respect to the winds, the situation of the two outfalls is about equally favorable. The prevailing winds* are those which blow between south and west, and these winds in either case would convey the smell of the sewage out to sea. The winds which would bring the smell into Madras, are, in the case of a northern outfall, those between N. N. E. and E. N. E., and, in the case of a southern outfall, those between S. and S. E. Both the former and the latter blow for about 80 days in the year.

With reference to the sea currents, the advantage lies decidedly with the northern outfall. The current which flows from the north southwards begins about the middle of October and ends in February, or runs for about 4 1/2 months in the year. This current would, in the case of a northern outfall, bring the sewage in the direction of Madras, and, in the case of a southern outfall, would carry it away from Madras. The current which flows from the south northwards begins in March and ceases in August, or continues to flow for about six months. During the remainder of the year, i. e., in September and the first half of October, the prevailing winds are from the south, and if, as is most probable, the currents run in the direction of the wind, this second current will have a northerly direction. Thus, for about 7 1/2 months, the northward current would, in the case of a northern outfall, carry the sewage away from Madras, while, in the case of a southern outfall, it would bring it to Madras. There is no doubt, therefore, that, so far as the currents of the sea are concerned, the outfall should be placed to the north of Madras.

The special advantages which the northern outfall offers are very great. There are no Engineering difficulties to be overcome in the construction of the works, or to render them expensive. If the sewage were taken to the

* Vide "Chart showing the number of days in the year the wind blows in Madras from each point of the compass," which is given further on.
south, the outfall should be placed at least one mile south of St. Thomè, in order to prevent any nuisance to the inhabitants of this locality. This would make it necessary to carry the sewage either by a tunnel beneath the river Adyar, or by an aqueduct over it. Either of these works would cost a large sum of money. In the south, the sewage could not be utilized for agricultural purposes so judiciously as in the north, for the prevailing winds would blow the smell to the town. The lands, moreover, are not well situated, whereas, in the north, there are upwards of 20,000 acres of waste ground situated on the most favorable level possible, and in the direction from which the wind blows least often during the year. All these considerations render it advisable to adopt a northern outfall for the drainage of Madras.

Having settled this point, it next becomes necessary to decide how far north the sewage should be discharged. And this admits of some difference of opinion. The arrangements made in this Project are to place the outfall, for the present, at a point two miles north of the Railway Station. This is 1½ miles from the nearest dwellings in Royapooram. I believe no nuisance will arise from this arrangement. When the northerly current is running, the sewage will have flowed a distance of more than two miles before it comes opposite to the nearest part of Black Town. Should it, however, be found hereafter that the outfall is not far enough away to the north, I have arranged so that it may ultimately be removed to a point three miles north of the Railway. Without positive evidence that the outfall at this distance would prove a nuisance, it would not be desirable to place it higher up on the coast. The question is one of expense only, for, so far as the Engineering difficulties are concerned, it would be as easy to carry the sewage four miles to the north as to discharge it where it is now proposed to place the outfall.

Having now arranged about the direction in which Madras is to be drained and the distance from the town at which the outfall should be situated, the next question requiring an answer is, "Can the sewage be discharged into the sea simply by gravitation, i.e., without lifting it at any intermediate point between the town and the outfall?" An examination of the Map of Madras,* which accompanies this paper, should convince any one that this is impossible. The present system of open drains is a practical attempt to answer this question in the affirmative. But what

* Given above p. 2.
the effect is, is known well. Hardly a single drain has sufficient fall to keep itself free from deposit, and the consequence is, that the work which the drains should do, has to be done by the scavengers of the Municipal Department, and at a tremendous cost to the people. It is, indeed, impossible to drain a place like Madras, which covers 27 square miles of country, and many parts of which, in all quarters of the town, are elevated from 3 to 6 feet only above the sea, by simple gravitation, and without raising the sewage artificially.

If this, then, be admitted, the next point to settle is, "Where shall the sewage be pumped up?" This is almost altogether a question of Engineering. If the ground were very favorable, i. e., if the soil were hard and there were no water to interfere with the construction of the sewers, it might be best to take the sewage right away to a spot near its ultimate outfall on the coast, and to pump it up there at once into the sea. But this is not the case. The strata beneath the surface soil consist chiefly of sand, and water is found in almost all parts of Madras at about the sea level. It becomes, therefore, positively necessary to raise the sewage at some intermediate point. I have selected a point very near the Madras Railway, but lying to the north of it and in the neighbourhood of the village of Coo-rookoopett. This will necessitate the construction of a tunnel under the Railway. But a tunnel would have been necessary, even if the site for the pumps had been to the south of the Railway; for the sewage of Tondiarpatt and of the neighbourhood to the north of the Railway must, in that case, have been brought to the site by a tunnel crossing the Railway. It will thus be seen that, under any circumstances, a tunnel was unavoidable. The site selected for the cesspool and pumps is situated in that quarter of the town from which the wind blows least often in the year, and it is near the lands on which it is proposed to utilize the sewage.

I have considered whether it might not be advisable to have two cesspools and two sets of pumps—one for the portion of Madras lying to the north of the Railway, and the other for that lying to the south of it. But the first cost of such an arrangement would be even greater than that of the tunnel now proposed, and the working expenses of such a system of sewerage would be nearly double that in which all the pumping work was concentrated at one point.

I trust that it has now been satisfactorily shown that Madras should be drained towards the north,—that (putting aside for the present the ques-
tion of utilizing the sewage) the best outfall is the sea,—that it will be sufficient if the outfall is placed on the coast three miles north of the Railway,—that it is not possible to drain the town by gravitation,—and that, consequently, the sewage must be pumped up at some intermediate point between the town and the ultimate outfall.

Separation of Sewage from Rain Water.—So far, this Project does not differ from the system of drainage adopted in many towns in England. I beg now to draw the attention of Government to a point which appears to me to demand the greatest consideration. In England, it is usual to have one and the same system of sewers to carry off both rain-water and sewage. I propose, however, that in Madras, sewage shall be carried away by a system of underground sewers and pipes of very small dimensions, and that rain water shall be removed by a system of open surface drains unconnected with the underground sewers and pipes. To justify such a departure from the stereotyped system of sewerage which has the sanction of European Engineers, it will be necessary that full and sufficient reasons should be given.

In designing sewerage works, the dimensions of the sewers are regulated almost entirely on considerations of rain-fall. The sewage proper forms so small a proportion of the total amount of fluid matter to be removed, that if a sewer is large enough to discharge the rain which falls on the district for the drainage of which it is constructed, it is hardly worth while to consider the small quantity of sewage which may flow into the sewer. In fact, sewers in England are constructed, first, for the removal of the rain-fall, and then for the removal of the sewage.* In a country, however, like England, where the rain-fall is pretty evenly distributed through all the months of the year, and where there are no extraordinary falls of rain such as we so often have in India, this principle of carrying off both rain water and sewage by one set of channels is not perhaps objectionable. It rains off and on throughout the year. Sometimes for days together there is no cessation at all. The consequence is, that the amount of water in the sewers does approximate to some extent to a constant quantity. In heavy rain-falls the amount is somewhat in excess of this quantity, and in light rainy weather it is somewhat below it.

But in India the conditions of rain-fall are totally different to those in

* In London the sewage proper is calculated at about 4th of the ordinary rain-fall.—*Page 305 of "Neville's Hydraulics."
Monthly Rainfall in England and Madras
England. In the first place the yearly rain-fall in India is double that of England. And while in England the supply is received in small monthly instalments all the year round, the supply in India is often received in 10 or 12 days only.

The accompanying diagram has been prepared with the view to explain the extraordinary difference between the rain-fall in England and in Madras. The first fact to which I beg to direct attention is the marked evenness of the line which represents the "mean" rain-fall in England. The greatest difference in the quantities of rain which fall in any two months is between those which fall in April (about 1\(\frac{1}{2}\) inches) and in November (about 3\(\frac{3}{4}\) inches). But even this difference amounts to only 2\(\frac{1}{2}\) inches. So evenly distributed is the rain-fall, that if it were said of England that the quantity of rain which falls in every month of the year is 2 inches, there would really be no great error made.

The second fact to which I would draw attention is the parallelism between the thick and thin red lines. The former shows the maximum quantity of rain that has been known to fall in England in each month of the year. It runs throughout about 2 inches above the thin line and thus indicates that the maximum quantity of rain in each month is 2 inches only more than the mean quantity.

Now, let me turn to the rain-fall in Madras, the yearly quantity (about 50 inches) being double that of London (about 25 inches). The thin blue line represents the mean rain-fall of 20 years' observations. It will be seen that in the first four months of the year there is, practically speaking, no rain at all—that in the next 5 months the rain-fall is only slightly in excess of that of England—but that in the months of October, November and December, it is considerably in excess of it. Now, if sewers are to be constructed for the removal of rain water, it is very evident that in Madras they must be large enough to discharge the rain-fall in the months of October and November, when the heaviest quantity of rain descends. Suppose that the dimensions of the sewers in Madras are regulated by comparison of the mean monthly rain-falls in London and Madras. Then, the mean rain-fall in Madras in October (about 18 inches) being more than three times the mean rain-fall in London in November (about 4 inches), it is evident that the sewers must have three times the discharging capacity. A single
mile of sewers laid down on this principle would cost more than the entire project now submitted to Government.

The difference between the maximum monthly rain-falls in Madras and in England, is even still greater than that between the mean monthly rain-falls in the two places. The maximum quantity which has fallen in one month in England is, as shown by the thick red line, nearly 6 inches. But the maximum in Madras is, as shown by the green line, nearly 38 inches, or upwards of six times the maximum of England.

Together with the mean and maximum monthly rain-falls in the two countries, I have projected on the accompanying diagram the monthly rain-falls in Madras of some of the most interesting years. From these it will be seen that it is far from an unusual occurrence to have upwards of 20 inches of rain in a single month of the year.

If we compare the daily rain-fall in England and in Madras, the difference becomes still more striking. The following are the greatest daily rain-falls in England of which I can find any record:

<table>
<thead>
<tr>
<th>Locality</th>
<th>Date</th>
<th>Rain-fall in 24 hours</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little Bridy,</td>
<td>July, 1858</td>
<td>2.06 Inches</td>
<td>Vide page 382 of &quot;Beardmore's Manual of Hydrology.&quot;</td>
</tr>
<tr>
<td>Dorsetshire,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxford,</td>
<td>July, 1858</td>
<td>1.82</td>
<td>Vide page 383, Ibid.</td>
</tr>
<tr>
<td>Wandsworth,</td>
<td>12th June, 1859</td>
<td>2.17</td>
<td>Vide page 393 of &quot;Neville's Hydraulics.&quot; This fell in two hours.</td>
</tr>
<tr>
<td>Manchester,</td>
<td>7th Aug., 1859</td>
<td>1.849</td>
<td>Do. do.</td>
</tr>
<tr>
<td>Southampton,</td>
<td>26th Sept., 1859</td>
<td>2.05</td>
<td>Do. do. This fell in 2½ hours.</td>
</tr>
<tr>
<td>Truro,</td>
<td>25th Oct., 1859</td>
<td>2.4</td>
<td>Do. do.</td>
</tr>
<tr>
<td>Holborn,</td>
<td>1st Aug., 1846</td>
<td>4.00</td>
<td>Do. do. These quantities are stated to have fallen in one hour.</td>
</tr>
<tr>
<td>Highgate,</td>
<td>Do.</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Greenwich,</td>
<td>Do.</td>
<td>-95</td>
<td></td>
</tr>
</tbody>
</table>

The following is a table of some of the heavy daily rain-falls in Madras in the years from 1832 to 1857:
<table>
<thead>
<tr>
<th>Date</th>
<th>Rain-fall in 24 hours</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th November, 1822</td>
<td>7.88</td>
<td></td>
</tr>
<tr>
<td>29th October, 1825</td>
<td>8.87</td>
<td></td>
</tr>
<tr>
<td>9th May, 1837</td>
<td>12.06</td>
<td></td>
</tr>
<tr>
<td>27th November,</td>
<td>7.77</td>
<td></td>
</tr>
<tr>
<td>31st October, 1836</td>
<td>7.90</td>
<td>This fall in the night only.</td>
</tr>
<tr>
<td>20th November,</td>
<td>9.65</td>
<td>* It appears to have commenced raining on the 18th October. Up to 9 A.M. on the 20th, however, only 14 inches fell. It then progressed very steadily for about 20 hours, till the maximum rate of 24 inches per hour was attained; after which it gradually decreased again till the expiration of about another 12 hours when the monsoon was over. In this storm, Madras received, in 24 hours, i.e., from 10 A.M. on the 20th to 10 A.M. on the 21st, about as much rain as falls in London during the whole year.</td>
</tr>
<tr>
<td>27th December, 1845</td>
<td>7.20</td>
<td></td>
</tr>
<tr>
<td>21st October, 1846</td>
<td>20.58</td>
<td></td>
</tr>
<tr>
<td>4th May, 1851</td>
<td>11.45</td>
<td></td>
</tr>
<tr>
<td>4th November,</td>
<td>7.90</td>
<td></td>
</tr>
<tr>
<td>20th November, 1856</td>
<td>6.22</td>
<td>This fall in 5 hours.</td>
</tr>
</tbody>
</table>

It will thus be seen that while 4 inches are the utmost that has been recorded to have fallen in England during the day, upwards of 20 inches have been known to fall in Madras in the same period of time. How could Madras afford to pay for sewers constructed to discharge five times the quantity of water which the London sewers discharge?

It will naturally be asked, "If the sewers are not to carry away the rain water, how is it to be got rid of?" The answer is—"by open channels." I propose, however, at first, to make use of the existing large drains as the outlets for storms. This will, no doubt, cause surprise to many, considering how much the present drains have been abused. It is well known, in drainage engineering, that when the quantity of water is great, the form of the sewer is of little consequence. Whether it has a rectangular section or an oval section, the velocity is still sufficient for all possible purposes. Now, the section of the Madras drains is certainly very far from faultless. Nevertheless for storm waters they will answer admirably. When Madras can better afford it, it will be time to reconstruct these channels, but having
them now at hand, I am decidedly of opinion that they should be used. The drains which I propose to keep are not, of course, the open street drains in all parts of Madras, but the few large underground and open channels which discharge immediately into the sea, the Cooum, or the canal. All the street drains should be taken up, for the bricks of which they are constructed are of the worst possible kind and so saturated with liquid filth, that every effort to cleanse the town without the removal of these drains will be ineffectual. At present, all that would be necessary would be to re-place these drains with broken granite, down which the rain water would flow until it ultimately entered, as it now does, one of the large outlet drains. The Municipal Commissioners, who spend yearly about 20,000 rupees in new drains, would have that sum available for this work, inasmuch as no new drains would be required in the town if this Project were carried out. Ultimately it might become necessary to have open channels of stone set in mortar, similar to those in use in England.

On this question of the separation of rain-water from sewage, I understand that it will be urged by the advocates of universal dry conservancy against me—"So, after all, your sewers will not get rid of the rain water." But these gentlemen forget that this argument tells, if possible, much more against them than against me. For, at all events, I do propose to dispose of all liquid refuse except storm waters, whereas the advocates of universal dry conservancy propose to get rid of 100th part only of the liquid refuse, and moreover of none of the storm water. If, therefore, it is necessary for the advocates of sewers, so also must it be necessary for the advocates of universal dry conservancy, to dispose of storm waters. It is no use to find fault with a sewer system from which storm waters are excluded, unless some mode of removing these storm waters, better than that suggested by me, is put forth by the objectors. All that I maintain is, that it will be unadvisable to adopt the European system of sewerage in its entirety in Madras, simply because, if rain water is to run in the same channel with sewage, the discharging capacity of the channel in Madras must be four times what it is in London for the same area to be drained—that sewers laid down on this principle will be perfectly useless for eleven months in the year—and that the cost of them will ruin the Municipality.

Details of Sewers.—The general system of sewers proposed to be laid down will best be understood by reference to the map of Madras given
above (p. 2), from an inspection of which the exact course of each sewer can be seen.

All the sewers proposed to be laid down in this Project are to be egg-shaped,—the diameter of the upper arch being double that of the invert. As it is now generally acknowledged by the Engineering profession that this is the best form for sewers where the quantity of sewage is constantly varying, it is unnecessary for me to dwell on the advantages of adopting it for the Madras sewers.

The formula by which the dimensions and slopes of the sewers have been calculated is the one used by Mr. Beardmore in his work, "Manual of Hydrology;"

\[ v = 55 \sqrt{2h f} \]

in which \( v \) is the velocity of the stream in feet per minute—\( h \) the hydraulic mean depth in feet—and \( f \) the fall in feet per mile.

A single example will best explain how the dimensions of the sewers for the Main Line have been decided on.

It has been assumed that the quantity of water used per head of the population, may ultimately be as high as twenty gallons per diem. Excepting the western portion of the neighbourhood lying to the north of the Railway, the population of which is about 54,000, the whole of Madras will be drained through the Main Sewer. If the population of Madras be taken at 428,000, the total quantity of water flowing into the cesspool in 24 hours through the Main Sewer will be \((428,000 - 54,000) \times 20 \text{ gallons} = 7,480,000 \text{ gallons, or } 1,196,800 \text{ cubic feet. Assume that half this quantity, or } 598,400 \text{ cubic feet, will run off in 8 hours, the period of maximum daily flow, then the quantity to be discharged every minute by the Main Sewer will be } \frac{598,400 \text{ cubic feet}}{8 \text{ hours } \times 60 \text{ minutes}} = (\text{say}) 1,247 \text{ cubic feet.}

Now, a sewer 6 feet by 4 feet, laid at a slope of 2 feet per mile, will discharge upwards of 1,650 cubic feet per second, assuming the co-efficient of friction to be .75. The velocity of the stream would be about 18 inches per second. Allowing a large margin for prospective population, I think if the Main Sewer at its junction with the cesspool is 6 feet by 4 feet and laid at an inclination of 2 feet per mile, it will be quite large enough. I very much doubt if the Main Sewer will for many years be more than one-third full. But it is safer to make the sewers too large than too small.

As it is not intended that the sewers proposed to be laid down according to this Project shall remove rain water, it is necessary that the principles
on which the general system of drainage have been designed should be explained. In order to utilize to the utmost the natural slopes of the ground for the street drains, I have run the Main and Branch Sewers, as a general rule, along the valley lines of each neighbourhood. To ascertain, however, at what depth they should be placed below ground, I commenced laying down the street drains from the highest points in each district, and working down to the Main and Branch Sewers. The slopes given to the street drains, which will be earthenware pipes of 6 and 9 inches in diameter, are such as to admit of the sewage flowing through them at the velocity of at least 3 feet per second. The 6-inch pipes at the highest points in each district will be laid at an inclination of from 1 in 150 to 1 in 100. and, in those streets which are situated nearer the valleys, the slopes of the drains will be much greater than this. The slopes of the 9-inch pipes range from 1 in 250 to 1 in 170. In fact, the levels at which the sewers are put below ground are such as to admit of the pipe-drains in all the streets being laid at such inclinations as will generally enable them to keep themselves clear of deposit.

On the accompanying plan of Black Town, the complete system of sewers and pipes for this district is shown. The general principles of drainage which I have adopted will be better understood by an examination of this plan than by any written explanation on my part.

I have given the greatest consideration to the question of slope. Had the strata on which Madras stands, been favorable to the construction of sewers at a great depth, I should have laid them at a much greater slope than that on which they are placed at present, but these strata consist almost everywhere of sand or clay, and water is found in all parts at about the level of the datum line. The building of the sewers, therefore, if they were put very deep below the surface, would be difficult, and attended with considerable expense. I have preferred to adopt a medium slope, and propose to turn the abundance of water to use in flushing the sewers.

The Main Sewer at its head will be 3 feet by 2 feet, and laid at an inclination of 4 feet per mile, and at its termination it will be 6 feet by 4 feet with an inclination of 2 feet per mile. It will start at about the level of the datum line and will terminate at the level of 16.25 feet below the datum line. Where each Branch Sewer joins the Main, the dimensions of the latter will be increased, and as the Main Sewer becomes larger the slope will be gradually decreased.
All the Branch Sewers, without exception, are to be 3 feet by 2 feet, and to be laid at an inclination of 4 feet per mile. They are considerably larger than they need be, so far as the quantity of sewage which they will have to convey away is concerned, but it would be difficult to cleanse a sewer of smaller dimensions thoroughly. I had thought at one time of using large earthenware pipe-drains for the branch sewers, but the expense of these would be as great as that of the sewers now proposed.

The entire system of sewers is designed to secure one uniform velocity (about 18 inches per second) for the sewage throughout its flow, from the beginning to the end of each sewer.

All junctions between the sewers will be effected by Bell-mouth Junctions.

As fast as the sewage arrives at the end of the Main Sewer, it will be pumped up by means of steam pumps to a height of 10 feet above the datum line, and it will immediately enter the Outfall Sewer, which will carry it to the sea. The position of this Outfall Sewer is shown in the map of Madras, above given. Its dimensions are the same as those of the Main Sewer at its junction with the cesspool, but while the inclination of the latter is 2 feet per mile, that of the Outfall Sewer is 3 feet per mile. This extra fall has been given with the view to secure a greater velocity for the flow of the sewage, as there will not be those facilities for flushing the Outfall Sewer which exist for the other sewers.

A great portion of the Outfall Sewer will run above the surface of the ground, but the line which has been adopted for it is very favorable, and no impediments to traffic will in any way be caused by this work.

The Outfall into the sea has been designed with great care. It will be built of solid ashlar masonry, standing on a groyne of granite boulders run out 200 feet into the sea. The invert of the sewer will be on a level with low water-mark. I think the Outfall will be found strong enough to resist the action of the surf.

Every sewer will be thoroughly ventilated through charcoal disinfectors. The ventilators will be placed at about 100 yards apart, and will be so arranged that dust or gravel falling through them from the roads will be intercepted and prevented from entering the sewers. The dirt can be removed at stated times without interfering with the action of the ventilator.

In connection with every ventilator there will be either a man-hole or
side entrance leading into the sewer, so that, when necessary, men may easily enter the sewers to clean or inspect them.

The St. Thomè and Outfall Sewers being above the level at which water is found, arrangements cannot be made for collecting water below ground for flushing them; but for all the other sewers there will be a flushing apparatus in connection with every ventilator and man-hole or side entrance, as the case may be. The flushing arrangements will, therefore, occur at intervals of about 100 yards apart, and it is expected that each apparatus will cleanse the sewer thoroughly up to that point in it where the next apparatus occurs.

The accompanying plan represents a flushing reservoir in connection with a man-hole and ventilator. The foul air from the sewer will travel up the man-hole shaft—pass through the charcoal in the box a, the bottom and top of which will be made of iron wire netting—and will escape, first through the opening b, and then through the ventilator g, to the open air. Any gravel or dust falling through the ventilator will be intercepted in the chamber c, and when it is necessary to remove the rubbish, the trap door d will be opened, the box a pushed into the recess e, and the chamber c will be cleansed through the door f, on the opening of which the rubbish will fall out and be received in a basket held at the mouth of the entrance. When the rubbish has been removed, the door f will be closed, and the box a will be pulled out of the recess and replaced in its original position over the man-hole shaft. Thus, all the foul air that escapes from the sewer will be made to pass through the charcoal which, it is expected, will in a great measure, disinfect it.

At the bottom of the man-hole shaft there will be a masonry reservoir (capable of holding about 350 gallons of water), which will be fed from a filtering well. The reservoir will be connected with the sewer by an iron pipe (6 inches in diameter) furnished at one end with a stop valve and at the other with a sluice gate. The water from the filtering well will pass into the reservoir through a small pipe, and when the reservoir has sufficient water collected in it, the pipe will be closed by a self-acting ball-valve.

In order to flush the sewer, the man employed on the work will first open the trap door at the surface of the ground—he will then descend the ladder, and, pushing the box of charcoal into its recess e, pass down to the bottom of the man-hole shaft. A few turns of the handle fixed to the stop valve will open the mouth of the flushing pipe, when the water from the
reservoir will rush through it, open the sluice gate & by the force of its pressure, and pass into the sewer with considerable velocity. After all the water has escaped, the sluice gate will fall down by its own weight, and the stop valve will be closed by the man, who may then leave the reservoir to fill again, and pass up the ladder to the open air. As soon as the reservoir is emptied, the water from the filtering well will begin to flow into it, and in the course of a few hours the whole apparatus will be again ready for use.

It is expected that a pressure of 2 feet of water in the reservoir will give sufficient scouring velocity to the water. If, however, this amount of pressure should, in practice, be found insufficient, the reservoir can be filled to the depth of 3 feet by altering the position of the ball-valve.

The Outfall Sewer and the St. Thomè Branch Sewers must be flushed by forming temporary dams across them and removing the dams suddenly. This is practised in England and found to answer.

All the sewers and other works will be constructed with machine-made steam pressed bricks laid in the best hydraulic cement. The inner surface of the sewers and other works will be lined with asphalt half-an-inch thick, and the inverts of the sewers will be formed with earthenware blocks of English manufacture. Round those sewers which run beneath the level of water, there will be a casing of concrete. A general idea of the form of the sewers and the manner in which they will be constructed, may be obtained from the accompanying diagram.

Pumping arrangements.—Assuming that 20 gallons of water will be used, per diem, per head of the population, the total quantity of sewage to be raised by the steam pumps daily would be:

428,000 \times 20 \times 10 = 85,600,000 Hs.

And if half this quantity be supposed to enter the cesspool during the 8 hours of maximum flow, the power of the engines should be sufficient to raise 42,800,000 Hs. in 8 hours. The average lift from the cesspool into the outfall sewer would be 26 1/2 feet. The power of the pumps, therefore, should be:

\[
\frac{42,800,000 \text{ Hs.} \times 26\frac{1}{2} \text{ feet}}{38,000 \text{ Hs.} \times 3 \text{ hours} \times 60 \text{ minutes}} = \text{say 70 horses.}
\]

I consider that two engines, each of 36 horse-power, would be ample for all purposes. I would not recommend the erection of a third engine as a
reserve, for I very much doubt if, for many years, the quantity of water used daily per head of the population, will even approximate to 20 gallons. Indeed, one engine of 36 horse-power would, in my opinion lift all the sewage that might flow into the cesspool during any hour of the day. The second engine, therefore, would be as a reserve. If, at any future period, it were found that these two engines were not sufficient for the work required of them, a third could easily be procured, but it would be very undesirable to go to the expense of providing more engine power at first than could be utilized afterwards.

By the cesspool, to which I have alluded so often, it must not be supposed that a large reservoir for ponding up the sewage for many hours is intended. This system, which is practised in England, and of which the most notable examples are to be found in the grand London Drainage Works, is obviously not suited to a country like India where decomposition sets in so rapidly. The cesspool for the Madras Drainage Works, will be a small well of, perhaps, 8 or 10 feet in diameter, into which the sewage will be led for conveniences of pumping. During those hours of the day when there is a little or no sewage to be raised, the engines will be stopped and the sewage will be allowed to accumulate in the Main Sewer, which, in fact, will be the ponding reservoir, and take the place of those enormous cisterns which are constructed in Europe.

As so many improvements are yearly made in England in pumping engines, of which the Indian Engineer is not so much as aware, I have thought that it would be useless for me to attempt the designs for the engines for the Madras Drainage Works. Much better designs could be obtained by the Government from some one of the numerous Engineers in England, who devote their entire attention to this class of work. A few remarks as to the requirements of the engines for Madras will not be out of place here. 1st. The boilers must be constructed on the most improved principles, and with the view to the smallest consumption of fuel in proportion to the work performed. Where, as in Madras, coal is sometimes not to be had at less than 50 shillings per ton, the necessity for the careful construction of the boilers, with the object of saving fuel, cannot be exaggerated. 2ndly. The furnaces must be made for the combustion of either coal or wood. 3rdly. In connection with the pumps, arrangements must be made for separating, if necessary, the liquid from the solid portion of the sewage: and a filth-hoist for the purpose of raising the latter must
be erected to be worked by the engines. I would leave it to the Engineer in England to decide what style of engine should be adopted—whether high or low pressure, whether condensing or non-condensing, whether single acting or double acting, &c.

On receipt of the plans of the engines, the buildings at the Pumping Station can be designed. With this report is forwarded a plan and sections of the ground where the sewage is to be raised, and such information is given on the plan as will enable the Engineer in England to understand the special requirements of the case.

*Street Drainage.*—The street drainage will be effected by means of 9-inch and 6-inch glazed earthenware pipes of English manufacture. Only in one instance will a pipe of larger dimensions be laid down. I propose to use pipes of these two sizes as the most convenient for the objects in view. Every street will be drained by a 6-inch pipe leading to a 9-inch sub-main, which will run directly to the main or branch sewers. The 6-inch street pipes will usually begin at 3 feet below the surface of the ground, and will slope down uniformly to meet the 9-inch sub-mains. The least slope for the 6-inch pipes will be at the top of the ridges in each District (about 1 in 150), and the greatest slope in those streets which are nearest the main and branch sewers (about 1 in 50). In laying down the street drains, it will be necessary to provide means of access to them at intervals of about three hundred feet apart, so that they may be easily cleansed when obstructed. In connection with these entrances leading to the drains, ventilators and small flushing reservoirs might be formed, similar to those adopted for the sewers. Where the pipes were above the level of the water, some other means of flushing would have to be arranged. A water-cart, with a long hose, would, perhaps, be the simplest plan.

I would strongly urge that the pipes used for the Madras drainage be of the kind known as "saddle and chair" pipes. If they get broken, they can easily be removed, and others can be substituted without shifting more pipes from their position in the line than the number to be replaced.

*House Drainage.*—The house-drainage will be effected by three and four-inch earthenware pipes laid at as great an inclination in each instance as the internal arrangements of the walls and rooms of the dwelling will admit of. The pipes will start from the back yard of the house and will issue into the street from under the front door of the dwelling. The admirable system

* Why should not these be made in India?—[RD.]
known as "back drainage" in England cannot be adopted in Madras. The destruction of property would be so great as to put it entirely out of the question. In London, where there is generally an open yard at the back of every house, there is no difficulty in draining the houses to the rear—in fact, it is cheaper to do so, but in Madras the back yard to the house is surrounded by small buildings, the destruction of which would be necessary before a pipe could be laid. Every house, moreover, invariably slopes, and some very considerably, from the back yard towards the street. To attempt "back drainage" will be to drain the houses against the natural slope of the ground. Many objections may be found and urged against carrying the pipe through the entire length of each man's dwelling and taking it into the street drain from under his front door, but long attention to this subject, and a careful inspection of numerous dwellings all over the town, have convinced me that this is the only method at our disposal. It is not possible to make use of the present house drains, which are usually channels of about 4 inches square, and run beneath the wall which separates two contiguous buildings, and is common to both. These drains having been built along with the houses, there is no means of getting at them except by pulling down the walls, which cannot be done without causing damage to the dwellings. In many of the streets, the slopes which have been given to these channels are very slight, and they constantly become choked up in consequence.

I would, therefore, leave the present house drains as the discharging channels for rain-water, and would lay down three and four-inch earthenware pipes in the manner already proposed for the sewage. In every yard, or wherever water may be used within a native dwelling, there would be a small cistern fitted up with a sink. The earthenware pipe, which would run from the back to the front of the house, would, in most cases, pass directly under these sinks and be connected with them by syphon traps.

To illustrate my meaning, I will take the most ordinary case—a native dwelling with, say, three open yards, one behind the other, and with a well in the back, and another in the front, yard. The earthenware pipe would start from near the well in the back yard, run across the second yard to the well in the first yard, and thence pass through the dwelling and out under the front door. It would join the street drain in the middle of the street. Round each well it would be necessary to put up a brick dam two or three inches high—just sufficiently high to intercept the
Madras Drainage.

PERSPECTIVE SECTION OF A FIRST CLASS NATIVE HOUSE IN MADRAS.

showing the System of drainage proposed.
water, and sufficiently far from the parapet of the well to admit of the inmates of the dwelling bathing and cleaning their pots in the space between the parapet and the dam. A sink would be fixed in this open space so that all the water that was used at the well would escape through the sink and pass at once into the earthenware pipe. In many cases the dam would not be required, for there is already a channel from each well, and the sink might at once be fixed in it. Care should be taken not to lay it at the lowest point in the open yard, as in that case, the rain falling on the roofs of the houses and in the yard would enter the earthenware pipe.

The house drainage should be carried out under the immediate direction of the Municipal Commissioners. Every house-owner should be at liberty to lay down the drains in his house himself, subject to the approval of the work by the Commissioners, or, if he preferred it, the Commissioners should lay down the drains for him at their own cost, and increase the rate charged on the house by such a sum as in 30 years would amount to the value of the work done, with interest thereon.

I must not omit to explain in this place how I intend that the excreta should be disposed of. So far as the urine is concerned the matter will be very simple. The connection at present between the privy drain and the house drain will be stopped, and the former will be joined to the new earthenware pipe through which all the urine will escape to the sewers. For the removal of the ordure I would encourage, as much as possible, the system which obtains at present throughout the town,* but I would, at the same time, try to improve it. The abominable smells in all parts of Madras are not produced, as is generally supposed, by the excreta of the population, but by defective drainage. It is the refuse water in the houses and in the streets into which all manner of garbage is thrown to ferment, and generate foul gases, that creates the dreadful nuisances so much complained of. What is chiefly required to prevent excreta producing a nuisance is a constant inspection of the privies in the dwellings. Although the ordure is removed daily, yet the privies themselves are not kept clean. Very often there is a stoppage in the channel which carries away the urine, or the ordure is dropped on the bare floor from which it is impossible to remove it altogether. Now, if the Municipal Commissioners would organize a system of inspection and insist on every householder keeping

* Vide page 8.
his privy in a wholesome state, we might soon get rid of the evil. Of course, the use of clay, ashes, &c., should be encouraged as much as possible. This would be nothing more than the dry system applied to dwellings, and would have this advantage, that each householder would be saddled with no more than the expense of removing the nuisance produced in his own house and by his own family. The cost of this plan to the Municipality would really be most trifling. For the first few months it might be necessary to examine each privy once in every two or three days, but after a few men had been punished for the filthy state of their privies, even this amount of inspection would not be called for. A weekly inspection would subsequently answer every purpose. Twenty-five Native Inspectors would suffice for the whole of Madras. In each District there should be one European or East Indian Superintendent, who should keep the Inspectors up to their work, and receive their daily reports. Both the Superintendent and the Inspectors should have no work but that of looking after the privies.

If each Superintendent received 30 rupees, and each Inspector 7 rupees, monthly, the total yearly cost of (say) eight Superintendents and twenty-five Inspectors would not amount to 5,000 rupees. The only objection which may be urged against this scheme, is, perhaps, that the householders would object to the privacy of their dwellings being invaded for the inspection of their privies. But, considering that ultimately the privies would not require to be inspected more than perhaps once a week or so, and that sweepers at present enter each house every day to clear away the ordure, the above objection would really be an absurd one.

The best system for the removal of excreta is the sewer system—provided that plenty of water can be employed to carry away the urine and ordure, and that a liberal use can be made of some deodorizing solution to prevent effluvia. There is nothing to equal the water-closet for cleanliness and wholesomeness. It acts perfectly if deodorizers are used as well as water. Both deodorizing and antiseptic solutions will, before long, be procurable at prices that will admit of their free use even by householders, but many years must elapse before every house in Madras is supplied with water. Until then, I am satisfied that it will be best to continue the present system.

Utilization of Sewage.—Having now explained the Project generally, it is necessary that I should return to a point in connection with it, to which
Ladras Drainage.

CHART

THE NUMBER OF DAYS IN THE YEAR THE WIND BLOWS IN MADRAS

ACH POINT OF THE COMPASS.

Winds blow amount to 87%, or to less than 3 months.

- N by W
  - 5 1/4 days
- N
  - 10 1/4 days
- N by E
  - 13 3/4 days
- NNW
  - 17 days
- NE
  - 22 1/4 days
- NE by N
  - 29 1/4 days
- NE by E
  - 36 days
- ENE
  - 43 1/4 days
- ENE
  - 50 days

- S by W
  - 20 days
- S by E
  - 25 days
- SSE
  - 23 days
- SE
  - 22 1/4 days
- SE by S
  - 19 1/4 days

Days during which the favorable winds blow amount to 2 1/2 or more than 2 1/2.

Convey the smell of the sewage away from Madras, are marked with arrows.

Note: Shown above are averages of 5 years observations.
I have hitherto only alluded, in order that the description of the works should be as clear and uninterrupted as possible. Under the heading "Objections to Sewers," I have already attempted to prove that sewage is a valuable manure, and that those who are best qualified to speak on the subject are unanimous in their opinion, that it should not be wasted but applied to agricultural purposes. It is unnecessary, therefore, that I should repeat the arguments in this place. The points to which I now wish to draw attention are the very favorable position of Madras for the utilization of its sewage, and the rare opportunity thus afforded to Government of making an experiment on a large scale on this very important question of the day.

The land on which it is proposed to use the sewage, lies to the north-west of Madras. It is a portion of that extensive low-lying tract stretching toward the north, along which the canal runs. The average level of the land is from 2 to 6 feet above datum (mean sea level). It is not possible to say how much land will be required; that will depend on the quantity of sewage available. But if this quantity should be even ten times as much I have allowed for, there is more than sufficient land for the purpose. The only objection which I can conceive will be made to the use of the sewage, is the general one that a nuisance will be created in Madras whenever the wind blows over the sewage-irrigated land towards the town. This objection I shall, therefore, at once attempt to meet.

The accompanying Chart shows the number of days in the year the wind blows in Madras from each point of the compass. All those winds marked with arrows are winds which would convey the smell of the sewage away from Madras. The other winds would blow over the sewage lands to some one or other inhabited quarter of the town. Now, a glance will convince any one by how very much the favorable winds exceed the unfavorable ones. While the latter blow for less than three months, the former blow for more than nine months of the year. It must not be supposed that each wind blows continuously during the number of days marked in the Chart. What is meant to be shown is, that the total number of days in the year during which the wind blows from any one point of the compass amounts to that shown in the Chart. The winds N., E. by N. and N. N. E., which I have marked as unfavorable, are really in only a very slight degree so, for they would have to travel nearly two
miles before they reached the nearest inhabited part of Madras, which would be the outskirts of Pursewakum. The nuisance, if there were any, which I altogether doubt, would, at all events, be so very slight as to be scarcely felt.

On the accompanying Map of Madras I have shown the position of the sewage-irrigated lands, and have projected the directions of the winds so that the course taken by each may be at once seen. The only winds, if any, which would be positively unfavorable, are those which blow from between W. by N. to N. by E., but, practically speaking, there are no winds from between W. to N. Only occasionally, for a day or two in each month of the year, does the wind blow from the points between these quarters. It never continues in them. To render this clear I have drawn the accompanying diagram which shows the number of days in every month of the years 1847, 1848, 1849 and 1850, during which the wind blew in Madras from each point of the compass. It will be noticed how thinly scattered over all the months of the year are the days on which the wind blew from between N. and W.

I think it will now be admitted that no inconvenience will be likely to arise from the use of the sewage on the site I have pointed out. But should the Government have any doubt on the matter, it would be very easy to select a much better site by going further away from Madras. It is a question of expense only, for the farther the land is situated, the longer must be the channel which conveys the sewage to it. I have merely chosen the nearest site on which I consider sewage might be applied without objection being made. My opinion is that the sewage might even be used around the very spot on which it is pumped up from the cesspool, without any nuisance to the inhabitants.

I had partly designed an Irrigation Sewer, but I subsequently decided not to complete it, as it was essential to know first what site the Government might select for the utilization of the sewage. The great advantage of using the sewage will be the saving effected by not having to construct the Outfall Sewer, a work that will cost about three lakhs of rupees. Besides this, the sale of the sewage may be expected to realize a considerable sum.

I beg respectfully to urge on the attention of Government the great im-

* I have not selected these years, but the Government Astronomer (N. B. Pogson, Esq.), gave me the records of them as being those which were in the most convenient form for reference. No records of later years have as yet been published.
Note A. The figures indicate the number of days in the year the wind blows from each point.

B. The favourable points are those marked with arrow-heads and plotted between the thick lines.
importance of this question of utilizing the sewage of Madras. Every town in India has an interest in its decision, and could it be proved that the sewage of towns could be profitably and safely applied to land in India, an in calculable benefit would be conferred on the whole country.

Cost of project.—The following is a list of the quantities of work to be done, and the rates at which they are calculated:

<table>
<thead>
<tr>
<th>Quantities</th>
<th>Description of work and rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cub. ft.</td>
<td>Brickwork in hydraulic cement, Rs. 0-6 per cubic foot,</td>
<td>Rupees. 5,01,637</td>
</tr>
<tr>
<td>1,837,751</td>
<td>Concrete, at Rs. 0-2 per cubic foot,</td>
<td>2,14,759</td>
</tr>
<tr>
<td>1,718,121</td>
<td>Asphaltiting, at Rs. 1-5 per square of 100 feet,</td>
<td>1,57,965</td>
</tr>
<tr>
<td>7,000</td>
<td>Plastering, at Rs. 2-8 per square of 100 feet,</td>
<td>175</td>
</tr>
<tr>
<td>Run. ft.</td>
<td>Invert lock, at Rs. 1-8 per running foot,</td>
<td>1,57,292</td>
</tr>
<tr>
<td>104,928</td>
<td>Ashlar granite, at Rs. 1-8 per cubic foot,</td>
<td>40,659</td>
</tr>
<tr>
<td>Cub. ft.</td>
<td>Earthwork, including excavation, re-filling, re-making road and every expense, at Rs. 1-4 per cubic yard,</td>
<td>6,61,461</td>
</tr>
<tr>
<td>539,169</td>
<td>Tunnelling, at Rs. 7 per cubic yard,</td>
<td>6,937</td>
</tr>
<tr>
<td>83,281</td>
<td>Embankment, at Rs. 1 per cubic yard,</td>
<td>38,281</td>
</tr>
<tr>
<td>20</td>
<td>Gravel, at Rs. 1-2 per cubic yard,</td>
<td>23</td>
</tr>
<tr>
<td>Cub. ft.</td>
<td>Teakwood, at Rs. 3-4 per cubic foot,</td>
<td>2,629</td>
</tr>
<tr>
<td>809</td>
<td>Galvanized iron netting, at Rs. 0-6 per square foot,</td>
<td>1,576</td>
</tr>
<tr>
<td>Sq. ft.</td>
<td>Wrought-iron, at 150 rupees per ton,</td>
<td>2,117</td>
</tr>
<tr>
<td>4,203</td>
<td>Rivets, at Rs. 0-1-6 each,</td>
<td>104</td>
</tr>
<tr>
<td>1,104</td>
<td>Cast-iron ventilators, at Rs. 80 each,</td>
<td>10,080</td>
</tr>
<tr>
<td>836</td>
<td>Trap doors, at Rs. 140 each,</td>
<td>47,040</td>
</tr>
<tr>
<td>263</td>
<td>Ball valves, sluice valves, sluice gates with pipes</td>
<td>23,670</td>
</tr>
<tr>
<td>Tons.</td>
<td>complete for each flushing reservoir, at Rs. 90,</td>
<td></td>
</tr>
<tr>
<td>6,258</td>
<td>Granite boulders at Rs. 2 per ton,</td>
<td>12,518</td>
</tr>
<tr>
<td></td>
<td>Total Rupees,</td>
<td>18,74,047</td>
</tr>
</tbody>
</table>

### STREET DRAINAGE

<table>
<thead>
<tr>
<th>Quantities</th>
<th>Description of work and rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run. ft.</td>
<td>Six-inch glazed earthenware pipe drains, including digging, laying down, jointing, filling up, and every expense, at Rs. 1-4 per running foot,</td>
<td>Rupees. 7,21,868</td>
</tr>
<tr>
<td>577,490</td>
<td>Nine-inch do. do. do. at Rs. 1-12 per running foot,</td>
<td>1,07,450</td>
</tr>
<tr>
<td>61,400</td>
<td>Twelve-inch do. do. do. at Rs. 2-4 per running foot,</td>
<td>6,300</td>
</tr>
<tr>
<td>Number.</td>
<td>Mar-holes and side-entrances for the nine and twelve-inch pipes, at Rs. 500 each,</td>
<td>1,07,000</td>
</tr>
<tr>
<td>214</td>
<td>Total Rupees,</td>
<td>9,42,613</td>
</tr>
</tbody>
</table>
I have thought it best to show clearly the exact quantities of work and the rates at which they are calculated, so that an opinion may be formed by the Government on the Estimate.

For sewerage works none but the best procurable materials should be used. Admirable steam-pressed bricks have already been made in Madras—sufficiently good for any engineering purpose. I propose to use bricks similar to these for the Madras sewers. Hydraulic cement can be made wherever lime and clay are to be had, and I have no doubt excellent cement will be produced when the time comes to begin the works. In London, brickwork for sewers, when the bricks are picked stocks and laid in Portland cement, costs under a shilling a cubic foot; but such brickwork will not be attainable in Madras. Brickwork with picked stocks in blue lias lime costs under 9d. a cubic foot. I have taken 9d. or 6 annas, as the rate for the Madras sewers.

In London, concrete, composed of blue lias lime and clean ballast, costs under 3d. per cubic foot. I have taken 3d. or 2 annas, as the rate for Madras. Hitherto, I believe, concrete has cost somewhat more than this; but it has been made in such small quantities, that it is difficult to say what the cost will be when it is manufactured on a large scale.

I think it will be necessary to coat the interior surface of the sewers with asphalte, and I do not apprehend any difficulty in the work, as the brickwork will all be built in blocks on the surface of the ground before it is laid in the sewers. The cost of the asphalte coating will, I think, be covered by the rate allowed for it, viz., 15 rupees per square of 100 feet.

It is most essential that the inverts of the sewers should be laid with the best material. They are exposed to much more friction than the other parts of the sewers. For smoothness of surface and for durability there is nothing to equal the glazed earthenware blocks which are now manufactured and used in such large quantities in England for the inverts of sewers. They have been laid down in the London sewers at 2s. per running foot. I have allowed 3s. or Rs. 1-8 per running foot for Madras.

Earthwork, including digging, re-filling, tamping, shoring, pumping, keeping the works clear of water, re-making road-ways, and every expense whatsoever, has been done for the London sewers at 2s. 6d. per cubic yard. There is no reason why this rate should be exceeded in Madras.

Six-inch glazed earthenware drain pipes have been laid down in London at 2s. per running foot, including digging, re-filling, and every expense
whateoever. Nine-inch pipes have been laid at 2s. 6d., and twelve-inch pipes at 3s. per foot run. The rates I have adopted for the Madras sewerage are,—for the six-inch pipes, including all bends and junctions, Rs. 1-4; for the nine-inch, Rs. 1-12; and for the twelve-inch, Rs. 2-4 per running foot. The use of none but the best earthenware pipes should be contemplated. It would be folly to use country-made pipes as they are manufactured by the potters at present.*

I have assumed that each Man-Hole or Side-Entrance for the street drains will cost 500 rupees. The quantities of materials will differ according to the position of each, but I think the above will be found a near approximation to the cost.

The other items in the preceding estimate are of small amount, and it is not necessary that I should refer to them, as any slight alteration in the rates for them will affect the total cost of the works in only a slight degree.

Some land will have to be bought up for the works, and the value of this has been ascertained, in communication with the Collector's Department, at 25,340 rupees. A few small buildings in the line of the sewers will likewise have to be purchased. The cost of these will be 20,000 rupees. The cost of the engine and pumps (72 horse-power) has been calculated at 1,500 rupees per horse-power, delivered in Madras, or altogether to 1,08,000 rupees. The Pumping Station, and works in connection with it, (including expenses of erecting the machinery) will, it is calculated, cost 70,000 rupees. There are no plans for this work, as I have already explained, but I believe 70,000 rupees will cover all expenses.

The total estimate for all the works is as follows:—

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main drainage,</td>
<td>18,74,047</td>
</tr>
<tr>
<td>Street drainage,</td>
<td>9,42,613</td>
</tr>
<tr>
<td>Land to be purchased,</td>
<td>25,340</td>
</tr>
<tr>
<td>Buildings do.,</td>
<td>20,000</td>
</tr>
<tr>
<td>Engines and pumps of 72 horse-power, at 1,500 rupees per horse-power</td>
<td>1,08,000</td>
</tr>
<tr>
<td>Pumping station, including cost of putting up machinery, and other works</td>
<td>70,000</td>
</tr>
<tr>
<td><strong>Total Rupees</strong></td>
<td><strong>30,40,000</strong></td>
</tr>
<tr>
<td>Add about 10 per cent. for sundries and contingencies,</td>
<td>3,10,000</td>
</tr>
<tr>
<td><strong>Total Rupees</strong></td>
<td><strong>33,50,000</strong></td>
</tr>
</tbody>
</table>

* But there is no reason why they should not be improved. Witness the earthenware pipes now made at Aligurh by the Irrigation Department, N. W. P. See No. CXXVI. of these Papers.—[Rd.]
If Government decide, as I trust they will, that the sewage shall be utilized for agricultural purposes in the neighbourhood of the Pumping Station, the cost of the Outfall Sewer, about three lakhs of rupees, will be saved. An Irrigation Sewer will, in this case, have to be built, but its length need not be more than one-third that of the Outfall Sewer, and its dimensions need not be so great. The cost of the Irrigation Sewer may be put at about a lakh of rupees. Deducting the cost of the Outfall Sewer (about 3 lakhs of rupees) from the amount of the above estimate (38\(\frac{1}{2}\) lakhs) and adding the cost of the Irrigation Sewer (say a lakh of rupees), the total of the estimate becomes 31\(\frac{1}{2}\) lakhs.

It will be seen that I have allowed the large margin of upwards of 3 lakhs (10 per cent. on the estimate) for unforeseen contingencies.

The cost of the establishment for superintendence will probably be as follows:—

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Engineer, specially brought out from England to superintend the working of the engine and to keep the accounts</td>
<td>400</td>
</tr>
<tr>
<td>2 European or East Indian engine-drivers, at Rs. 50 each</td>
<td>100</td>
</tr>
<tr>
<td>4 trained firemen, at Rs. 15 each</td>
<td>60</td>
</tr>
<tr>
<td>4 ordinary firemen, at Rs. 8 each</td>
<td>32</td>
</tr>
<tr>
<td>25 men (mostly sweepers) to look after the sewers and pipe drains, and to be available generally for any work, at Rs. 5 each</td>
<td>125</td>
</tr>
<tr>
<td>1 Storekeeper and accountant</td>
<td>50</td>
</tr>
<tr>
<td>1 Clerk</td>
<td>25</td>
</tr>
<tr>
<td>4 Poons, at Rs. 6 each</td>
<td>24</td>
</tr>
</tbody>
</table>

**Total Monthly cost, Rupees:** 816

**Yearly cost, Rupees:** 9,792

If 5 rupees yearly represent a Capital of 100 rupees, the above sum for superintendence would represent a capital of (9,792 \(\times\) 20 =) say, 2 lakhs of rupees.

I think it may fairly be assumed that for many years to come, the quantity of sewage will not exceed 10 gallons per diem per head of the population. The total quantity of sewage to be raised by the pumps daily, taking the population of Madras at 480,000, would, therefore, be 4,300,000 gallons. Good engines of the largest size (of about 200 or 300 horse-power) lift from 2 or 3 million gallons of water a hundred feet high with a ton of coal.
Small engines (such as those proposed for the Madras Drainage) would not lift more than half this quantity, or say $1\frac{1}{2}$ million gallons a hundred feet high. This is equivalent to more than $4\frac{1}{2}$ million gallons 27 feet high, which is the height to which the pumps will have to raise the sewage. About a ton of coal or say $1\frac{1}{2}$ tons at the outside, will, therefore, be consumed daily in Madras. The cost of coal, if imported direct from England and not purchased in the local market, may be taken at 20 rupees a ton. The yearly cost for fuel will be $(365 \times 30 = ) 10,950$ rupees.

To this sum we should add, say 2,050 rupees for oil, tallow, and other sundries, which would then make the total yearly expenditure about 13,000 rupees. This would represent a capital of $(13,000 \times 20 = )$ say $2\frac{3}{4}$ lakhs of rupees.

If the works are properly executed in the first instance, and a sufficient establishment, such as that proposed, is maintained to look after them, the repairs ought to cost little or nothing. There are sewers at home which have cost nothing for repairs for years after they have been laid down. But I will assume that the repairs every year will amount to $\frac{1}{3}$ per cent. on the cost of the works, i.e., on $31\frac{1}{2}$ lakhs, supposing that the Outfall Sewer is not built. This will be equivalent to, say, 16,000 rupees yearly, or to a capital of about $3\frac{1}{4}$ lakhs.

The total estimate, then, under all heads, will be as follows:—

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of works</td>
<td>$31\frac{1}{2}$ lakhs.</td>
</tr>
<tr>
<td>Superintendence</td>
<td>$2$</td>
</tr>
<tr>
<td>Fuel and sundries</td>
<td>$2\frac{1}{4}$</td>
</tr>
<tr>
<td>Repairs</td>
<td>$3\frac{1}{4}$</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$39\frac{1}{4}$ lakhs.</td>
</tr>
</tbody>
</table>

We are now in a position to compare the cost of sewerage with that of Dry Conservancy. In my estimate above of $39\frac{1}{4}$ lakhs of rupees, I have included every possible charge. I will even assume now that the works may cost as much as 50 lakhs, or half a million pounds sterling. And what will the rate-payers receive for this sum? All liquid refuse will be removed from the precincts of their dwelling and will be utilized on land. Ultimately, I have no doubt that the value of the sewage for agricultural purposes will repay the cost of maintenance, but I will not assume this now.

The Estimate I prepared of the cost of Dry Conservancy* was 75 lakhs.

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* Vide Page 19, i.e. capitalising the annual cost of establishment and carriage, and adding it to the first cost of the privies, &c.—[ED.]
of rupees. But I did not include the cost of procuring clay, which amounted to 31 lakhs, and I excluded all cost of repairs and a number of other items. The calculations based on the enquiries made into the cost of Dry Conservancy by the Sanitary Commissioners, brought up the cost of this system to 258 lakhs. Let me suppose, though for argument's sake, that a million pounds sterling will cover all expenses. We then have half a million pounds sterling for a system of sewerage by which all liquid refuse is removed, and a million pounds sterling for Dry Conservancy by which only urine and ordure are removed, which together amount to one hundredth part of the sewage. So that it will cost at least twice as much to remove urine and ordure only, according to the Dry Conservancy system, as it will to remove a hundred times their amount of sewage by the Sewer system.

It has been urged that the cost of draining Madras according to this Project will amount to as much as the value of all the house property in it, and that it will be better to remove the town bodily, as the Americans remove their houses, than to attempt to drain it. It is best to meet arguments of this kind by facts. The value of a house is usually considered equal to 30 years' rental. The number and yearly rent of all the houses in the town may be obtained by any one from the Municipal Commissioner's Office, and the value of all the houses will be found to be 850 lakhs of rupees, or 8½ million pounds sterling. Half a million pounds sterling (the assumed cost of this Project) is not 6 per cent. on the value of the houses at present, and a good system of water supply and drainage will raise their value in the course of a few years by at least twenty per cent. Money laid out in water supply and drainage works is merely capital sunk to improve house property. The inhabitants recover the outlay by the enhanced value of their houses.

There is an impression that Madras can be drained for a very small sum of money. I have no hesitation in saying that the idea is absurd. It is possible to have a cheap system of water supply, but it is utterly impossible to have a cheap system of town drainage. In supplying a town with water, you may carry a few pipes to a few central stations and make the inhabitants fetch their water from them. But in draining a town, you must carry a pipe from every single house in the town, without exception, to some one central spot. The length of drains in the latter instance becomes enormous. Whatever scheme of drainage is adopted for a town,
the length of the sewers and pipes must be almost exactly the same. In the case of Madras, there must be about 140 miles of sewers and pipes, or, if not, some parts of the town will be left undrained. For whatever sum of money 140 miles of drains can be laid down, for that sum only, and for no less, can Madras be drained.

It is necessary for me to add only, that the success of this, or of any Project for the drainage of the town, will depend, in a great measure, upon the manner in which the works are executed. Contractors who have had practical experience in sewerage works will have no more than the ordinary difficulties to contend with in the building of the sewers and the laying down of the pipes for Madras, but should any one attempt the work who is unacquainted with town drainage, certain failure will overtake him. In the present day, contractors in England have attained great skill in the execution of sewerage works, and I therefore, venture to recommend that, when the Government shall have come to a decision on the subject, they should invite tenders for the Madras Drainage Works in London and accept not necessarily the lowest tender, but the tender of some well-known builder who has already proved himself competent, and who possesses the requisite amount of capital for the undertaking.

H. T.