

The drainage and sewerage of Bombay : being a report submitted to the Bench of Justices of that city / by their Executive Engineer Hector Tulloch.

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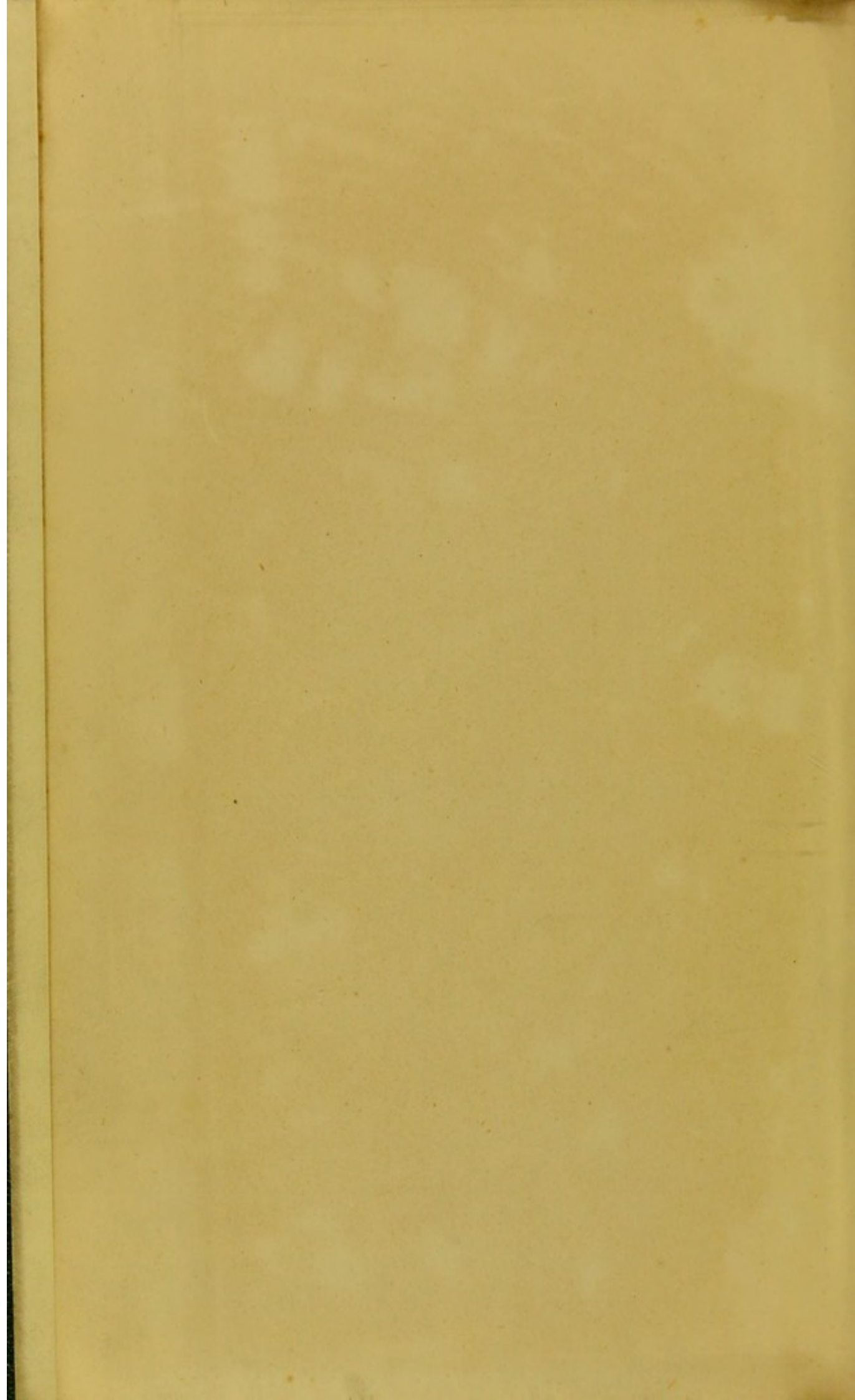
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J. — Tulloch, Hector, Major, R.E.,
"The Drainage and Sewerage of
Bombay." Being a Report—
submitted to the Bench of
Justices of that city. Presented by—







GEOLOGICAL MAP OF THE ISLAND OF BOMBAY

SHOWING PROPOSED SYSTEM OF SEWERAGE AND THE POSITION OF THE LANDS
ON WHICH THE SEWAGE MIGHT BE UTILIZED.

COLOURS, &c.

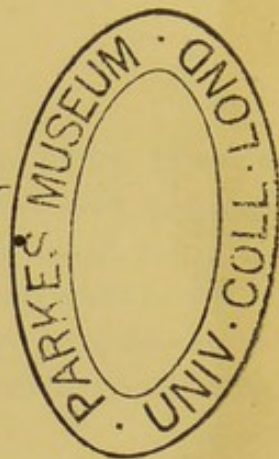
- Alluvium and other superficial deposits
- Basaltic trap of Malabar Hill
- Fresh-water beds, shales, and flags
- Amygdaloidal trap
- Gray trap with shales interstratified
- Sion breccia
- Black rock of Antop Hill Felstone

Scale 1 inch = 1 Mile

10000 Feet

THE
DRAINAGE AND SEWERAGE

OF
B O M B A Y



BEING A
REPORT SUBMITTED TO THE BENCH OF JUSTICES
OF THAT CITY

BY THEIR EXECUTIVE ENGINEER,
H E C T O R T U L L O C H,
MAJOR, ROYAL ENGINEERS.

LONDON:
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PREFACE.

IN criticising the present project, which does not profess to enter into details, I hope the difficulties under which it has been prepared will be borne in mind. I have had to work without any of the plans of the proposed railway, and without the survey of the lands on which the sewage is to be utilized. These papers have not been forwarded to me in England, so that it has been impossible for me to go minutely into the subjects.

The Scheme must be judged by its main features, which are: To completely separate the drainage from the sewage; to allow the former to escape into the sea entirely by gravitation; to utilize the latter on land; and to remove the night-soil by a narrow-guage railway to the north-west of Trombay.* If the Bench approve of these, then detailed estimates for the sewers, for enlarging the sluices, and for the railway, can be prepared by their able Executive Engineer, Mr. WALTON, in the course of two or three weeks. And if a survey of the land on which the Bench decide to utilize the sewage be sent to me, I shall be very glad to draw the designs for them, to show how the fields should be laid out, according to the best approved methods adopted now by so many towns in England.

H. TULLOCH,
Major, Royal Engineers.

34, VICTORIA ROAD, KENSINGTON,
19th October, 1872.

* It must be understood that I make this proposition simply because the Justices will not dispense with the halalcore system. My own opinion is, that the night-soil had much better be allowed to go into the sewers.

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THE DRAINAGE OF BOMBAY.

CHAPTER I.

BOMBAY AS IT IS.

THE PHYSICAL FEATURES OF THE ISLAND.

The Island of Bombay may be said to consist of an alluvial valley about six miles long and a mile and a half wide, running north and south, and flanked on either side by broken ranges of basalt. The depth of the alluvium is not great. As a general rule, excavations made in any part of the valley will reveal a substratum of rock. Indeed, the entire island is simply a mass of trap, the middle portion of which has been scooped out, and filled up with the *débris* of the hills on the sides.

The western range of basalt, which is more continuous than the eastern one, attains in parts an elevation of more than 150 feet, but it does not reach to the northern end of the island, stopping somewhat abruptly about two-thirds of the way up, so that the upper portion of the valley is not protected on the west by hills at all, and the sea washes over a low sandy beach. The eastern basaltic range, although it may be considered to extend from the extreme northern to the southernmost point of the island, and although it occasionally attains an altitude of more than 100 feet, is, in many parts, however, nothing more than a simple elevation of the ground above the adjacent lands. Both the eastern and western ranges extend to the south considerably beyond the limits of the alluvial valley, and by their projections into the sea they enclose what is known as Back Bay.

In the middle of the western range of basalt there is a gap about half a mile long, and through this the sea used at one time to enter and flood a great portion of the island, extending itself even as far as Bycullah; in fact, nearly the whole of the alluvial valley used to be under water during spring-tides. About the end of the last century a stone embankment was thrown across this gap in order to prevent the encroachment of the sea. It has been perfectly successful. The sea has been effectually shut out, but the drainage of the island has, at the same time, been impeded, for, whereas formerly the rain escaped freely to the sea, now it only finds an exit through the small sluices which have been constructed a little to the north of the causeway.

The lowest part of the island is that lying near the embankment. The lands here, termed the Bombay "flats," are in parts as low as two feet below mean sea-level, and only three above low-water of ordinary spring-tides. The greater part, both of the town, properly so called, as well as of the island, slopes towards the flats; and this extensive area, which is the principal part of Bombay, may well be termed the First, or Town Drainage District.

The small narrow strip of the island, about a third of a mile wide, lying about Back Bay, slopes in that direction, and this I propose to call the Second, or Back Bay Drainage District.

There is a small portion of the town to the west of the Elphinstone Reclamation and about Mazagon which slopes towards the harbour, and this I shall call the Third or Elphinstone Drainage District.

The Fort and Colaba are isolated districts. Practically, the Fort stands on a level plain, raised from 16 to 20 feet above mean sea-level. In reality, the ground has a slight inclination towards the harbour, into which, therefore, it has hitherto been drained.

Colaba, being the military station of the island, belongs

almost exclusively to the Government, and it is so thinly populated, and so far removed from the rest of the town, that it is not necessary to consider it with reference to any general Drainage Scheme.

So also with Malabar Hill, Worlee, and other outlying parts of the island. The time has not come yet to sewer them. They are too thinly peopled for drainage. Such arrangements as exist at present must be allowed to continue till the sewage is sufficient in quantity to admit of its being removed by a system of sewers.

Practically, then, if we exclude the Fort from our consideration for the present, that portion of the island which calls more immediately for drainage consists of three districts: 1st, a very extensive one, sloping towards the flats; 2nd, a very small one, sloping towards Back Bay; and 3rd, another very small one, sloping towards the harbour.

THE EXISTING ARRANGEMENTS FOR DRAINAGE AND SEWERAGE.

At present Bombay is drained in the directions in which the different localities slope. The first, or Town District, sloping as it does towards the flats, is drained in this direction by a large underground sewer which runs as nearly as possible along the bottom of the valley. On approaching the flats this sewer no longer remains covered, but becomes an open drain, and continues so up to its termination near the western coast. From the point where the underground portion of the sewer ends, there was constructed five years

ago a small low-level sewer for use during dry weather. The very wide section of the large drain and its small fall caused the sewage to flow so sluggishly that it was considered advisable by Mr. Aitken, then Executive Engineer to the Municipality, to construct a smaller sewer with a greater fall. The bottom of the large drain being at the level of low water of spring-tides, it will at once be seen that the outlet for the drainage is not always free. Only when the tide is at its very lowest can the drain empty itself thoroughly. At neap-tides the water stands several feet deep in the drain, and only a partial discharge takes place.

The small new sewer has its bottom at a still lower level than the open drain, and it could never discharge itself into the sea. It was not built with this object. It was simply built in order to bring the sewage more rapidly to the outlet than before. The sewage is raised from the small sewer by steam-pumps during eight or nine months of the year, dependent on the duration of the monsoon, and then flows into the sea. During the rainy season the work of pumping is stopped, and both drainage and sewage escape along the open drain and through the sluices. The low-level sewer remains full of foul matter, and even under pressure, till the monsoon has cleared off, when pumping is resumed.

Although the main sewer is 20 feet wide and 10 feet high, still, in heavy floods, it is not capable of discharging all the rain which falls on its drainage area. Parts of even the town itself are for many hours under water.* Of course, in dry weather, just the opposite state of things prevails. The sewer having then to carry away nothing but the sewage of the town, it is enormously too large for the purpose. The sewage in it is but a few inches deep. In fact, what is the case in Bombay must be the case in nearly every town in

* I have seen the sewer full up to the crown of the arch, and have stood in water 3 feet deep in one of the streets near Grant Road.

India in which it is attempted to make the same set of underground channels answer for both drainage and sewage. In rainy weather the channels must be too small, and in dry weather too large. During the former period they are liable to burst from pressure, and during the latter they are certain to give off offensive gases many times greater in volume than need be.

From what has now been said it will be seen that, for the greater portion of the island and the town, the system of drainage in force is this : during the eight dry months of the year, when practically no rain falls at all in Bombay, the sewage is pumped into the sea on the western side of the island, but during the prevalence of the monsoon both drainage and sewage escape on to the flats, and gradually discharge themselves into the sea by gravitation through the sluices constructed to the north of the causeway.

But while the First District is relieving itself on the western coast, the Second discharges its drainage and sewage into Back Bay. There are two main outlets, one near Sonapore and the other near Girgaum, and at both there is an intolerable nuisance. In the first place, the sewage cannot escape during all states of the tide, but only when the level of the sea falls below the mouth of the outlet. The consequence of this is that the sewage is dammed up in the sewers for many hours of the day, and contaminates the neighbourhood. In the second place, Back Bay is practically a confined spread of water, and sewage discharged on the shore does not flow out to sea, but simply floats about and increases the nuisance. A walk along the shore will convince the most sceptical of the injurious effects produced by the present sewers.

While the First District is drained into the sea on the west, and the Second into the sea on the south, the Third, or Elphinstone District, is drained into the harbour. In this case, also, the existing sewers carry away both drainage and

sewage ; but as there are currents along the coast the filth is not so liable to be deposited on the shore as in Back Bay. But still, that a nuisance is produced by the existing drains hardly any one can doubt who will visit the locality and enquire into the matter for himself.

THE HALALCORE SYSTEM.

I have already mentioned that in Bombay no separation is attempted between drainage and sewage—that the sewers, such as they are, and wherever they have been laid down, remove both rain and sewage—but every effort is made to exclude night-soil from the sewers. The Halalcore System, which has prevailed for so many years in this town, and has been brought to so great a state of perfection by the indefatigable energy of the present Health Officer, Dr. Hewlett, demands special notice at my hands.

It is a system for the removal by hand of all solid human excrementitious matters from the precincts of the town. The night-soil is collected from the privies at the backs of the houses every morning in baskets by men and women sweepers, who convey it on their heads to certain central stations, where carts are waiting to carry it off to the Main Dépôt at Chinch Bunder. These carts are merely iron boilers on wheels, and they are so constructed that the contents can be almost hermetically sealed up. A man stands by the side of the cart and empties the baskets into the boiler. When full, the mouth of the boiler is closed by a lid tightened by means of a screw and handle, and the

boiler is sprinkled over with disinfecting powder. Theoretically, there should be no smell from the carts, and sometimes there is none ; but, practically, the presence of a cart in a street is almost invariably made known by a very distinct effluvium, and when a string of these carts passes through the town there can be no question of the nuisance produced.

At the Main Dépôt at Chinch Bunder is an underground reservoir built of masonry, and sufficiently large to contain all the night-soil of the town. In the roof of this reservoir are several trap-doors fitted with iron gratings. A cart is brought to the spot and placed over one of the doors, and a valve in the bottom of the boiler is opened. The night-soil then drops on to the grating, and a man, armed with a long broom, keeps working it about and forcing it through the bars of the grating till nothing but a few stones and pieces of brick or wood, or other refuse, are left. It is in order to exclude these from the reservoir that the gratings are required. At the same time that the boiler is emptying itself, a man with a large hose is directing water on to the night-soil, which becomes more liquid than it is in its natural state, and thus escapes all the more easily into the reservoir. When the boiler is nearly empty it is cleaned and scoured out with water from the hose, and at the same time the floor of the ground is sluiced all over. The water thus used escapes into the reservoir, and serves still further to liquify the night-soil.

Connecting the reservoir with the sea in the harbour is a 12-inch cast iron pipe, and, when the tide is in ebb, the mouth of this pipe is opened and the contents of the reservoir escape by gravitation into the sea.

The effluvium in the neighbourhood of the outlet, and of the Chinch Bunder Dépôt, is perfectly sickening to an European, and such a nuisance would never be tolerated for a week in any English town. Indeed, it is marvellous how Bombay has put up with the existing state of things for so

long. That it can continue is impossible. It is opposed to the most ordinary feelings of our nature. The mere fact that the system demands that hundreds of men, and women too, shall be engaged for several hours of the day in handling the very filthiest matter that can be produced, is sufficient to condemn it. I say "handling," for this is the plain and unvarnished truth. The sweepers handle the night-soil just as a baker might handle so much dough.

Can it be necessary, in this age of mechanical skill, to employ human beings in this degrading occupation? If those who are advocates for the Halalcore System cannot find some method which does not necessitate actual contact with the excrement, then I think they will find it impossible to maintain the system much longer, do what they may at present to uphold their views.

Those of the Justices who may think my description of the Halalcore System overdrawn and exaggerated, will do well, before deciding on this subject, to examine it properly for themselves. I would beg them to spend an hour of the morning in the back gullies of the town, and to observe and note carefully what takes place at the privies—to accompany the sweepers, with their baskets on their heads, to the stations, and to note what takes place there—to follow the carts from the stations to the Main Dépôt, and to watch what takes place there. I venture to say that not ten of the Justices will be able to spend half an hour in the gullies, and not one of them ten minutes in the Chinch Bunder yard without feeling sick.

It may be all very well for some people to maintain that it does not follow because Europeans cannot stand it that natives are not able to do so. This is not the question. The question is, whether the whole system of the native—both his moral and physical nature—is not lowered and debased by it. If it is, then, I say, the consequences must be reflected on the general community.

Until the recent census was taken, and so long as the population of Bombay was reckoned at 850,000, it was generally believed that Bombay could compare favourably, in its sanitary condition, with the most healthy towns in England. But now, when the population has been ascertained to amount to no more than 650,000, the mortality-tables do not give us much cause for boasting.

Hitherto, moreover, the assumed healthy state of the town has, in great part, been attributed to the fact that no night-soil has been admitted into the sewers,—that it has been removed by an exceptionally good system of manual labour. I have never been of the opinion that the supposed good health of the town could be due to the Halalcore System; but now that it is ascertained that the mortality in Bombay is much higher than that in those towns of England in which the water-closet system has been carried out to perfection, I am inclined to believe that this high rate of mortality is, in part, directly due to that very Halalcore System which is upheld by so many sanitarians.

The question of the removal of the night-soil of a town is an important one, but so far as any general system of sewerage is concerned, it does not affect the latter at all. For many years have I tried to make this clear to the public. Whether night-soil is admitted into the sewers or kept out of them, the sewers need not be made any larger or smaller. The night-soil forms an inappreciable fraction of the total quantity of sewage;* so that, if the sewers are made large enough to carry off all the rest of the sewage, they will practically be large enough to carry off the night-soil in addition. This being the case, it follows manifestly that the

* The average quantity of night-soil produced per head per diem may be taken, according to the most eminent authorities, at about $\frac{1}{4}$ lb. Suppose the water-supply of a town is 10 gallons (100 lbs.) per head per diem, which is about that of Bombay, and suppose half this quantity escapes into the sewers; then the night-soil will be just $\frac{1}{200}$ th part of the whole of the sewage.

consideration of a sewerage scheme for a town need not be hampered by the question of the removal of the night-soil. Whether the night-soil is thrown into the sewers, whether it is carried into them by the water-closet system, or whether it is excluded from them altogether, the town must have a sewerage system. But as it would be all the better for that system if the question of the removal of the night-soil were considered simultaneously with it, the engineer is bound to state his views on the subject.

Not being an advocate for the present Halalcore System, I will point out the great objections to it.

In the first place, the night-soil is removed only once a day—between half-past four and eight in the morning. It is clear, therefore, that a large quantity of the filthiest matter must lie about from nine to eighteen hours of the day, giving out the foulest exhalations. To satisfy oneself that this is the case, it is only necessary to visit the gullies at the backs of the houses at any hour after the sweepers have done their work. It will be found that every privy has more or less ordure in it awaiting removal. Can it be conducive to the well-being of the people to keep excrement in the precincts of their dwellings all the day long?

In the second place, it is impossible to remove all the night-soil from a privy by hand. Theoretically, the halalcore sweeps up all he finds; but, practically, a sufficient quantity is left behind to create as great a nuisance as before. In order to prove this to one's satisfaction, it is only necessary to visit the gullies at that hour—say nine in the morning—when every privy ought to be clean and inoffensive; when, in fact, it has just been swept and made clean by the halalcores. My experience is that the privies are very little less offensive at this time than at any other. The very processes of sweeping and removing such foul matters create and intensify the nuisance which they are intended to prevent.

In the third place, I am of opinion that the back slums

of no town in England in which the water-closet system prevails are so offensive as the gullies of Bombay ; and I have had some experience on this point. With all its inconveniences, the water-closet system does, at all events, remove the night-soil from the dwelling immediately after it is produced ; but this can never be the case where manual labour is employed for the purpose.

In the fourth place, simply by excluding night soil from sewers, while every other kind of abomination is permitted to enter them, we do next to nothing to purify the sewers, while, at the same time, we burden ourselves with the cost of a special system for its removal. Sewage is almost, if not quite, as offensive without night-soil as with it. In those towns in England where the night-soil has been kept out of the sewers by the adoption of some of the so-called dry systems, it is not found that the sewage at the outfall is at all less offensive than in other towns where the sewers remove human ordure. In fact, it is impossible from an examination of the sewage, to say whether it contains night-soil or not. The truth is, that, as compared with the large quantity of other foul matters which run in sewers, the night-soil is but a small portion of the whole, so that its being thrown into or kept out of them is a matter of little or no moment.

In the last place, the cost of the Halalcore System is very great. Taking it at 2 lacs per annum, this amounts, at 5 per cent. to a capital of 40 lacs, or £400,000. If the cost of any Sewerage Scheme were supplemented by such a sum, a most complete water-closet system might be carried out throughout the town, and sufficient water be brought in to make it effective.

Such being my views on the general questions of sewerage and removal of night-soil, I will now proceed to point out what has already been done in this direction for the health of the town of Bombay.

CHAPTER II.

SCHEMES OF DRAINAGE AND SEWERAGE
ALREADY PROPOSED.

It is no intention of mine to give the Justices a history of all that has previously been proposed with regard to the drainage of the town. Even if I had the wish, I have not the materials for the purpose. At the same time, it is necessary, for the proper understanding of the subject, that the Justices should be informed of the main features of such schemes as have from time to time been put forward. And by schemes I mean complete engineering projects for drainage, not mere proposals to remove local nuisances or to drain particular districts. I mean comprehensive designs treating the subject as a whole.

Practically, then, there have been only four schemes suggested for the drainage of Bombay. The first was put forward by Mr. Tracey in the year 1861. The second was proposed by Mr. Aitken in the year 1866. The third was proposed in 1868 by Mr. Rawlinson, C.B., the eminent hydraulic and sanitary engineer in England, to whom Mr. Aitken's Report was submitted by the Secretary of State for India. This is the scheme subsequently amplified and worked out by me in the latter part of the same year. The fourth scheme, if it can be called by this name, was that proposed by Mr. Sowerby, of Surat, in 1868, while I was engaged on the previous one.

MR. TRACEY'S PROJECT.

Mr. Tracey, a man of considerable ability, but who unfortunately died shortly after submitting his report, and before he could mature his project, went into the subject of drainage very comprehensively. His system was practically based on that carried out in London, and it may well be termed the Intercepting System. The higher parts of the town he proposed to drain by one set of sewers, the lower by another. He was opposed to the utilization of sewage. He thought that the experiments which had been carried out on the flats eight years before by Mr. Conybeare showed conclusively that sewage could not be applied to land without creating a great nuisance; and he was of opinion that, excepting in one case, viz., that of Leicester, the application of sewage to land had never been successful. When Mr. Tracey wrote, the subject of sewage utilization was in a very different state to that in which it now is, and it would be rash of any one to repeat his assertions. At the same time, it must be remembered that eleven years ago there was much to bear out his view of the subject.

Mr. Tracey considered that Bombay had the option of only two outfalls—the western coast and the harbour. He was opposed to Back Bay, probably because it was a confined inlet, and one from which the sewage would never be able to escape entirely; and we may assume that he was opposed to taking it northwards, because he did not think it could be applied to land.

The reasons Mr. Tracey gave for rejecting the western coast for the outfall were—1stly, that the western side of the island was the windward side; and, 2ndly, that the sewage would not be carried away from the town effectually

if it were discharged in this direction. He thought the wind, blowing as it does for about eighteen hours of the day from the west, would not only bring the effluvium to the town, but that all the roads along the western coast—those most resorted to for the purposes of health—would be contaminated by the smell from the floating sewage, great part of which would probably be deposited on the shore. On the other hand, he thought that none of these objections could be urged against the discharge of the sewage on the harbour-side of Bombay. The harbour was to the leeward of the town, and any sewage thrown into it, when the tide was in ebb, would be carried right away to the open sea in about an hour and a half, and could never return to create a nuisance either to the inhabitants or to the shipping. In addition to these advantages, Mr. Tracey considered the harbour to possess others from a special engineering and constructive point of view. He said:—

“The difference in length of main sewer alone, from centre of main drainage area, is as 18 to 25 in favour of the harbour; and the fall, and consequently the lift for the sewage from the low levels, is in almost the same ratio. Gravitating drainage to the west would be impossible, except on the present intermittent system, which it is the object of this Scheme to avoid. By eastern outfalls, however, the gravitating sewers we are about to propose will drain at least one-third of the urban area of the Native town, and may possibly, on more detailed investigation, be made to drain nearly one-half of the present urban area.”

Mr. Tracey, moreover, thought that the outfall-works could be not only constructed much more easily on the harbour side where there was still water, but that the works would be far more secure than if placed on the western coast, where they would have to resist the action of the heavy seas which prevail during the monsoon.

Having thus decided on the harbour for the outfall, Mr.

Tracey discussed the question of the mean inclination to be given to his sewers, and he fixed this at 1 foot in 500 for his gravitating sewers, and at 1 foot in 750 for his low-level ones. On these data he proposed to drain the town into the harbour at two points. The first was situated at Wady Bunder to the south of Mazagon, and the second at Carnac Bunder—close, in fact, to the spot where the present outfall of the night-soil pipe from the Chinch Bunder Dépôt is placed. All the low-level sewers—draining Dhobee Talao, Commatteepoora, Girgaum, &c.—were to discharge at the former outfall. The gravitating sewers were divided into two systems—one, draining Oomerkharee, Tarwaree, and Nowrojee Hill, was to discharge at Wady Bunder; and the other system, draining Mandvee, Sonapore, and the Market District, was to discharge at Carnac Bunder.

The fort was to be drained into the harbour by a special system of gravitating sewers not connected with any other part of the town.

Mr. Tracey suggested that the soles of the gravitating sewers at the outfalls should be placed at 2 feet below high-water, or 13 feet above low-water mark; but, in the absence of sufficient information to enable him to come to a positive conclusion on the subject, he thought it possible that some modification of his proposition might require to be made subsequently. He felt certain, however, that the soles of his gravitating sewers could not be put at high-water mark without increasing the area to be drained by the low-level sewers to such an extent as to render the scheme practically impossible.

The soles of the low-level sewers were to be put at 23 feet below extreme high-water mark, and, as already mentioned, only sewage—no surface-drainage—was to be admitted into the channels.

As the sewage would have created a nuisance if it had been discharged into the harbour while the tide was in flow,

Mr. Tracey proposed to pond it up for eight hours of each day in four large reservoirs, each 500 feet long, 50 feet wide, and 10 feet deep; and, to pump up the sewage from these reservoirs into the harbour, he provided three engines, each of 100 horse-power.

The cost of the entire Scheme was estimated at Rs.33,20,000, or £332,000.

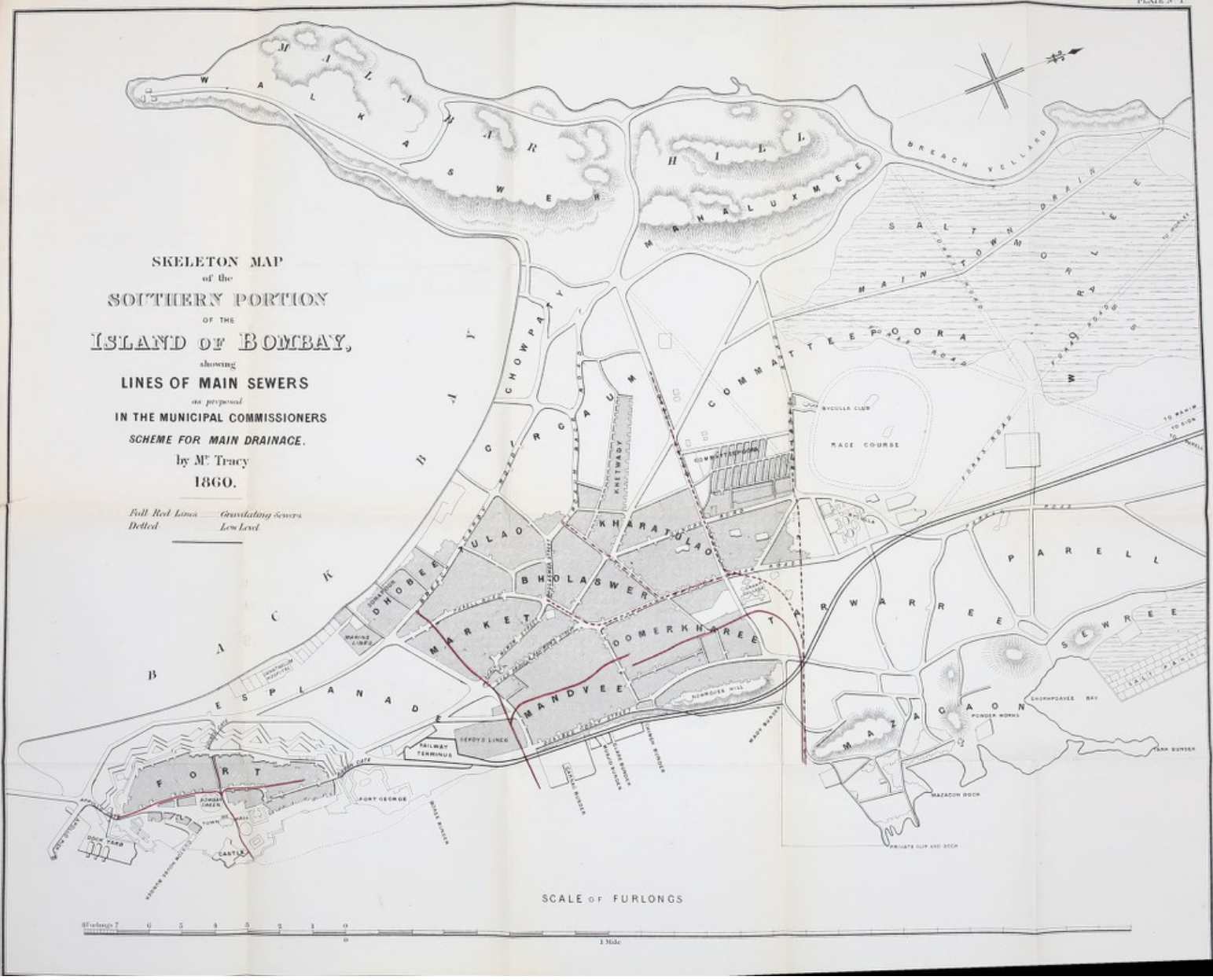
MR. AITKEN'S PROJECT.

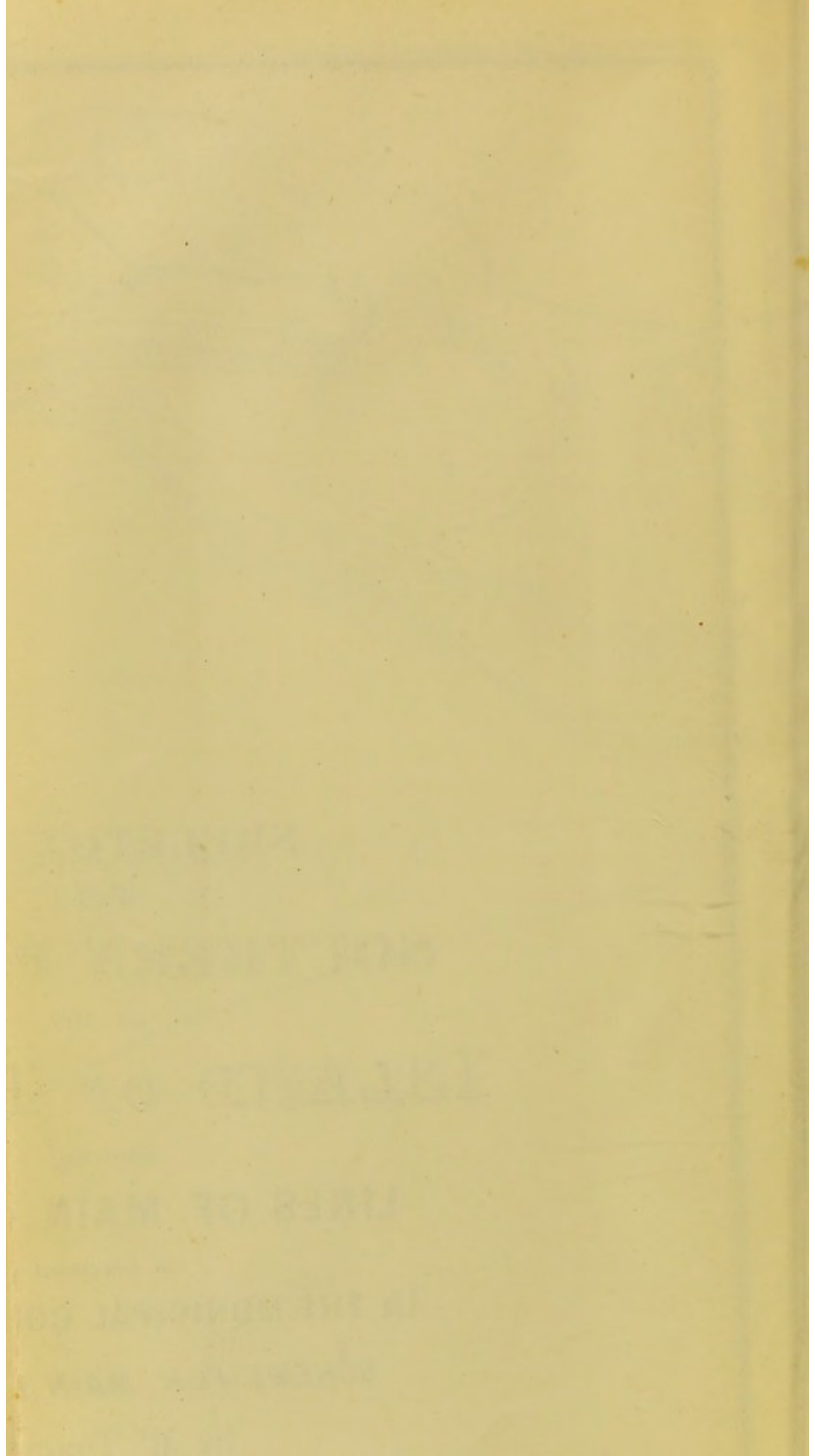
Mr. Aitken's Scheme, also, was one for discharging the sewage into the harbour, and he likewise based his system on that adopted for the Main Drainage of London.* He was opposed, however, to placing the outfalls so far north as those fixed by Mr. Tracey. He considered that, if the sewage were discharged either at Wady Bunder or Carnac Bunder, it would prove a nuisance both to the town and shipping, and he therefore removed his outfalls more to the south. He suggested three spots—the first was opposite to the Oyster Rock, the second was at the extreme end of Colaba and close to the Lighthouse, and the third was on the "Prongs," out in the sea. He recommended the Oyster Rock, or the northernmost outfall; but a Commission appointed by the Government having selected the Lighthouse outfall, Mr. Aitken prepared his designs accordingly.

* "The general nature of these Drainage Works will be similar to those which have lately been completed by the Metropolitan Board of Works for the Main Drainage of London."—Page 13, Mr. Aitken's Report.

SKELETON MAP
of the
SOUTHERN PORTION
OF THE
ISLAND OF BOMBAY,
showing
LINE OF MAIN SEWERS
as proposed
IN THE MUNICIPAL COMMISSIONERS
SCHEME FOR MAIN DRAINAGE.
by M^r Tracy
1860.

Full Red Lines — Gravitating Sewers
Dotted — Low Level





Taking the population at 816,000, he was of opinion that the sewers should be made large enough to carry away the sewage of a prospective population of about double this number, or of one and a half million people. He was opposed to the separation of rainfall and sewage. He thought such a system impracticable. His proposition, therefore, was to provide sewers capacious enough to carry away both ; but, considering that so large a portion of the town lay at a very low level, he proposed to let as much of the sewage and drainage as possible escape into the sea by gravitation, and to pump up only the remainder, or that portion which could not by any means be disposed of in that way.

For eight months of the year, while there was no rain, all the sewage was to gravitate towards Colaba, where it was to be pumped up into reservoirs, and discharged into the sea at high tide. But during the monsoon the high parts of the town, viz. Mazagon, the district about Doongre Coolee Street, the Fort, the Esplanade, Sonapore, and Chowpatti, were to be cut off from the main-sewer running to Colaba, and the drainage and sewage from these districts were to be discharged into the harbour and Back Bay. The engines at Colaba during the monsoon were thus to have pumped the sewage and drainage of only the low districts about Bholeshwar and Commatteepoora.

Mr. Aitken did not think that the sewage discharged into the harbour and Back Bay during the monsoon would be a nuisance. He was of opinion that it would be so diluted that all chance of its proving obnoxious would be destroyed.

With the object of placing his main-sewer as high as possible, and in order to avoid having to pump more than necessary, Mr. Aitken thought it was essential to the proper drainage of Bombay that the very low-lying district enclosed by the Bellasis Road, the Duncan Road, the Girgaum Back Road, and the Breach Candy Road, should be raised by filling up the area (150 acres) with earth three feet deep. He

reckoned that this would enable him to place his sewers three feet higher than he could otherwise build them. Indeed, so important did Mr. Aitken consider the raising of this land for his Drainage Scheme that he said it was not practicable to get rid of the monsoon waters without. In fact, it was the centre of his scheme, on which all his plans and estimates were based.

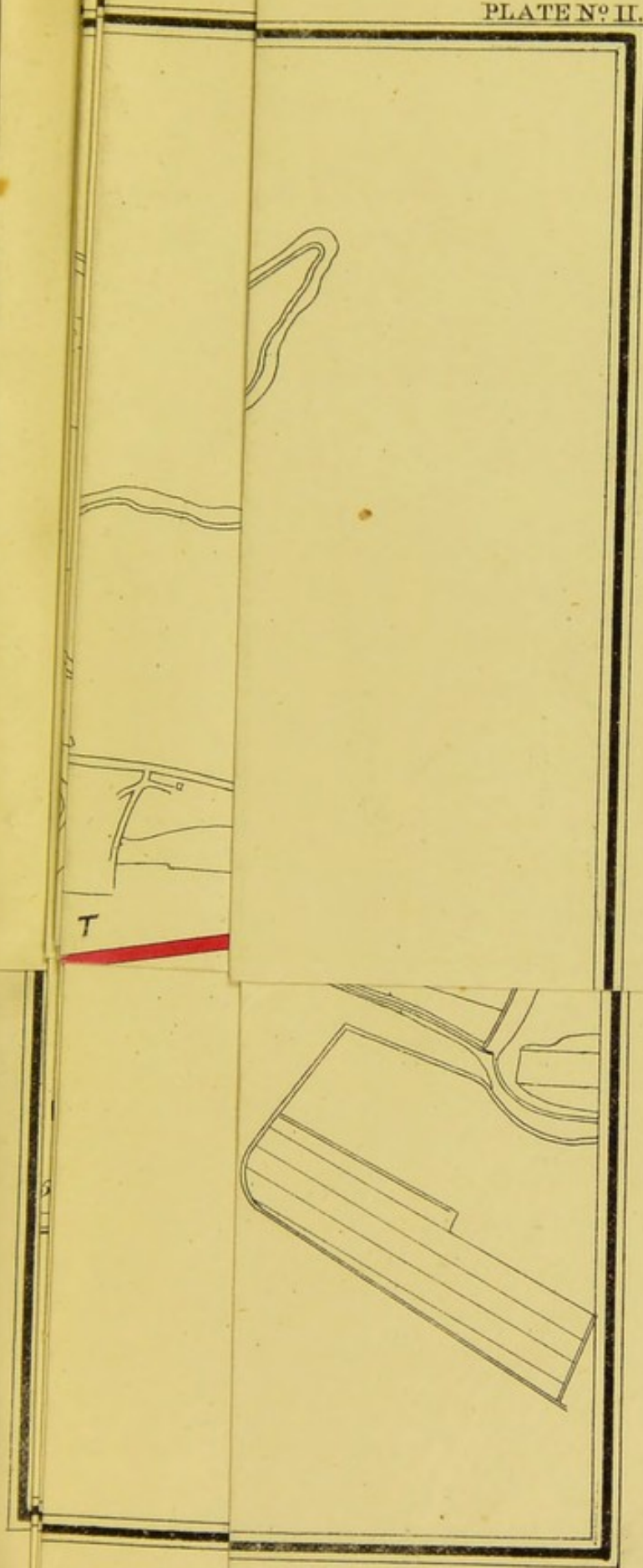
The main sewer to Colaba was to have been 10 feet in diameter, and laid at a slope of 2 feet per mile, and, in order to get a better direction than the existing streets in the town admitted of his obtaining for it, Mr. Aitken proposed the construction of an entirely new highway, which was to be 60 feet wide, and to run through the heart of the town.

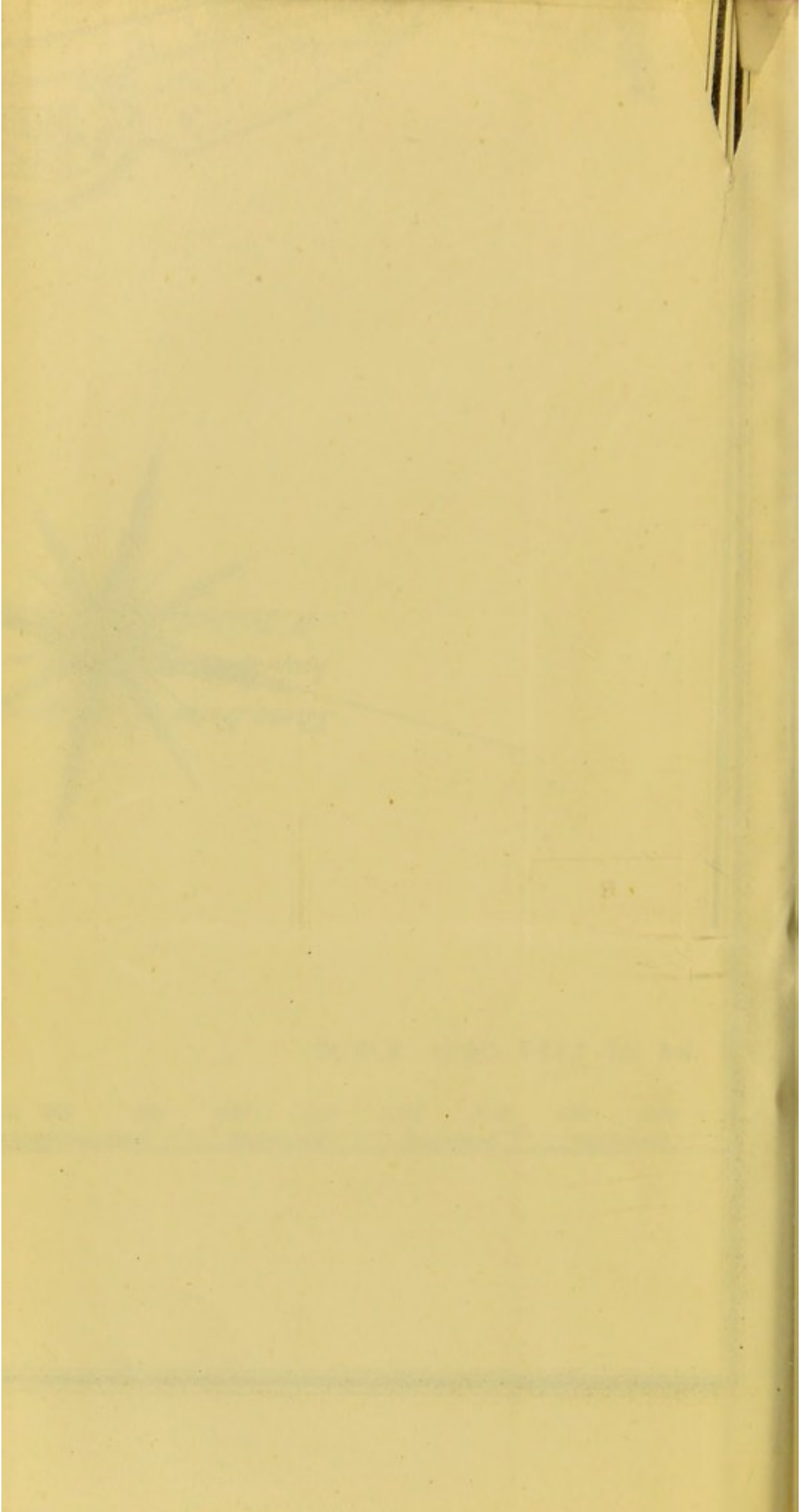
All the intercepting sewers—*i.e.*, all those which were to have discharged the mixed sewage and drainage into the harbour and Back Bay during the monsoon—were to have been made large enough to carry away 8 inches of rainfall in twenty-four hours. But as it would have been impracticable to construct the main-sewer to Colaba, to remove such an amount of water from even the 150 acres of ground proposed to be raised, Mr. Aitken intended that his main sewer should be only large enough to remove 2 inches of rain in twenty-four hours, or $\frac{1}{12}$ th of an inch per hour, and the ponding reservoirs at the outfall were to be made large enough to hold this quantity.

The sewage was calculated at 20 gallons per head per diem for 900,000 people, and the reservoir was to have an area of four acres and a depth of 12 feet. During the fair season a maximum engine-power of about 400 horses was to be used; but during the monsoon this was to be increased to 650 horses. The velocity of flow in all the sewers was to have been $2\frac{1}{2}$ feet per second, or $1\frac{3}{4}$ miles per hour, in the monsoon; and from $\frac{3}{4}$ of a foot to 1 foot per second in fine weather.

All those sewers which were to have discharged into the main-sewer were to have been provided with overflows, and

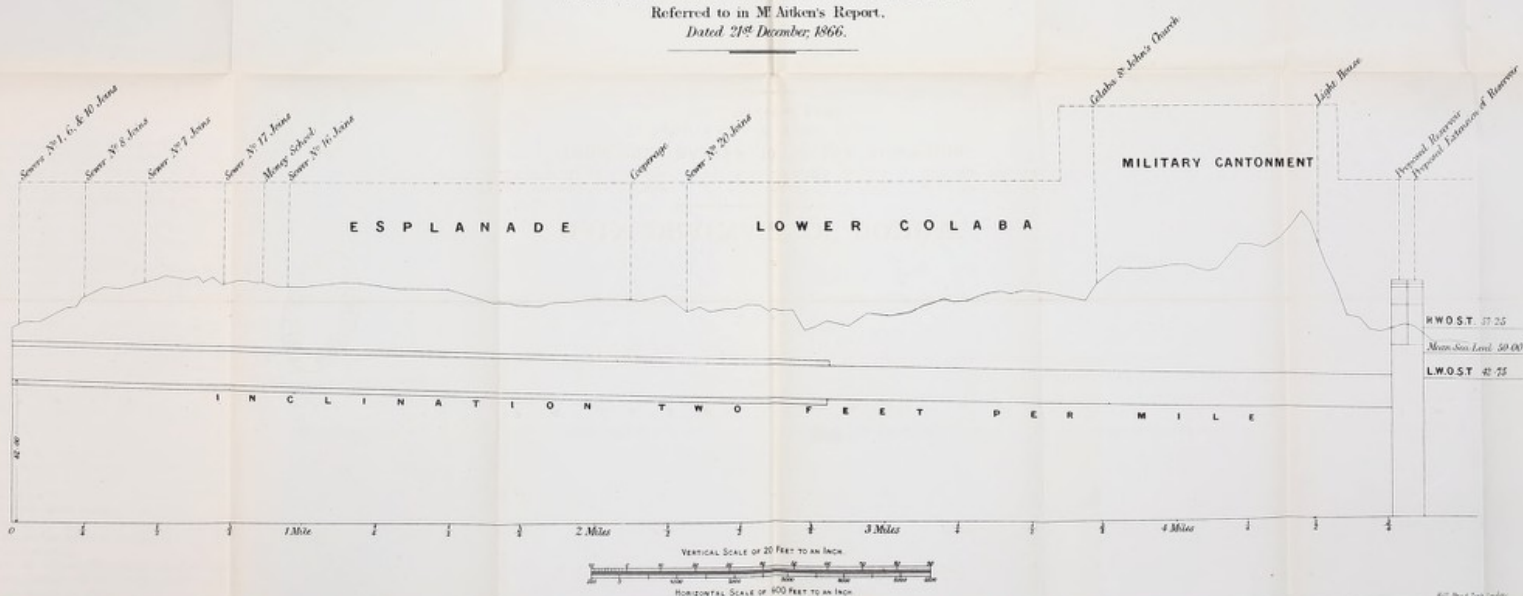
PLATE N^o. II.

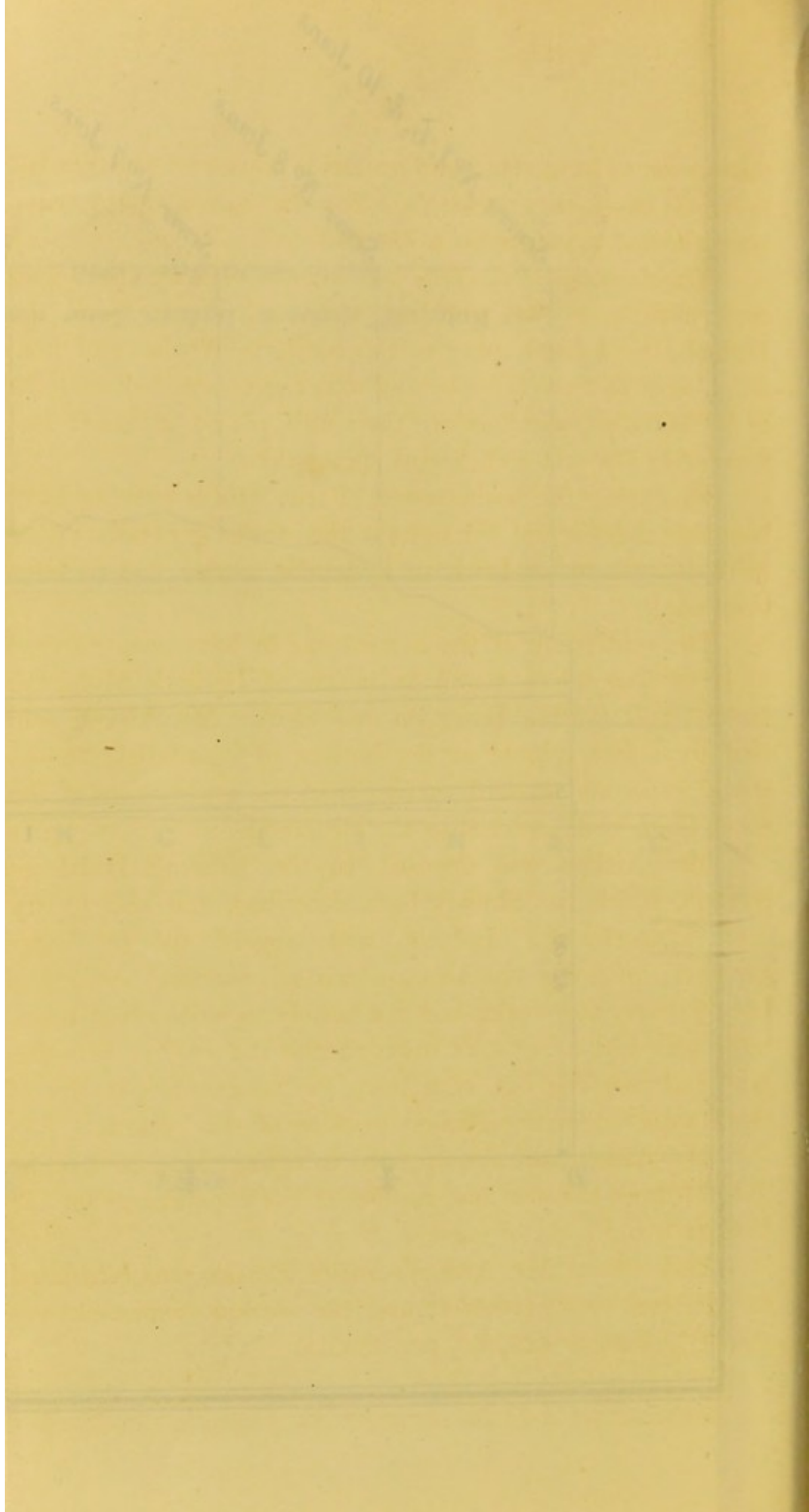




Note, Mr Aitken's Datum Line was 50 Feet below mean Sea Level.

MAIN DRAINAGE OF BOMBAY. SECTION OF MAIN SEWER, FROM NULL BAZAAR TO COLABA RESERVOIR. Referred to in Mr Aitken's Report. Dated 21st December, 1866.





these were to have come into operation whenever the rainfall exceeded two inches per diem. The sewage was then to have been allowed to escape on to the flats.

The drainage of the flats was to have been effected by an open cutting, 60 or 100 feet wide, extending from the Bellasis Road right away to the north to Worlee, and here there were to have been several sluice-gates erected, each 15 or 20 feet wide, and having their cills placed at about two feet below low-water of lowest spring-tides.

Excepting the main sewer, all the others were to have been egg-shaped, and throughout the works generally either brick in cement or brick in hydraulic mortar was to have been used.

The ventilation of the sewers was to have been effected by screw-fans driven round by means of Barker's Mills, the turbine and the fan being on one shaft. Mr. Aitken said that these fans, placed at the bottom of ventilating shafts, would cause an upward current from the sewers even if the air in them were cooler than the air outside.

Mr. Aitken was opposed to the existing Halalcore System, which has already been described, and also to dry earth conservancy. Indeed, with regard to the latter question, he holds the views which all practical men, who have to carry out works, and not merely to write about them, must arrive at as soon as they go into the cost of bringing into and carrying out of a town the enormous quantity of earth required for the efficient working of this system.

Mr. Aitken was also opposed to sewage irrigation, as he did not think the previous results of the experiments on the flats gave any hope of success.

The cost of Mr. Aitken's entire Scheme was calculated at 110 lacs, or £1,100,000; and the working expenses were put at $2\frac{1}{2}$ lacs, or £25,000, per annum.

MR. RAWLINSON'S PROJECT.

In the latter part of 1867, Mr. Aitken's Report was forwarded by the Secretary of State for India to Mr. Robert Rawlinson, C.B., who went carefully into the subject.*

Mr. Rawlinson thought that the very facts which had been brought forward to show that the sewage would not return to the harbour if it were discharged at Colaba, proved, on the contrary, that there was every likelihood that the harbour would be polluted by the return of the sewage. He pointed out the immense importance to a town like Bombay, which owed its position to its magnificent harbour, of keeping the latter free from contamination ; and he thought it hazardous to carry out an experiment which had failed in so many English towns situated on the sea. He recommended that the sewage should be taken right away to the north of the island, and should then be utilized on land far away from all the inhabited districts. The information placed before Mr. Rawlinson was not sufficient to enable him to do more than sketch out the main features of his scheme, but these were distinctly explained.

As nearly the whole of the town sloped towards the flats, that was in his opinion the direction in which the sewers should be laid, and from the flats he considered the sewage should be carried northwards to the land best suited to its application. The flats were to be relieved by a proper system of sluices. Mr. Rawlinson left the details of this scheme to be worked out on the spot, as he was of opinion that no one without a thorough examination and personal knowledge of the town could specify in detail the exact nature of the works.

* I am compelled to give only an outline of Mr. Rawlinson's scheme, as I have not succeeded in getting a copy of his Report ; unfortunately it was sent to Bombay in original, and no copy was retained in the India Office.

In July, 1868, the Secretary of State for India directed me to proceed to Bombay, and the Municipality consulted me on the subject. While I was engaged in preparing my scheme, Mr. Sowerby, of Surat, submitted his project, and this was forwarded to me for report.

MR. SOWERBY'S PROJECT.

Mr. Sowerby proposed that—

“In order to meet the peculiar circumstances of Bombay, with its heavy rainfall at certain periods, it would be advisable to have a large and open canal carried along the middle of the island from Back Bay to Mahim. This canal should communicate with the sea at Back Bay and Mahim, and have two or three branches connecting it with the harbour at various suitable points. It should be of considerable width, say 150 to 200 feet, and of depth enough to admit of laden barges, forming a canal of navigation, the excavation to afford sufficient material to raise and reclaim the adjacent low-lying ground on either side, so as, in a great measure, to repay the cost of formation. This canal would form a perfect catch-water drain for all surface rain-water, and to prevent its becoming stagnant, by a proper arrangement of sluices at each end at the branches, a continuous stream could be kept passing through it. Alongside of this canal should be two intercepting sewers of sufficient capacity, one on each side of the canal. Two small sewers would be better than one large one, owing to the expense of construction and the convenience of forming junctions. The whole of these sewers should be as low as possible, so as to get a natural outfall towards the north and to take advantage of the head of water in the canal for the purpose of flushing, if need be.”

... "If it was found necessary to let the sullage fall into the sea, as it would probably be, then at about half-tide, or earlier, a body of water could be obtained from the canal and basins attached to it to flush the sewage rapidly away."

... "An alternative plan would be to have no intercepting sewers alongside the canal, but to have the main drains all running at right angles to it and emptying themselves into the harbour at one side and the sea at the other—something similar to the plan proposed by Mr. Tracey, using the water from the canal for the purpose of flushing the drains to the right and left. This plan, however, would most probably not be so good as that of carrying the whole body to the north alongside the canal, there to be disposed of for irrigation purposes, if possible, or swept into the sea at a point far away from Bombay."

I reported against this scheme. Indeed, in justice to Mr. Sowerby, I assumed, and it turned out subsequently to be the case, that he could not have had a personal knowledge of the features of Bombay, or he could never have made, what every one at the time thought, and what most must still consider, such impracticable propositions.* It is quite unnecessary for me to go further into this subject, as my doing so could answer no useful purpose. No engineer whom I have ever met in Bombay has thought the question worth consideration. Canals are bad enough in the towns of Holland and other countries where it is impossible to dispense with them; but the proposition to intersect Bombay, with its population of nearly three-quarters of a million, in all directions by huge canals, is sufficient to condemn any scheme. Every canal would be a mere cesspool, a receptacle for all the filth of the town, and a work impossible to cleanse.

* Mr. Sowerby himself, in a long rejoinder on my criticisms, actually made the admission that his scheme had been prepared without even a proper plan of Bombay!—*i.e.*, one with the levels of the different localities marked on it.

THE PROJECT SUBMITTED BY MYSELF IN 1868.

The project which I submitted to the Municipality was the same as that proposed by Mr. Rawlinson, but worked out in considerable detail.

I was opposed to the sewage being discharged on the eastern shore, because I thought it most unwise to permit the slightest pollution of the harbour. I proposed to drain the town in the direction of the flats, and to effect a complete separation of the drainage from the sewage. The drainage was to be allowed to escape through the existing sewers in the direction in which the different localities sloped, and a new and complete system of sewerage was to be provided for the sewage, properly so called. I pointed out that the numerous propositions which had, from time to time, been put forward to raise the flats, without at the same time raising the low parts of the town, and also enormously increasing the discharging capacity of the sluices, would cause the town to be flooded,*—that the flats, being the lowest parts of Bombay,

* I wish the Bombay public would master this fact, which is as clearly demonstrable as a proposition of geometry. In order to render the matter clear, I will give a second explanation. The flats are the lowest part of the island, and in very heavy rain the water collects on them, and in the low parts of the town, much faster than the present sluices can discharge it into the sea. Besides this, the sea is, during many hours of the day, at a higher level than the water on the flats and in the town. During these hours the floods cannot escape at all. Now, just suppose that the flats were to be raised, and the low parts of the town were to remain at their present level, and also that the present sluices were not to be enlarged. What would be the consequence? Surely the water—as it could not escape fast enough through the sluices, and could not escape at all during those hours of the day when the sea was above the level of the floods—would collect in the lowest part of the island. The flats being raised, the low parts of the town would become the lowest part of the island, and the water must collect in them. If, therefore, it is proposed to raise the flats, the low parts of the town must also be raised, and the sluices must be enormously enlarged, so as to discharge between the falling and rising of every tide all the rain which can possibly find its way to them.

and below high-tide level, the rain in a heavy monsoon collected on them, and could not possibly escape during those hours when the sea stood at a higher level than the floods. This being the case, I showed that the water must collect somewhere, and that, if the flats were raised so that they became higher than the low parts of the town, the water, instead of stopping on the flats, where it was doing comparatively little harm, would flow to the town, where it would, on the contrary, do considerable mischief. Under these circumstances, I recommended that the idea of raising the flats should be abandoned—that the sluices should be enormously enlarged—enlarged, indeed, to such an extent that the heaviest floods might be discharged into the sea in a single day during those hours when the surface of the sea fell below the level of the surface of the water on the flats. I proposed that three sluices, each 120 feet long, should be provided, and I considered that, if this were done, not only the town but even the whole island would be relieved of floods of 14 inches of rain in twenty-four hours, this being the heaviest known rainfall in Bombay.

With regard to the sewage proper, I proposed that this also should be taken towards the flats, but by an entirely new system of sewers into which no rainfall was to be admitted. The main sewer was to terminate at the present Pumping Station at Love Grove, where the sewage was to be raised by engines of 500 horse-power, and to be carried in iron pipes to the north of the island, and ultimately to be utilized on land.

An examination of Plate IV. will give the reader all the information he may require.

The entire cost of this double scheme of drainage and sewerage was estimated by me at Rs.75,00,000, or three-quarters of a million sterling; and this sum included Rs.22,00,000, or £220,000, the cost of a complete system of sewage utilization.

REPORT OF THE GOVERNMENT COMMISSION OF 1869.

After the issue of my Report, a controversy arose between Mr. Russel Aitken, the Executive Engineer of the Municipality, and myself; but it is unnecessary for me to go into the subject of dispute.* At this stage the Government stepped in, and appointed a Commission† to take evidence on the subject of my Project, and to advise them as to the measures which should be adopted in the future. The main conclusions at which the Commission arrived were as follows:—

They approved of the separation of drainage from sewage, but objected to the drainage being discharged into the sea on the western coast. They were of opinion that it should be removed “to as great an extent as the levels will permit by gravitation direct into either Back Bay or the harbour, and that no rain and storm waters—which it is possible to divert by either the construction of new underground-channels, or by surface-drains—should be allowed to pass down through the present drains on to the flats near Beach Vellard.”

On the subject of sewage, the Commission said that, as the leading feature of my project was to pump it into the sea on the western coast, they considered the scheme objectionable on engineering grounds.

* Those who wish to study the question thoroughly should not fail to read Mr. Aitken's pamphlet, and my rejoinder. They will find a great deal of information in the two papers. Mr. Sowerby also published a pamphlet defending his scheme and criticising mine. This should also be read. I did not reply to Mr. Sowerby, as he did not bring forward any argument against my scheme which demanded refuting, nor could he possibly maintain his own propositions in the face of the obvious objections to them.

† It was composed of the following gentlemen:—President, the Hon. A. R. Scoble; Members, Colonel Kendall, R.E., Lieut.-Colonel Trevor, R.E., Doctor W. G. Hunter; Secretary, Doctor J. B. Lyon.

The Commission were, moreover, opposed to the Water-Closet System, and preferred the existing halalcore arrangements. They did not think, moreover, that it was possible to carry out dry-earth conservancy; and, while they recognized the advantages of sewage irrigation, they still thought it would be unwise to incur the large outlay which my project contemplated.

How such a Report could ever have been issued by a Commission, with two engineers sitting on it, is beyond my comprehension. To say that my project was not understood by them would be far short of the fact. Not only was it not understood, but it was rejected because, according to them, it aimed at doing what was in reality the very opposite of its object.

The Commission say,—

“They cannot concur with my proposal to carry off the rain-water by the present underground drains to the present main drain, by which it will be carried to Love Grove, *where it will be pumped into the sea.*”

The Commission have here confounded a proposition of mine to use the pumps at Love Grove during very exceptional floods,* in order to keep the town from being flooded, *with a proposition to pump all the rain-water every day into the sea.* The slightest consideration should have prevented them from making such a mistake. Why, I actually proposed to enlarge the present sluices at Love Grove, Worlee, and Daravee, which are now about 40 or 50 feet wide, *to a length of 360 feet!* What could these enormous sluices have been for but for letting the water escape into the sea by gravitation?

* Perhaps for one day in a year or so. These are my words—*vide* p. 14 of my Report—“In times of extraordinary storms (but not oftener, on the average, than once a year) the sewage for a few hours might, with hardly any nuisance, be pumped into the sea.”

After having made such very exceptional and special arrangements for a particular purpose, it is too absurd to find myself charged with proposing to do the very opposite of my real intention, according to which my estimates were framed.

But even this, bad as it is, is put into the shade by what follows. The Commission say :—

“As the leading feature of Captain Tulloch’s Project is to pump not only the storm-water, but the sewage of Bombay into the sea, the Commission consider that it is, in that respect, objectionable on engineering grounds.”

How is any engineer ever to hope that his views will be accepted if they are liable to be so utterly misrepresented as mine have been? The Government are told by the Commission that my scheme is objectionable because its *leading feature is to pump the sewage into the sea*, and in my estimate of 75 lacs of rupees, nearly one-third of it, viz., 22 lacs, is *for utilizing the sewage*.

In the conclusion of my Report, I actually took the precaution to state all the main objects of my scheme, and the sixth was put in these words :—

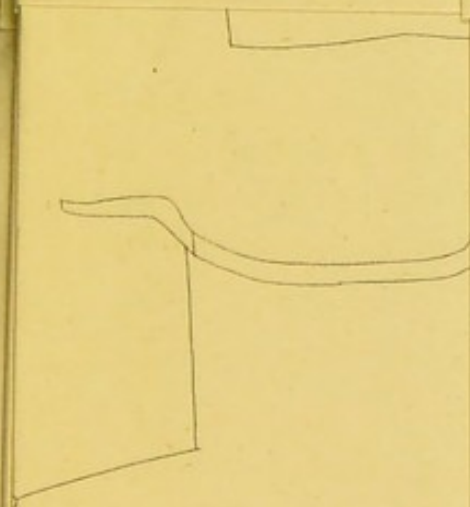
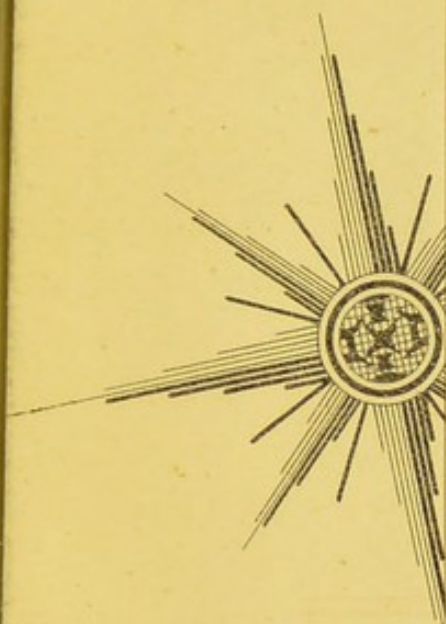
“Instead of being thrown away as worthless, the sewage will be utilized on land. Thus, what is rightly termed a source of wealth by the leading scientific men in Europe will be secured to the inhabitants.”

And after this the Commission inform the Government that I propose to throw the sewage into the sea! If the question of the drainage of Bombay is to be treated in this way, it would be far wiser to let it alone—to go on in our present course, which would not, at all events, entail the cost of the preparation of any projects nor the cost of Commissions to report on them.

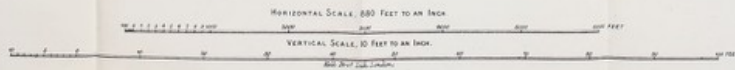
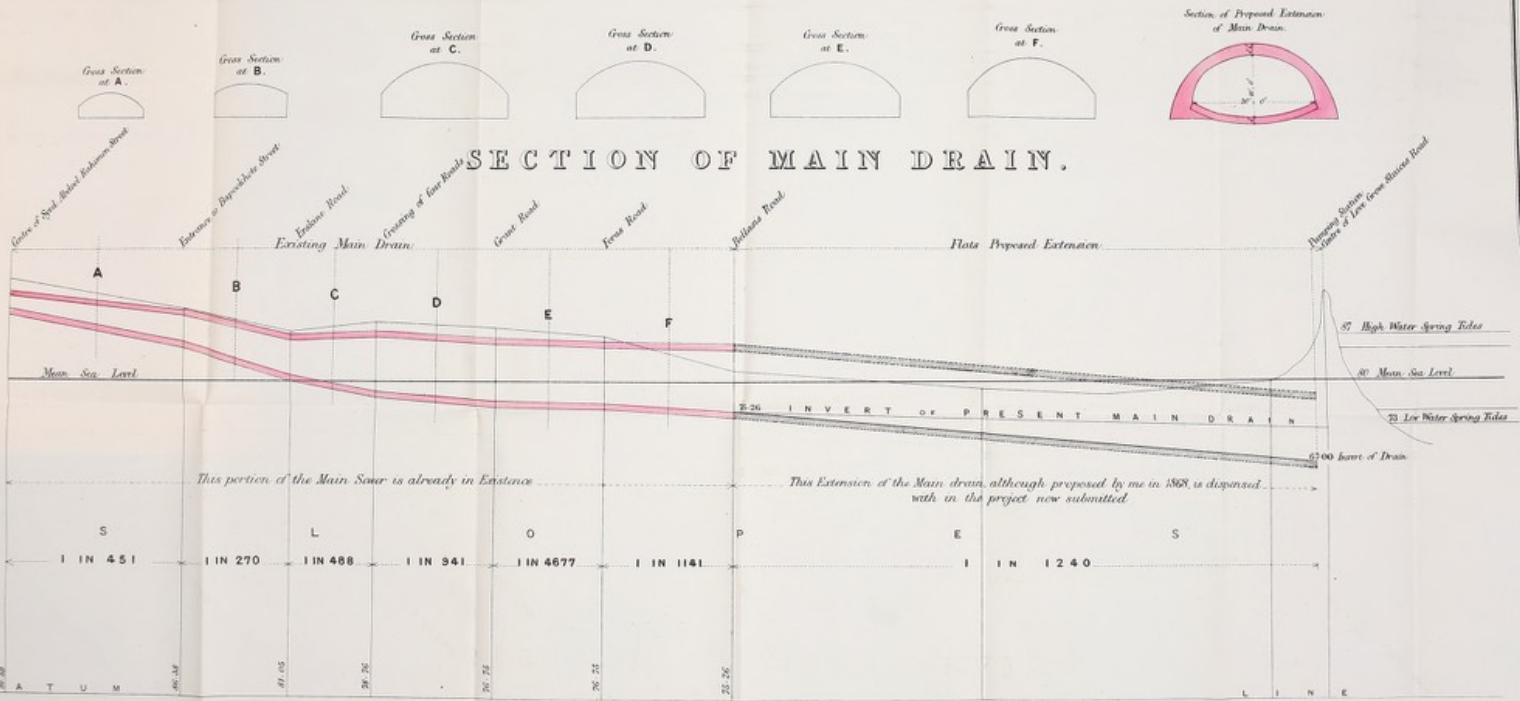
It is bad enough for the engineer to find his scheme

rejected on its merits, but to find it rejected on the ground that it proposes to do that which it has been especially designed to avoid, is, indeed, a severe trial.

How such ludicrous mistakes could have been made it is not for me to say ; but, considering the way in which my former project was explained to the Government, the Bench, and the public, I think I may claim to be heard once more. And in order that there may be no chance of misapprehension this time, I will not only explain what I propose to do, but also what I propose not to do.



SECTION OF MAIN DRAIN.



H. Lubbock
Capt. R.E.S.

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CHAPTER III.

THE PROJECT NOW PROPOSED.

THE DRAINAGE AND SEWERAGE.

I propose to allow all the rain-water falling on the island—not the sewage—to escape by gravitation into the sea. I do not propose to pump any portion of it at all. According to the slope of the different localities, so will the drainage be effected. No. 1 District, comprising the greater portion of the town and island, slopes towards the flats, and drains at present in this direction. It will continue so to drain; but instead of the sluices at Love Grove, Worlee, and Daravee, being of their present small dimensions, these works will be enormously enlarged.

No. 2 Drainage District, sloping as it does towards Back Bay, will be drained into it by gravitation through the existing sewers, which, having been found large enough for all practical purposes, will remain without alteration. If, in the future, they should be found inconveniently small, they can be enlarged.

So also with the 3rd, or Elphinstone Drainage District, which, as it slopes towards the harbour and drains into it at present, will continue to do so by gravitation, and the sewers need not be enlarged, unless further experience should prove such a measure to be necessary.

I trust now that the charge of proposing to pump the rainfall will not be brought against me, and that this project

will not be rejected on that ground at any rate, as my former one was.*

The present project is for utilizing the sewage proper, and not for throwing it into the sea on the western coast. Formerly I proposed to pump the sewage at Love Grove, and to send it to the north of the island in iron pipes. Now, I recommend that, instead of the main sewer stopping at Love Grove, it should be continued to the north of the island, and terminate at a point near Sion, where the sewage should be pumped up into a high-level sewer running across the swamps lying between the island and Trombay. The high-level sewer is to end on the land now being reclaimed by Dr. Hewlett with the dry refuse of the town. I propose that the sewage should be utilized at first on the north of the island, and on the newly-reclaimed lands; and that, if experience should hereafter prove that a nuisance is created by the use of the sewage on the northern portion of the island, it should then be applied only to the reclaimed lands, and to the lands lying to the north and north-east of Bombay. After use, and when it is comparatively pure, I propose that the sewage shall escape into the creek north of Trombay.

If a map of the country be referred to, it will be found that this region is seven miles from Bombay, and that there is not even a large village near it. The nuisance, therefore, which may be produced will not be felt by any one. Even such villages as there are might be bought up at a moderate cost.

* In order to show the extraordinary mistakes made by the Commission, it will be sufficient to draw attention to the following: They say, quoting Mr. Rawlinson, the great English hydraulic engineer, "Any attempt to provide large sewers to receive tropical storm-waters, and steam-power to pump the same, must either be most extravagantly costly or must fail, and the calculations made by Mr. Ormiston as to the expense of pumping confirm this view." It will hardly be believed after this that the Commission actually recommended that the drainage "should be removed to as great an extent as the levels will permit by gravitation direct into either Back Bay or the harbour; and that no rain and storm-waters which it is possible to divert by either the construction of new underground channels, or by surface drains, should be

THE REMOVAL OF THE NIGHT-SOIL.

With regard to the removal of the night-soil, I have already mentioned that I am opposed to the existing halalcore arrangements. I think the money spent on them would be far better laid out in bringing more water to the town and introducing the Wet System. But this will probably not be approved, and I have therefore, while explaining my views, thought it best at the same time to consider the following question. As Bombay refuses to alter the Halalcore System, what measures do you recommend in order to improve that system to the utmost degree of which it is capable?

At present all the night-soil is discharged into the harbour at Chinch Bunder, and all the garbage and refuse found in the streets of the town is removed by the G. I. P. Railway Company to the lands under reclamation, lying to the west of Trombay. No objection is made to the latter method of getting rid of our solid filth. In fact, those gentlemen, viz., Mr. Arthur Crawford and Dr. Hewlett, to whom we

allowed to pass down through the present drains on to the flats near the Breach Vellard."

I ask how is it possible to carry any of the drainage falling on No. 1, or the Town District (*i.e.*, the district which slopes towards the flats) to Back Bay or the harbour except by huge underground sewers—the very works to which the Commission expressed such a dislike! In fact, the Commission have proposed extensive works of the very nature which they condemn so strongly.

In order to satisfy himself on this point, the engineer has only to examine Mr. Tracey's and Mr. Aitken's projects, both of whom proposed to carry as much of the drainage and sewage of the town as they possibly could to the harbour side of Bombay. The number and sizes of the underground sewers are very great. In my project, I do not propose the construction of a single underground channel for the removal of rain-water, and the consequence is that I have only three small sewers which remove sewage only. The rain-water in my system escapes by gravitation through the *existing underground channels*.

are indebted for the present excellent arrangements, deserve the best thanks of the community. The difficult question which remains for solution is, how to get rid of our night-soil.

The Bench are aware that the Government have given them notice that unless the Chinch Bunder Depôt is done away with in a reasonable time, and the night-soil prevented from entering the harbour, proceedings will be taken to compel them to remove the nuisance. I need hardly say it would be hopeless to resist the Government at law. In ninety-nine cases out of a hundred, however exceptional may be the circumstances under which a great nuisance is produced in a town, courts of law invariably issue an injunction to remove it. The result, therefore, of a dispute with the Government would, in my opinion, be that the Bench would be compelled not only to do away with the night-soil depôt, but would have to pay all the law expenses of both sides. What is to be done therefore? The Bench will not dispense with the Halalcore System, and they must carry the night-soil elsewhere. This being the case, why should not the night-soil be taken to the same place to which the solid filth is conveyed—to the lands under reclamation to the west of Trombay, and why should it not be utilized there just as the sewage would be?

There are two ways in which this might be done. An arrangement might be made with the G. I. P. Railway Company, or the Bench might have a narrow guage railway of their own. Although I am not by any means opposed to the idea of the G. I. P. Railway Company undertaking the removal of the night-soil, I think it would be better if the Bench had a railway of their own, and the reason why I recommend this is, that in constructing this railway very little would be required but the iron for the permanent way and the rolling stock. On reference to Plate 7, it will be seen that the proposed main sewer will run from Bycullah right away to Sion. Now in constructing this sewer, a large

quantity of material, earth and stone, would be left after the trench in which the sewer would lie were filled up. This earth would form the embankment for the railway and the stone would form the ballast. The Bench therefore would have the embankment completed for the greater portion of the way at a very trifling cost.

An important question would be from what point should the railway commence and where should it end. I should prefer to begin it behind the Race Course, and to carry all the night-soil in carts to that spot; but Dr. Hewlett has pointed out to me that if this were done, he would require very many more carts than he has at present, and that under these circumstances it would be well to consider whether it would not be better to carry the railway right into the heart of the town. If it would, then I think there should be two branches from behind the Race Course, one running into Commatteepoora, and the other to Chinch Bunder. The construction of the former would be a very easy matter, as there are no engineering difficulties on the line. But the construction of the latter branch would require some skill.

I have examined the line very carefully, and find the best plan would be to start it from Chinch Bunder itself. After running in a tunnel under Doongree Coolee Street,* it would take a curve into Baboola Tank, which would be filled up with the material excavated from the tunnels, and then reclaimed. It is at present one of the foulest tanks in the town.† From Baboola Tank the line would start in a tunnel and run to the west of the Jamsetjee Jeejeebhoy Hospital, and, joining the main Parell Road, would run under it, then cross it to the

* *Vide* Plate VII. Unfortunately the plans for the railways have not been sent to me, so that I am unable to treat the subject except by description.

† When more water has been brought into Bombay it would be a great boon to the poor if all the tanks in the town were filled up and converted into washing-houses. The greater portion of the area of each tank might be kept open, but floored with asphalte and supplied with water from hydrants. A covered shed might be added for use during wet weather.

south-east of the Byculla Tank, and ultimately join the other branch-railway behind the Race Course.

If it were found advisable afterwards, the railway might be continued in tunnelling from Chinch Bunder to the Fort, so that all the night-soil from the latter district also might be collected and sent direct to the north.

The railways could also be used for passengers during the day in order to make them pay. It is here where the difficulty lies. Of course there would be competition between the G. I. P. Railway and this new line, and the Government, interested as they are in the former, would probably object to the latter, unless some kind of compensation were given for the loss of traffic. The new line might be made to run right into the heart of the Fort, and if this were done, it would induce a large number of people to travel by it. There is no engineering difficulty which cannot be overcome in the construction of an underground-railway to run from the flats through Byculla, the Baboola Tank, Doongree Coolee Street, across the Esplanade, and into the Fort.

From the Pumping Station at Sion the railway could be continued across the swamps on an embankment, which could be thrown up with material excavated from one of the small hills on the spot.* I am of opinion that it would be better not to incur the cost of conveying the night-soil beyond the Pumping Station, but to throw it at that spot into the high-level sewer, which would carry it to the irrigation fields without further trouble. But if this be objected to, there will be no help for it but to employ the locomotive engine up to the reclaimed land.

The great objection to the Halalcore System would still apply in a measure to the new arrangements, and it is on this account that I think the town would do better to adopt the

* None of the survey plans made of the line from the Pumping Station to the irrigation lands have been sent to me in England, so that in this case also I can only describe the works generally.

Wet System. At present, all the night-soil is collected at Chinch Bunder, and the nuisance is so great that the Government insist upon its removal. But remove it wherever we may, it must be collected somewhere or other previous to removal. It is the process of collecting it, not the act of removal, which constitutes the real nuisance. So that if we determine that no more sewage shall be thrown into the harbour, we must still fix upon some spot at which to collect it. Now, if we fix on a spot out of the town—say on the flats—the consequence will be that we shall require a great many more carts than at present, so that the cost to the town, instead of being reduced, would be increased. It already represents, as I have pointed out before, a capital at 5 per cent. of £400,000. If the cost is increased by half, which I think it is certain to be, the town would be spending on what I think an absurd hobby a capital of £600,000. Let it be remembered, too, that at present it is admitted, perfect as the halalcore arrangements are maintained to be, that only about half the night-soil is really removed from the town. If this is the case, the ultimate cost of the system promises to exceed a million sterling—a sum for which 20 gallons of water per head per diem for the present population might be delivered to the town.

If the proposition of a railway for the removal of the night-soil is not approved, I do not see how else we are to get rid of the filth, except by employing a steamer to take it every day out of the harbour and to discharge it into the open sea away from the influence of all tides. The collecting carts should be pulled right on to the deck of the steamer and be made to empty their contents into a large tank under the deck, but above the surface of the water. The discharge pipe should be fixed in the bottom of the steamer, so that when opened the sewage should the better mingle with the sea-water and not float on the surface. In this case, however, we should require a separate dock in which the steamer could

lie, and the deck of the vessel would have to be so constructed that no night-soil, accidentally escaping from a cart, could flow over the sides or into the water of the dock. If night-soil were allowed to fall over the deck, the Chinch Bunder nuisance would simply be repeated in another place. When the steamer was not employed, instead of remaining in the dock, it might be anchored in some part of the harbour where it would not be a nuisance to the shipping. It should be borne in mind that unless the steamer were well built, it would not be able to go out to sea in rough weather. At exceptional times, however, the night-soil might be discharged into some part of the harbour. No greater nuisance would arise than under the present system.

The advantage of employing a steamer would be that, for the most part of the day, we should be able to dispense with a Central Dépôt, which, from the great amount of filth brought to it, must always be the chief source of nuisance and danger. While the steamer was in dock and loading, the nuisance would of course be no less than it is at Chinch Bunder at present, but after she left the town, there would be, or rather there need be, if proper arrangements were made, no nuisance at all.

If neither the narrow-guage railway nor the steamer is approved of, then the best plan will be to come to an arrangement with the G. I. P. Railway Company; but as I have pointed out already, we shall still require a Central Dépôt at which the railway waggons would have to be filled, and this Central Dépôt will be nearly as great a nuisance as the one we have already in Chinch Bunder.*

* While suggesting so many different ways of removing the night-soil if the Halalcore System is to be continued, I am of opinion that the onus of improving the system, so that it shall not stink in our nostrils as it now does, rests with those who are advocates for it, and not with those who, like myself, are opposed to it. The former should not look to the latter to perfect the system for them.

THE UTILIZATION OF THE SEWAGE.

With regard to the utilization of the sewage, I am of opinion that the Bench should adopt the simplest methods. At this present moment so many patents have been taken out for the conversion of sewage into a saleable manure, that if I were to describe even those which find most favour with the English public, I should have to write a treatise on the subject. Fortunately this is unnecessary. The manufacture of manure in India cannot be successful until the system of agriculture is improved. What ryot or what land-owner in the neighbourhood of Bombay would ever pay for the manure a sufficient price to cover the expense incurred by the Bench? In England nearly all the most eminent chemists are agreed that it is not possible to make a manure from sewage which shall fetch a price in the open market to pay the cost of production. Many good manures can be made, and have been made, but the prices they fetch are not such as to encourage the manufacturers to continue their operations. Company after company has failed. Under these circumstances it would at present be the height of folly for the Bench to attempt the manufacture of manure on a large scale. There would be no harm in making experiments of an inexpensive kind, but even these I would discourage till the subject is better understood in England.

There is one process, however, which is not only the most original that has yet been put forward, but which has met with such extraordinary approval from all the chemists of the day, that I should not be doing right to omit mention of it.

Hitherto all the companies and all the chemists have

been trying to manufacture *manure*, and nobody has attempted anything else. But a gentleman, who for years past has devoted great attention to the chemistry of limes, has discovered that an excellent cement may be made by first mixing the sewage with lime, then allowing it to settle in tanks, then drying the mixture, then calcining it at a high temperature, and finally grinding the burnt material to a fine powder.

Portland cement is known to be nothing more than a mixture of lime and clay. Now, sewage contains a large quantity of clay and also a large quantity of organic matter. Major-General Scott, formerly of the Royal Engineers, throws into the Ealing sewers a solution of lime which mixes most intimately with the clay and the organic matter. The result is a substance containing all that is required for cement, and mixed with it is a sufficient quantity of fuel to enable it to burn in a kiln after it is once lighted. Thus it will be seen that by using a certain quantity of lime, we get not only sufficient clay mixed with it to form a cement after calcination, but we save almost all the expense of fuel—the organic matter obtained from the sewage acting as fuel.

I have examined the works at Ealing where the sewage of 8,000 people has been treated for months past by General Scott, and in the Appendix will be found a full explanation of the process, and the opinions of the most eminent chemists of the day.

Promising as I think General Scott's method is, and especially for India, where the sewage is charged with so much more organic matter than in England, and where, therefore, the dried mixture of lime, clay, and organic matter, would burn so much more easily, still I do not recommend the Bench to do more than make an experiment on the subject before adopting it. For this purpose nothing more would be required than to pour a solution of lime into the main sewer,

and, after the sewage had been pumped up by the present engines at Love Grove, to allow it to settle in a small tank, then to dry the solid portion and burn it in a kiln, and, lastly, to test the cement so manufactured.*

The Bench should be made aware that the cost of Portland cement in Bombay is very great. If another cement could be cheaply manufactured, not inferior to it, this might be sold at a very remunerative price. I should mention that by throwing lime into the sewers high up in the town we should secure the additional advantage of disinfecting the sewage to a very great extent. Let it be borne in mind though, that General Scott's system is not one specially but only incidentally for the disinfection of sewage. His system is mainly for the manufacture of cement at a price far cheaper than it can be made by any other process.

Now with regard to the method of using the sewage for irrigation, I would first pass it into settling tanks, and then let the clear fluid only flow over the fields. These settling tanks could, in the case of Bombay, be made most inexpensively. Nothing more would be required than to decide on a convenient size for each tank, and then to throw round the area an earthen embankment. By preventing the insoluble portions from going over the fields and by collecting them in tanks, we should be securing two advantages. The water would flow off the fields in a purer state, so that the roots of the crops would not be choked up with solid impurities, and we should be reclaiming land. After each tank had been filled, and the clear sewage water had been drawn off, the residue would be allowed to dry, and when it had become perfectly so, as it soon would under an Indian sun, about six or twelve inches of the dry rubbish of the town would be thrown over the

* I have no doubt that Mr. Walton, the present Executive Engineer, could make some very valuable experiments at the cost of about a thousand rupees, and I would beg the Bench to place this sum at his disposal for the purpose.

top. Each tank then would become an irrigation field, and help to disinfect so much more sewage.

As to the crops which should be grown, it is still found in England that the grasses are the most profitable. In Bombay there is no green fodder at present for eight months of the year. Only during the monsoon is fresh grass for horses and cattle to be procured, but from October to June the community have to put up with hay, and hay of the most inferior kind. But while the greater portion of the fields should be laid down with grass and lucerne, there is no reason why at the same time vegetables of different kinds should not also be produced. Considering how successful the experiments made on the flats have been, and that the natives themselves have for two years past been using sewage for their own lands, there can hardly be a doubt of the success of the application of sewage for agricultural purposes.

THE PROPOSED WORKS.

After this general description of what is proposed to be done, it is necessary that I should enter into some particulars regarding the works that will have to be carried out.

There will be four branch-sewers altogether, and these will be for the removal of sewage only, no rain-water. The first will start from the Fort, pass through the heart of the town, and join the main sewer in Commatteepoora. If considered advisable, the drainage of the Fort need not be connected with the drainage of the town at first or even at all.

The Second Branch will be for the drainage of Mazagon and the Elphinstone District, and will join the First Branch soon after the latter enters the town.

The Third Branch is for the drainage of the Back Bay District. This sewer would run along the Alfred Road, and, passing through Girgaum, would join the main sewer in Commatteepoora.

The Fourth Branch, which is a very short one, is for the drainage of the northern part of the town, and would join the main sewer on the flats.

The main sewer itself would start from Commatteepoora, pass to the west of the Race Course, and, after running parallel with the B. B. and C. I. Railway up to Parell, would turn towards the east, and, crossing the main road at Matoonga, would continue its course to the Pumping Station, which would be situated to the south-east of Sion.

The main sewer would start at such a level as to admit of its catching the sewage from the present main drain, so that if the Bench chose at first to complete it only, they could, during eight months of the year, convey the sewage to the northern part of the island for utilization; of course, during the summer, when the main drain was charged with rain-water, the main sewer would be closed, and drainage and sewage would escape as it now does through the sluices at Love Grove.* When, however, the branch sewers were completed, the works would be in operation during both dry and wet weather, and all the sewage would be taken to the north. The object of this explanation is to show the advantage of finishing the main sewer as soon as possible, and of

* I hope I shall not be misunderstood here, and the charge be again brought against me, that I propose to throw the sewage into the sea on the western coast. Till the new works are completed, of course the sewage must go where it now does, but when the branch sewers are ready, not one drop of sewage would be discharged at Love Grove.

first concentrating all expenditure on it, leaving the branch sewers for after construction.

I need not trouble the reader with the sizes of the different sewers, or the exact levels at which they are to be laid, as all this information may be gathered from Plates IV., V., VII., and VIII. They would be capable of removing the sewage of more than 1,500,000 people calculated at 20 gallons per head per diem, and on the supposition that one-half the daily quantity is to be removed in eight hours of maximum flow.

From the Pumping Station at Sion the sewage would, as I have already mentioned, be taken to the north-west of Trombay in an open sewer running on an embankment.* A trench would be made in this embankment, and the bottom and sides puddled to the thickness of 18 inches, or 2 feet. The slope of the high-level sewer need not be more than 2 feet per mile, and no portion of the surface of the land reclaimed should be below high-tide (say under 89 feet on Town Hall datum), or above 91 or 92 on datum. There would thus be a gentle slope on these lands of 2 or 3 feet, so that the sewage discharged on to the fields at the higher points would flow slowly off to the lower parts, and, after purification, escape into the creek to the north of Trombay.

As the sewage would enter the Pumping Station at about $58\frac{1}{2}$ feet on Town Hall datum, and would have to be raised to 98 on datum, the lift would be $39\frac{1}{2}$ feet—say 40 feet. Now it would be unnecessary to provide more engine power than sufficient to pump up the present sewage. If more water were brought into the town afterwards, more engine-power

* It would be very desirable that Mr. Walton, the Executive Engineer, should ascertain whether the main sewer could not be extended underground from Sion to the irrigation lands. It is possible that the sub-soil across the swamps may not be unfavourable for the construction of an underground sewer. Borings might be taken along the proposed line of sewer. If it could be constructed, an underground sewer would be preferable to one running above the surface of the ground, and the Pumping Station could then be fixed, not on the island as at present proposed, but on the north-west of Trombay.

could be added; but it would be mere waste of money to erect larger engines at first than there was the chance of employing. I calculate the present sewage to be not more than half the water-supply (8,000,000 gallons daily); but let us suppose that it amounts to three-quarters, or 6,000,000 gallons daily; then the engine-power should be sufficient to raise half this quantity in eight hours of maximum flow:—

$$\frac{\begin{array}{ccc} \text{galls.} & \text{lbs.} & \text{ft.} \\ 3,000,000 & \times 10 & \times 40 \end{array}}{\begin{array}{ccc} \text{foot lbs.} & \text{mins.} & \text{hrs.} \\ 33,000 & \times 60 & \times 8 \end{array}} = \text{say 76 horses.}$$

According to the usual principle adopted by engineers, I would provide three engines of half this power—or, say, three engines, each of 40-horse power.

In my former project I proposed that the sluices at Love Grove, Worlee, and Daravee, should be enlarged to a total length of about 360 feet. I would now recommend that the sluice at Love Grove be widened to 100 feet, that at Worlee to 80 feet, and that at Daravee to 80 feet. If subsequent experience should show that these sluices are not large enough, they can be added to; but it would be better to proceed gradually with these works, instead of incurring a large outlay at once.*

The minor sewerage of the town would be effected exactly as explained in my project of 1868—*i.e.*, by earthenware pipes. These pipes would, as a general rule, run along the gullies between the houses and join the larger pipes under the streets, which again would join larger ones further on, till at last a sewer was reached. A complete system of ventilators and manholes has been provided.

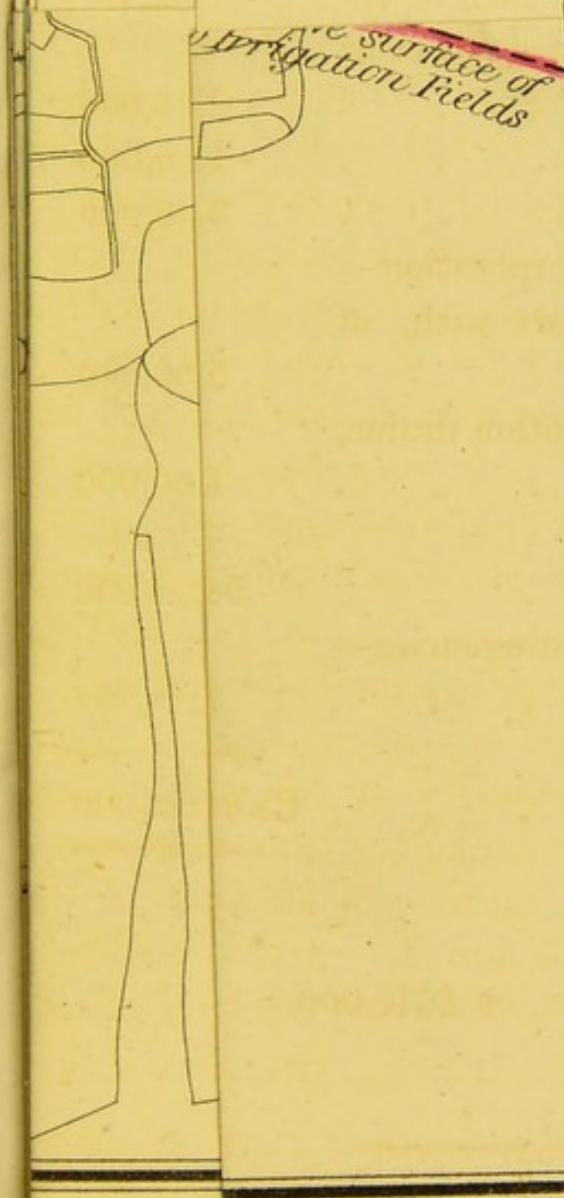
* Why the Bench hesitate in the construction of these works I cannot understand. They are independent of all systems of sewerage, and must be carried out if the flats are to be relieved of floods. I do hope this question will be considered in its proper light.

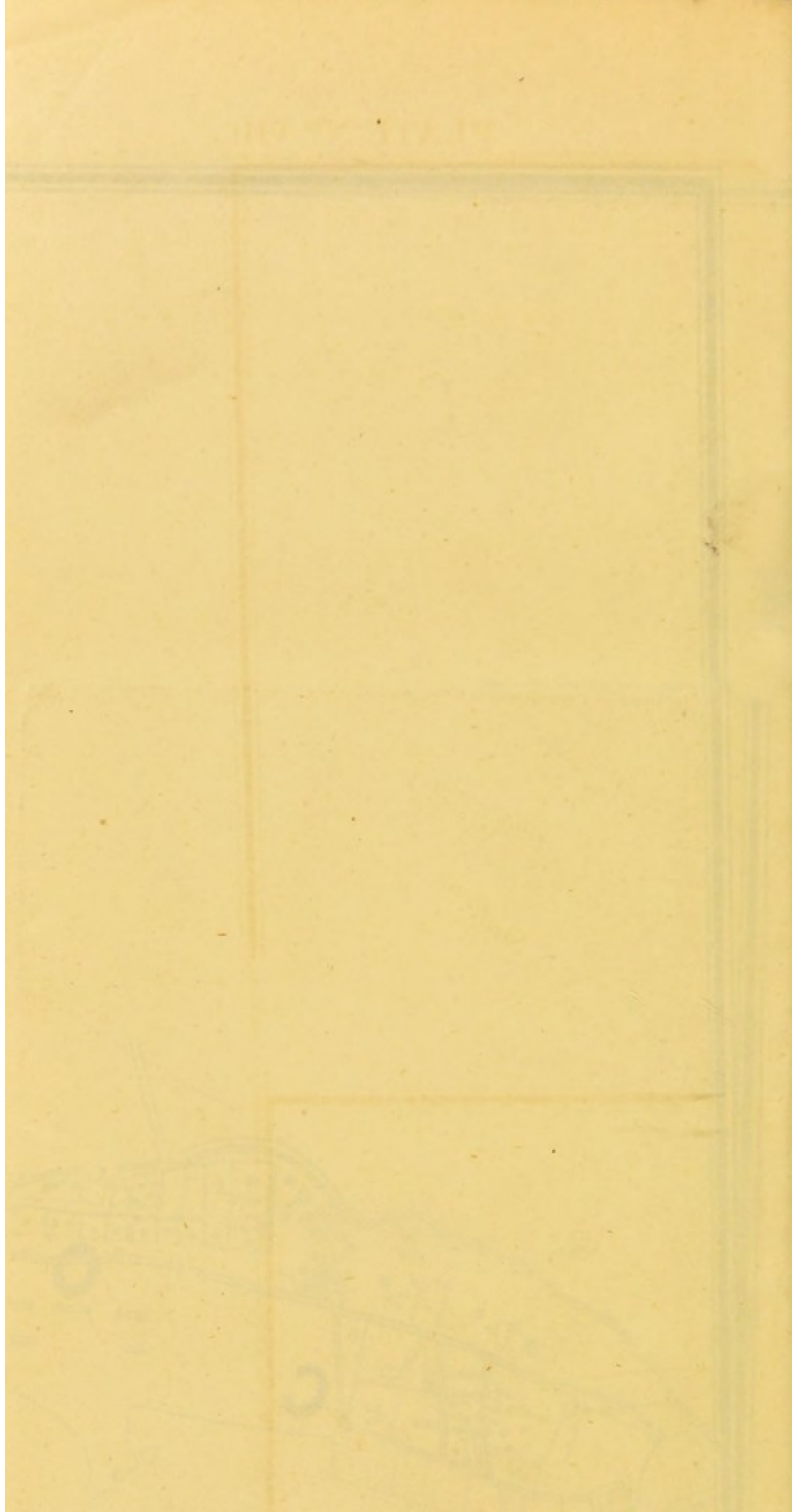
The cost of the entire scheme I estimate as follows :—

	Rs.
Main and branch sewers	22,00,000
High-level sewer across swamps	8,00,000
Street drainage, as in my project of 1868	11,61,336
Manholes, ditto	4,11,000
Three condensing engines, each of 40- horse power ; or 120-horse power at Rs.1,800 per horse-power	2,16,000
Engine and boiler house	1,00,000
Sluices with outlets to sea	3,50,000
Land, if bought by the Corporation— say 1,000 acres to start with, at Rs.500 an acre	5,00,000
Preparing land, with irrigation drains, at Rs.100 an acre	1,00,000
	<hr/>
	58,38,336
Add 10 per cent. for contingencies— say	5,81,664
	<hr/>
Total.	<u>Rs.64,20,000</u>

Or say 64 lacs, or £640,000.

PLATE N° VII.

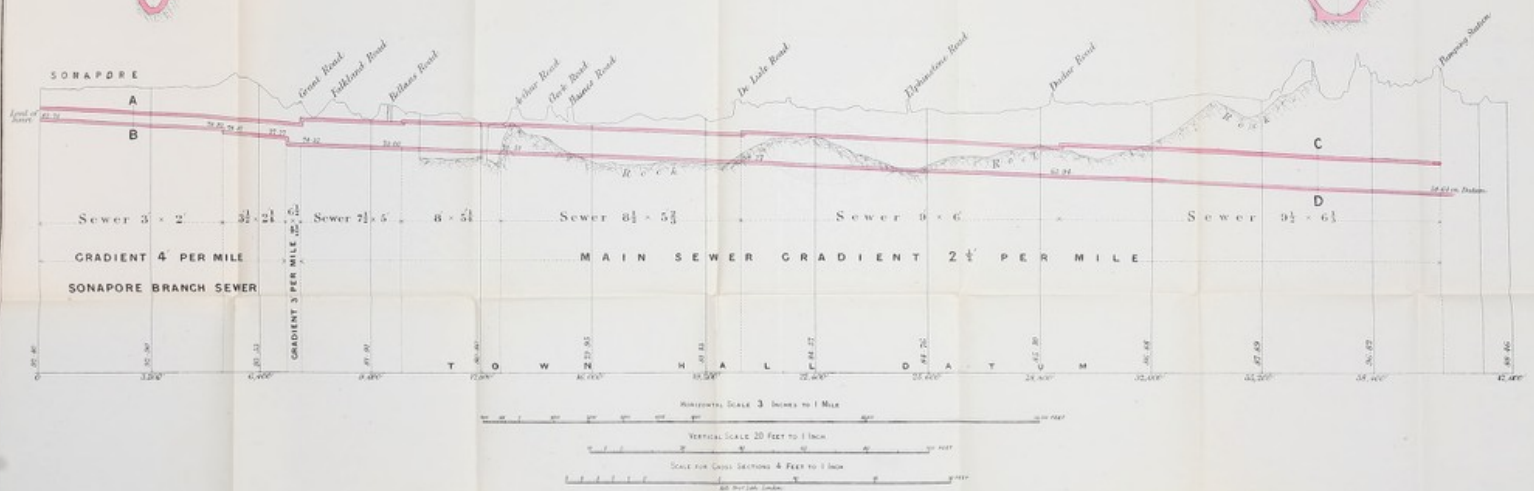




CROSS SECTION OF SEWER AT A. B



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SE

CROSS SECTION OF SEWER AT A. I.



SONAPORE

A

THE PRESENT LEGAL ASPECT OF THE DRAINAGE AND SEWERAGE QUESTION.

At present the sewage and drainage of the greater part of the town is discharged on the western coast. The sewage and drainage of the Back Bay District is discharged in Back Bay, and the sewage and drainage of the Elphinstone District is discharged into the harbour. The night-soil is all collected by hand and discharged into the harbour.

The owner of the property lying to the north of the Pumping Station has applied for an injunction to restrain the Bench from discharging the sewage at Love Grove, and has recovered damages for the loss of rent, &c., caused by the nuisance arising from the sewage. The following extract from the *Times of India* will explain the result of the proceedings:—

“Mr. Justice Green, in an elaborate judgment, found the first four issues in favour of the plaintiff, and on the fifth and sixth issues—as to whether the plaintiffs were entitled to recover any and what damages for the alleged wrongful acts of the defendants, and whether they were entitled to the injunction prayed for—his Lordship ordered that the defendants should pay the plaintiffs Rs.300 per mensem for three months before the suit was instituted, making a total of Rs.900; and in order to restrain the further continuance of the nuisance, his Lordship directed the issue of a writ of injunction restraining the defendants from causing or permitting sewage or other offensive matter to be discharged into the sea through the new outfall-sewer mentioned in the plaint, so as to injure the health or otherwise injuriously affect the plaintiffs, their tenants, servants, and workmen, resident or employed on the premises. But as the defendants might be advised to appeal against this decree, and, in order to allow them time to do so, and to avoid, in the meantime, and so long as they might give the plaintiff the substantial redress he asked, the unpleasant

consequences of non-compliance with an injunction, which would be sequestration of their property, and also to allow a remedy, if possible, to the nuisance complained of, he directed that the said writ should not issue until after the 1st of December next; and that it should not then issue if the defendants, on or before that date, shall have paid to the plaintiff the sum of Rs.12,300, being the amount of the rent of the bungalow at the rate of Rs.300 per month from the 1st April, 1869, till the 1st day of December next, deducting the sum already accorded, Rs.900, as damages for loss of rent for three months prior to the institution of the suit. His Lordship further ordered that the defendants having paid the Rs.12,300 within the time mentioned, the writ should not issue in case the defendants should, on the 1st day of January, 1873, and on the 1st day of every calendar month after that time, pay to the plaintiff the sum of Rs.300; the plaintiff being at liberty, in case of default of payment at the times mentioned of the sums of Rs.12,300 and Rs.300, to apply to the Court that the said writ might issue, and that the defendants pay the plaintiffs' costs in the suit."

It is clear, therefore, from this that the Bench will be unable any longer to discharge the sewage of Bombay into the sea on the western coast.

Nor can the Bench discharge it into Back Bay. Without considering the engineering difficulties, nor the fact that Back Bay is a confined inlet, from which the sewage could not escape to the open sea, the nuisance at present produced by the small sewers which do discharge in this direction is so great, that the subject has attracted the attention of the Government, and it is well understood that, only in order to give the Municipality time to mature a scheme, have the Government forbore to take proceedings against them. Back Bay, therefore, is out of the question for the outfall.

Nor do we get over our difficulty by turning our attention to the harbour. With regard to the outfall being situated at Colaba, the Government have already expressed themselves thus: "Government could, however, never consent to receive the sewage in the immediate foreshore of the new

Military Cantonment at Colaba, and the proposed outfall is, therefore, inadmissible." *

Nor do we get over the difficulty by proposing to place the outfall higher up on the harbour side of the island, for Government have already given the Bench notice that, unless the night-soil depôt at Chinch Bunder is removed within a reasonable time, proceedings will be taken against them. If, therefore, we are not to be permitted to discharge the night-soil, it will be absurd to suppose that we shall be permitted to discharge the sewage into the harbour.

What then are we to do? The western coast is closed to us; Back Bay is closed to us; Colaba is closed to us; and the upper side of the harbour is closed to us. In the west, south, and east, we cannot place our outfall. There is only one other point of the compass left to us. That is the north, and that is the direction to which this project contemplates that the sewage shall be taken.

* *Vide* their Resolution, No. 105 of 1867.

CONCLUSION.

All the rain-water falling on the island is to be allowed to escape by gravitation, and no portion of it is to be pumped.

Not a single underground channel for rain-water, to which the Drainage Commission of 1869 so strongly objected, is proposed to be constructed.

I do not propose to pump the sewage into the sea, but to utilize it, and after utilization, and when it is pure, to discharge it into the creek north of Trombay, at a point seven miles from Bombay, where there is no large village, and where the nuisance, if any, cannot be felt.

The sluices at Love Grove, Worlee, and Daravee, are to be enlarged as already explained. Regarding these works I cannot restrain from impressing their importance on the notice of the Bench. Whatever the Bench do in the matter of drainage, they should not delay the construction of these sluices, which of themselves, and without the help of a single additional sewer or drain, would affect a wonderful improvement in the health of the town.

The flats would be converted into a park as proposed in my project of 1868.

Unless the drainage and sewerage are separated (as proposed by me), and unless the drainage is allowed to escape by the existing sewers, just as it escapes at present, it is a physical impossibility to dispense with the construction of new underground channels, and it is practically (*i.e.*, on account of its great expense) impossible to drain the northern portion of the town, let alone the whole island, without having more than one drainage and sewerage system, and without having several outfalls into the harbour.

My scheme is one for the drainage and sewerage of the whole island. It does not matter for it in what direction the town spreads. The sewage of each new neighbourhood which may spring up can be delivered into my main sewer by gravitation. Into no single main sewer carried to the harbour side of Bombay could the sewage of the northern part of the island possibly be taken, unless the sewage were pumped.

I beg the Government and the Bench to weigh these points. Let them ask the engineer who proposes to take the sewage and drainage to the harbour side of Bombay the following questions: How will you drain and sewer Chinchpooglee, Parell, Worlee, Mahim, Daravee, or Sion? The town must spread—it is spreading—to the north, because the southern portion of the island is already as thickly populated as it can be. When the time comes, and it is rapidly approaching, when these neighbourhoods will have to be considered, what will you do for their drainage and sewerage? Where will you discharge the sewage? Will the town be compelled to have a separate system for each part of the island? The fact is, that the town will be compelled to have a separate scheme for each, and the cost of such systems will simply be ruinous.

These facts have never been put clearly before the Bench.

Now, any one glancing at the position of my main sewer, running as it does for nearly its whole length along the bottom of the valley of the island, will see at once that it will drain any and all of the districts mentioned above. The fact is palpable to the most ordinary understanding. If once this main sewer were constructed, nothing would be required for the sewerage of any part of the island but a sewer leading as directly as possible to the main sewer. The latter work is at a sufficiently low level to admit of the sewage of any district flowing into it by gravitation.

If then the question be put to me, How would you drain and sewer Chinchpooglee, if it were necessary? my answer would be—I have already in my project actually provided for the drainage and sewerage of Chinchpooglee, while nobody else has. The Fourth Branch sewer is for the sewerage of this district, and the drainage would escape, as it now does, to the flats, from which the sluices at Love Grove, Worlee, and Daravee, after having been enlarged, would discharge it into the sea by gravitation.

But let the question be put to me, How would you drain and sewer Mahim and Sion, perhaps the most difficult districts for the engineer to deal with. Suppose these distant parts of the island became ultimately as thickly populated as the rest of the town, what system could be adopted for them? My answer is—the drainage would escape by gravitation, like that of the rest of the island, through the sluices at Daravee, Worlee, and Love Grove, and the sewage would be brought by gravitation into the proposed main sewer. In the case of Mahim, a small sewer, running through the wood in a south-easterly direction would join the main sewer to the south-west of Matoonga; and in the case of Sion, a small sewer running along the west of the high road, would join the main sewer between Matoonga and the proposed Pumping Station.

If Bombay, then, can be drained without the help of any new underground channels, and simply by enlarging the present sluices, would it not be folly for the Bench to incur the expense of any scheme which involved underground channels?

And if the whole of the sewage of the island can be removed by one single main sewer of moderate size (about which there can now surely be no doubt), and can be pumped at one spot, would it not be very hazardous to sewer the town according to any scheme which considered the sewerage of the southern part of the island only, and left that of the

rest of the island to be provided for in the future as best it might? Should this be the policy of a great town like Bombay?

I do hope, therefore, that whenever the question of drainage and sewerage is really taken up by the Justices, they will insist upon its being dealt with in a comprehensive way, and not merely consider one part of Bombay without reference to the rest. Bombay comprises the entire island, every part of which, sooner or later, will be covered with dwellings. Surely the question then which the engineer should be compelled to answer for the inhabitants, is not how shall this or that district be drained, but how shall the whole island be drained?

P.S.—I received the following letter from MR. ARTHUR CRAWFORD after my report was printed, and I have considered it my duty not to withhold it from the Bench. Many things are known to him which are known to no one else, and as the paper has been written absolutely without any communication between us—without either being aware of what the other proposed to say—the Bench will have the opportunity of considering simultaneously the independent opinions of two of their former officers on this vexed question of drainage and sewerage.

H. TULLOCH.

THE CONSERVANCY AND DRAINAGE OF BOMBAY.

London, 21st October, 1872.

MY DEAR TULLOCH,

I observe that you are on the point of reporting on the drainage of Bombay, and I think it my duty to place before you a few remarks which, if they seem serviceable to you, can accompany your report.

You, Dr. Hewlett, and myself, of necessity well acquainted with all details bearing on the question, were so entirely in accord on this subject, and worked so harmoniously together, that it was never necessary for me to record any formal memorandum, so long as we were together. When you were compelled to leave us by ill-health, however, I had intended, and even commenced, a paper on the subject, which my own illness prevented me from completing. As matters have turned out, I am glad this was so, for certain minor matters, affecting the general question of the drainage of Bombay, have since been settled, and I am myself able to write, after some study of the subject in England.

The history of the drainage question, so to speak, is written up to 1870, and concludes with Government resolution in the P. W. D., dated 31st March, 1870. No. 17, C. W. 72 of 1870.

We, the municipal officers of the city, had to recommence the attack from such ground as had been gained by the report of the Drainage Commission and the aforesaid Government resolution thereon.

On some important points, sound and solid ground was left beneath our feet ; but in others (some of them of primary importance), no firm or stable footing was to be found.

Thus—it was firmly and finally decided, first, that whatever the drainage system, rain-water and sewage should be separated ; second, that no night-soil should be admitted into sewers—the present system of collecting being continued, and, if possible, improved ; third, that the storm or rain-water outlet at Love Grove, and elsewhere, should be improved, and the flats generally be recovered by reclamation ; fourth, that the present system of removal of solid refuse was good, and should be maintained.

So far, so good. But the most vital of all points—the future outfall of sewage—not only was not discussed, but was apparently lost sight of entirely by Government and the Drainage Commission alike—while the Government partly, and the Drainage Commission altogether, omitted to deal with the question of disposing of the refuse water from kitchens, baths, &c., which I will term house sewage.

In proof of what will be considered a strange assertion, I have only to point to the Commission's Report, otherwise practical enough.

The Commission (par. 26) very accurately describes a complete system of town conservancy as providing for the removal of the following sources of impurity :—

- (a) Solid refuse, such as débris of food, vegetables, &c.
- (b) Rain water.
- (c) Refuse water from kitchens, baths, &c. (*i.e.*, the sullage, or house sewage, of which I speak).
- (d) Latrine matter, both solid and fluid.

In paragraph 29 the first class of impurities (*a*) is treated of.

In paragraphs 30 to 32 the second is disposed of.

In paragraphs 33 to 38 the Commission propose to discuss the best method of disposing of the refuse water (*c*)—*i.e.*, house sewage—and latrine matter (*i.e.* (*d*), night-soil)

together, but really only dispose of the question of night-soil (latrine matter), which is in Bombay separately removed by hand—viz., by the Halalcore System, described in these very paragraphs.

In paragraphs 39 to 42 the Commission treat your proposal to utilize the sewage of Bombay, as if it concerned only the *night-soil* of the city (see par. 39).

Thus the present actual house sewage, or sullage, of Bombay, which is discharged in thousands of gallons by gravitation, along the eastern foreshore into the harbour, into Back Bay (principally at Sonapore, but at other points also), and, last of all, which is discharged by pumping at Love Grove, has been altogether forgotten.

The Government appear to have detected this omission by the Commission, but afterwards to have fallen into the same error, for in paragraph 12 of the Resolution cited, the Commission is described as “thinking that the drainage of the town of rain-water (*and probably of refuse, though this is not so clearly stated*) should be effected by gravitation.”

And further on, in paragraph 14, it is declared that—
“If the halalcore system be, for the present, adhered to, *it only remains to get rid of as much rain-fall* as possible, and prevent it from collecting on the flats.”

Night-soil and rain-water are thus dealt with, but the house sullage or sewage now existent is forgotten!!

We found nothing more disheartening in dealing with this most serious municipal question, than this confusion of ideas, even among the best informed, as to what is involved in the drainage of Bombay.

The most intelligent resident of the Bycalla Club would argue that the abolition of the neighbouring main drain and the consequent nuisance on the flats, was a simple matter, only involving expense. Government itself was never tired of insisting that no more sewage should be discharged from the Sonapore drain into Back Bay—forgetful that the sewage

of the same populous quarters has been discharged into Back Bay at this and other points from time immemorial.

It has been impossible of late to get any one but a few professional gentlemen to understand that the abolition of the one nuisance or the other, or both of them, involved besides the questions of storm-water and night-soil, a decision as to the general house-sewage outlet for Bombay, and the disposal of a vast volume of *house* sullage, now finding its way mingled with rain-water and subsoil drainage, by imperfect ditches, gutters, and sewers, to the outfall at Love Grove into Back Bay and the harbour.

Perceiving how futile, under the circumstances, would be any public discussion of the Report of the Drainage Commission, and knowing that such a solution of the general sewage outfall question, as we desired, must shortly be forced on, by a combination of circumstances then gathering on the municipal horizon, I purposely avoided any discussion of the matter by the Bench, and directed you to prepare a new detailed scheme based generally on the views expressed by the Drainage Commission, so far as they were approved by Government.

You and Dr. Hewlett and myself went back to the *a b c* of the question as laid down in paragraph 26 of the Commission's Report, which I again quote in full :—

“ 26. Every complete system of town conservancy should provide for the removal of the following sources of impurity : (*a*), solid refuse ; (*b*), rain-water ; (*c*), refuse from kitchens, baths, &c. (or house sewage) ; (*d*), latrine matter, solid and fluid.”

Now, as to (*a*) “solid refuse,” the present system of removal was pronounced good, it only remained to consider whether the cost could not be reduced. As to (*b*), Government had declared that the Love Grove storm-outfall should be improved, and had approved generally the Commission's

suggestions that rain-water should be otherwise discharged as far as possible by gravitation into Back Bay and the harbour.

It became, therefore, your duty to plan the improvement of the storm-water outlets, especially at the Love Grove sluices, and as far as possible to utilize all existing sewage outfalls for the future discharge of rain-water only. As to (d) latrine matter, it was decided that the existing halalcore system of hand removal should be continued and improved, and that *no night-soil* should enter sewers. It remained for you to consider whether some plan might not be devised by which the night-soil now cast into the harbour might be removed like the solid refuse without offence to a distance from the City, perhaps in conjunction with the solid refuse, at a reduced cost to the town. At the same time it was for us to consider whether, when so removed, the soil might not be utilized. (c) The disposal of house sewage remained, involving the question of outfall, and on this point we had no definite decision to guide us.

But we foresaw that in a short time the question must be indirectly settled, and that the house sewage of the town must hereafter, as we all desired, follow for a considerable distance the natural levels of the town, and be carried on to the most distant north-east point of the island, where it can either be discharged or utilized without offence or danger to any one.

The following were the questions pending which we foresaw would solve the sewage outfall problem. Government had already peremptorily rejected Mr. Aitken's proposal for a sewage outfall at Colaba, and had generally expressed disapproval of the discharge of sewage into the harbour. It now insisted on the removal of the night-soil discharge-pipe into the harbour at Carnac Bunder, and has even insisted on the cessation of the nuisance within a certain time. Simultaneously the Custom House authorities are complaining of the nuisance from the Fort outfalls.

It follows that no sewage outfall can be planned towards the eastern or harbour-side of the town.

At the same time the military reclamation and railway departments have, since the opening of the Queen's Road along Back Bay, joined the general public in condemning the nuisance from the discharge of sewage into Back Bay, and last of all Government have given legal notice that this nuisance must be removed by a certain date.

No future sewage outfall is, therefore, possible in Back Bay.

Meantime the principal sewage outlet of the town by the main drain at Love Grove has received its quietus in an action by Mr. Vurjeevundass Mahdowdass, the owner of property adjoining, who has justly succeeded in a suit against the Corporation, which must now remove the nuisance within one year, and further pay a heavy sum to the plaintiff for damages.

It follows that no sewage outfall can exist hereafter to the west of the City.

There is but one other direction by which it can be guided, and that is to the north-east, where there is the greatest facility for disposing of it; and it is to this point that you have planned to carry it.

The scheme which, after many consultations with the Health Officer, we all agreed to was as follows:—

You were to lay down a main sewer from the marine lines along the Queen's Road up Churney Road, across Breach Candy Road, past the Portuguese Church, across the Girgham Road at the ice factory, and thence almost in a straight line through the oarts and Khetwadee, past the corner of the Dhurmsalla on the Commatteepooras Road, then to intercept the main drain, and continue along the east side of the B. B. and C. I. Railway to a little beyond Dadur; there to pass the G. I. P. Railway, and travel almost in a direct line past the new Portuguese Cemetery to the vacant uninhabited ground adjoining the swamp east of the Sion Fort.

This sewer would, in the first place, intercept all the

Sonapore sewage, and carry off the house sullage of the extensive undrained Oart District and all the quarters now draining towards Back Bay. At the point of intersection with the main drain it would pick up all the house sewage now passing to and pumped up at Love Grove—the sewer from this point up to Sion Fort to be constructed of sufficient capacity to carry at any future time all the house sewage of the entire city—which would be pumped up and discharged, as I shall presently explain.

All branch sewers and house connections to be for house sewage only—existing side gutters and outlets into Back Bay to be used for storm-waters only, and new storm outlets to be made along the shore where needed.

This was the first section of the scheme to be first executed—with this proviso, that from the point where the new main intersected the present main drain, it should at once be constructed large enough to carry the whole house sewage of Bombay.

The second section of the work was the connection of a similar system for carrying the house sewage only of all the rest of the city now draining into the old main drain.

The third section of the scheme would be the enlargement to the greatest possible width of the storm-water outlets at the Love Grove sluices, and at other points towards Mahim, and thus to render the reclamation or filling in of the low-lying area on and near the flats easier and less costly, because up to a lower level than would be necessary.

The fourth section would deal with the removal of the night-soil bodily by rail either from the present dépôt, near the Carnac Overbridge, or from a new one on the border of the Baboola Tank at a suitable tank selected by us.* The

* The removal of the soil in iron tank railway wagons, presented no serious difficulty. I believe that the Superintendent of workshops had already designed the plant. As to the other alternative of removal in hopper barges. I never allowed it to be seriously gone into because the maintenance of such a system would be imperilled in the heavy monsoon weather.

same lines to be used for removing all the solid refuse of the town. The guage to be narrow—the line, the property of, and worked by the Corporation, and either to commence at the present night-soil depôt at Carnac Overbridge and pass by tunnel at once through the rocky ridge by Dongree Coolee Street to Baboola Tank (for which portion of the work there were to be separate estimates) or to commence at the Baboola Tank,* pass by an easy line across to Agreepada, and so along the flats by the line of the new main sewer to the new Sion Pumping Station, and across the swamp on to the municipal sweepings reclamation at Coorla, and hereafter, if necessary, to the vast swamps beyond.

You had ascertained that the interest and sinking fund on the capital required for the construction of this line, added to the cost of working it, for removing both solid refuse and night-soil would still be much less than the exorbitant sums now paid annually to the railway companies, while it would be possible still further to economize, and even to utilize, the line by a branch to the Slaughter Houses at Bandora, and, perhaps, by a siding to the New Portuguese and Sewree Cemeteries.

Up to this point all had been settled. Surveys had been completed, and detailed plans and estimates were far advanced when you were taken so dangerously ill a year ago.

The question of the disposal and possible utilization of both house sewage and night-soil when arrived at Sion had not been definitely decided upon. You and I were of opinion that the night-soil, arrived at the Pumping Station at Sion, might be discharged into large settling tanks into which the house sewage would be continuously pumped, and that the overflow might, during the seven or eight dry months, irrigate the immense area of land already under cultivation extending from Dharvee to Rowlee Fort, while in the wet season it

* Probably also with a branch or sides to Commatteepoora.

might be carried on to the extensive swamps north-east of Coorla. Dr. Hewlett, on the other hand, contended for the perennial discharge of the overflow on the fields and swamps at a greater distance to the north of the Coorla Creek. This was a point of minor importance, not affecting the general features of the scheme, which, viewed as a whole, would form such a complete system of town conservancy as was defined by the Drainage Commission in para. 26 of their report. The solid refuse would be removed as at present, but more conveniently and at reduced cost—the rain-water would be separately and rapidly discharged. Refuse water from kitchens (*i.e.*, house sewage) would be carried off separately by a cheap system of sewers. Night-soil would, as at present, be collected by the halalcores, but instead of polluting the harbour, be removed to a considerable distance, and there carried off and utilized with the house sewage, or separately prepared for use, on a spot where no nuisance would be occasioned to any one.

While, moreover, the scheme would be complete as a whole, there would be nothing to prevent its being carried out in detail, section by section, as opportunity offered or funds were available. One other great advantage in the scheme is that while it does not commit the town to any particular method of sewage utilization, it leaves the door open for the adoption of any system which may in future years be found best adapted to a tropical city. Experiments of every kind can be inoffensively and inexpensively carried on; while the overflow from the settling-tanks, in every respect inoffensive, will be available either to irrigate the lands of the cultivators in the neighbourhood, by the simple earth chemicals with which they are so familiar, or to irrigate lands purchased or rented, or reclaimed by the Corporation, or may be discharged harmless on the extensive swamps to the north-east, or into the vast body of water in the Tannah Creek by Trombay.

Sewage utilization is in its infancy even in Europe, and of all the many methods now employed (with which I have endeavoured to make myself familiar during the past year), there is not one which would suit Bombay. That problem has yet to be solved, but, pending the solution, ordinary irrigation can, at least, be tried, and assuredly will yield some return.

In conclusion, there is one point which I wish to bring prominently forward, lest it escape notice at a critical moment. I have unfortunately mislaid my private copy of papers, but the originals can easily be traced in the records.

It must not be forgotten that after disposing of Mr. Aitken's Drainage Scheme, the Secretary of State suggested in a despatch (copy of which was forwarded to me) that in any future scheme, he hoped that the question of utilizing the sewage might be considered, and that the numerous swamps, foreshores, and low-lying waste lands, in and near Bombay, might thus be made to yield a considerable income to the municipality, and that all such Government lands might be granted to the Corporation.

I write from memory; but such was the tenor of the despatch: and, in consequence of it, I addressed the then Collector of Bombay with a view to claim the Government swamps of Bombay within the limits of the island, especially the flats.

I soon saw that it would be politic to refrain from pressing the question until such time as a Sewage Scheme should have been approved by the Government of Bombay.

The despatch of the Secretary of State was just and fairly liberal towards the Corporation; it has never been cancelled, and I need not say that it cannot be set aside in India without the express consent of Her Majesty's Secretary of State. But even if the despatch does not involve the grant of the Government swamp on the flats to the Corporation, or if, on the other hand, the despatch should be cancelled

(which I cannot think probable), I need not point out that the Corporation will have a great and equitable claim on Government for a large contribution towards the cost of the works you are proposing.

The Government estate on the flats is lower than any other part of them. In the monsoon it is simply a lake of about 500 acres in area. The expensive works which you propose for enlarging the outlet at Love Grove, and which must be carried out sooner or later, will in a great measure reclaim the whole of this Government estate ; at any rate, the cost of reclamation will be immensely reduced, because, if I remember aright, it will then only be necessary to raise the general level of the Government estate some three to four feet instead of seven to eight feet, or even more.

In common fairness then, Government should either contribute largely in cash, or should make a grant of the land.

But, in whatever way this question is settled, this area of swamp should be reclaimed directly the new storm outlet works are completed. There is abundance of Government material in the Coorla Hill, and I believe I am right in supposing that a vast quantity will be soon available from dock excavations in or near Moody Bay. Two or three years should see this hideous spot converted, as I proposed years ago, into a handsome public park.

In the above remarks, which are penned simply from recollection of our innumerable discussions in India, I have purposely abstained from controversy of any kind. Thus while Dr. Hewlett and myself do not share your objections to the present halalcore system, and are opposed to the passage of night-soil into sewers, I have not attempted to discuss the question here. We agreed to accept and act upon the decision of Government and the Drainage Commission wherever there was a definite decision. I have not attempted here to dissect the Commission's Report, or presumed to criticise the Government resolution on it, though the former contains

abundant evidence that your proposals were hopelessly misunderstood, and consequently, misrepresented to the Government. But I could not avoid showing that neither document touched on the most important question of all, viz., the *sewage* outfall; while both ignored the existence of the House Sewage of Bombay.

In other respects this paper only professes to state from my own point of view what will be the best system of conservancy and drainage for Bombay, based on the decisions arrived at up to March, 1870. I shall rejoice if what I have said should prove of any use in discussing the question to the general, as distinguished from the professional, public.

I am yours, very truly,

ARTHUR CRAWFORD.

...in other respects this paper only pretends to state from
 my own point of view what will be the best system of con-
 vention and exchange for the day, based on the decision
 arrived at up to March 1871. I shall not repeat what I have
 said should prove of any use in discussing the question to the
 general as distinguished from the professional public.

I am, Sir, very truly,
 Yours,
 Arthur Cayley

ARTHUR CAYLEY

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 from the professional public.

APPENDICES.

APPENDIX A.

REPORT OF THE COMMISSION APPOINTED BY GOVERNMENT IN 1869 ON CAPTAIN TULLOCH'S DRAINAGE AND SEWERAGE SCHEME OF 1868.

In considering Captain Tulloch's Scheme for the drainage of Bombay, the attention of the Commission was directed to two points: 1. Whether it possessed any engineering or sanitary defect, either as regards the principle adopted, or in the mode of applying that principle; and 2. Whether Captain Tulloch's calculation fairly represented the outlay that would be involved in giving effect to his Project.

As a preliminary enquiry, under the first head, it became necessary for the Commission to consider what system of drainage is, on sanitary and engineering grounds, best adapted to the requirements of Bombay. The Commission, therefore, proceed briefly to state their views upon the general question, at the same time that they discuss Captain Tulloch's Project.

Every complete system of town conservancy should provide for the removal of the following sources of impurity:—

- (a.) Solid refuse, such as *débris* of food, vegetables, &c.
- (b.) Rain-water.
- (c.) Refuse water from kitchens, baths, &c.
- (d.) Latrine matter, both solid and fluid.

The best system is that which provides for the continuous and complete removal and disposal of these sources of impurity, by means involving the least possible injury to the public health.

The problem to be solved, therefore, involves two branches: 1. How best to carry away these impurities to a safe distance from human dwellings; and 2. How to get rid of them in an innocuous and, if possible, a profitable manner.

With regard to the first class of impurities—solid refuse—little need be said. It is collected by hand labour, deposited in large bins which have been erected in convenient positions throughout the town, and thence removed in carts to a siding at Boree Bunder, from whence it is carried by rail to Koorla, a distance of nine miles from Bombay, where it is spread over a tract

of swampy ground belonging to the Municipality. This is probably as satisfactory a method as could be devised for its disposal.

The next point is the disposal of rain-water, which in Bombay is a serious question during four months of the year. The Commission are of opinion that it should be removed, to as great an extent as the levels will permit, by gravitation, direct into either Back Bay or the Harbour; and that no rain and storm waters which it is possible to divert by either the construction of new underground channels, or by surface drains, should be allowed to pass down through the present drains on to the flats near the Breach Vellard.

While, therefore, the Commission entirely agree with Captain Tulloch in desiring "to effect a complete separation of rain from sewage," they cannot concur with his proposal to carry off the rain-water by the present underground drains to the present main drain, "by which it will be carried to Love Grove, where it will be pumped into the sea." This, in the opinion of the Commission, would be a costly and unsatisfactory process. Mr. Rawlinson says:—
 "Any attempt to provide large sewers to receive tropical storm-waters, and steam-power to pump the same, must either be most extravagantly costly, or must fail;" and the calculations made by Mr. Ormiston as to the expense of pumping confirm this view.

As the leading feature of Captain Tulloch's Project is to pump not only the storm-water, but the sewage of Bombay into the sea, the Commission consider that it is, in that respect, objectionable on engineering grounds.

With regard to the disposal of the two remaining classes of impurities—the refuse water and latrine matter—the first question which the Commission had to consider was, whether the night-soil should be allowed to pass into the drains. This, in a climate and community like those of Bombay, is a question of the most serious importance to the public health, and, if decided in the affirmative, would involve a radical change in the habits of the bulk of the population. To carry out with any degree of safety in Bombay a system of drainage similar to that of any English city, would necessitate the introduction of water-closets, and the Commission are of opinion that this could not be successfully accomplished. Dr. Lumsdaine says:—"If there is to be water-carriage, there must be water-closets; and it will take some time, I think, to adapt the native houses for these. Admit that they would use them, and there is still the difficulty about repairing them. They would also require a continuous water-service, and no matter how much the payment was in arrears, you could never cut off the supply." But there is a graver objection, which is well stated by Mr. Blaney: "In the large sewers the disengagements of noxious gases would be very considerable. Direct connections of the sewers with native houses would necessitate traps and sinks; but I don't know that we could get a trap which would be beyond the reach of the tenants, and the gases would be coming into the houses with the thermometer in the month of May at from 90° to 95°, which would be a very serious

Report, p. 23.

Report, p. 32.
Evidence, p. 112.

Report to Secretary of State, "Bombay Municipal Record," p. 112.

Evidence, p. 108.

Evidence, p. 133.

matter, and I should expect a heavy death-rate. I cannot find words strong enough to express what I consider would be the danger of such a proceeding." Dr. Lumsdaine also says:—"I am in favour of the present halalcore service being continued, because as yet I have not heard of any tested method by which you can get rid of the gases that would be engendered if the night-soil were passed into the drains. Until this problem be solved, we had better keep to our old system, disgusting and rude though it be."

The Commission consequently consider Captain Tulloch's Project objectionable on sanitary grounds, inasmuch as it proposes to carry off all the night-soil by means of sewers.

The Commission are aware, from the evidence which has been laid before them, that, under present circumstances, a large proportion of night soil—Mr. Aitken says fifty per cent.—finds its way into the sewers; and there is no doubt that, from the habits of the people, this will always, to a certain extent, be the case. But as the Halalcore System is perfected, the quantity will diminish year by year; and it is not unreasonable to hope that before long it will be reduced to a minimum.

How, then, is the night soil to be disposed of?

The present system is thus described by Dr. Lumsdaine: "The night-soil is removed by hand. At certain points throughout the town there are stations and iron cylinder carts. Upon these points the halalcores work, and as the carts are filled at the stations, they go to the main dépôt at Boree Bunder, where there are two receiving tanks. These tanks have a discharge-pipe that delivers at (the end of) Carnac Bunder" into the harbour. Dr. Lumsdaine considers this system satisfactory, "if it were more complete;" and states that the halalcores serve 14,738 houses, or about two-thirds of the whole number of houses in Bombay, and that they clear off "pretty nearly the whole of the night-soil that is to be found in the houses." Mr. Blaney believes that "the Halalcore System, although it is an expensive and an imperfect system, is capable of much improvement. . . . It is a system that we must not depart from until we are sure that we have found a better one;" and he adds that he thinks the halalcores do their work pretty thoroughly.

With regard to the discharge of the night-soil at Carnac Bunder, Dr. Lumsdaine says he is not aware of any objection to it, "if discharged when the tide is going out." Mr. Ormiston says, "I am less afraid now than I was at a former time of polluting the harbour, more thoroughly understanding the advantages which we have here by the diurnal variation of the tide;" but he adds, "still it is a great nuisance—I have no doubt about that; and if there could be any other means of disposing of it, it should be adopted."*

Two other methods of dealing with the night-soil were brought to the

* Might not the pollution of the harbour be prevented by delivering the sewage at Carnac Bunder into hopper barges, in which it should be taken out to sea, and discharged? This could be done during the fair season, if not throughout the year.

notice of the Commission : 1. The Dry-earth System ; and 2. Captain Tulloch's project of sewage utilization for agricultural purposes.

The Dry-earth System could not, in the opinion of the Commission, be introduced into a large city like Bombay. According to the Army Sanitary Commission, "the matter from latrines, including solid and fluid excreta, amounts to about 1 lb. per man per day, or, in round numbers, half a ton per day per 1,000 men. The quantity of dry earth required for latrines alone is about $2\frac{1}{2}$ lbs. per man per day, proportionately increased if the latrine is used oftener than once. To absorb and deodorize the urine of one man about 7 lbs. of dry earth is required per day. Thus, for 1,000 men, the total daily amount carted into the station and distributed would be 9,500 lbs., and the

Memorandum upon
the Dry-earth System
of Sewage.

amount to be collected and carted away would be 12,000 lbs. The daily movement of earth and soil would thus be nearly 10 tons for 1,000 men." These figures are conclusive that, from its cost and from the practical difficulties which would attend the mere cartage, distribution, collection, and removal of so much earth, the Dry-earth System is inapplicable to any large community. In jails, barracks, and hospitals, where strict discipline is maintained, the system may possibly be made to work ; but in a free community it is impracticable.

With regard to sewage utilization, the Commission, while fully recognizing the advantages which would result from its successful introduction into India, cannot but hesitate to recommend the trial of so gigantic an experiment as would be involved in the adoption of Captain Tulloch's Scheme. They think there is the less reason for trying the experiment in Bombay, as it is now on the eve of being tried in Calcutta. Sewage utilization has its advocates there, at least as enthusiastic as its advocates in Bombay. But one of the foremost among them, Dr. Chevers, though asserting that thereby "the now deadly swamps eastward of Calcutta may be made, in ten years, the gardens of the country," judiciously qualifies his opinion thus:—"While strongly recommending the reclamation of the Salt Lake and the extensive utilization of the sewage of Calcutta in manuring the land thus obtained, I cannot say that I believe the measure to be unattended with risk. . . . The utilization of the entire sewage of so large a city as Calcutta has never yet been attempted even in a temperate climate. Here it will be attended with dangers, the obviation of which will demand considerable science and unremitting care." And Dr. Smith, the Sanitary Commissioner for Bengal, writing on the same subject, says:—"That the lake should be scientifically recovered from its now barren and boggy condition, there can be no doubt ; but whether human excreta in enormous quantity (either in its natural condition, or largely diluted with water) should ever be allowed to reach its soil, is quite another question, regarding which there is a mass of conflicting evidence."

Report on the
Drainage and Con-
servancy of Calcutta,
p. 57.

In this doubtful state of things, the Commission consider that it would be extremely unwise to incur the large outlay which Captain Tulloch proposes for sewage irrigation. They learned with pleasure that the Municipal Commissioner had been trying experiments on a small scale near the Love

Grove Sluices, and that those experiments had been comparatively successful. It may therefore be expected that before long these problems will be solved :

1. Whether the native cultivators will use and pay for sewage as manure ; and
2. To what crops and land sewage manure is best adapted.

But for the solution of the great problem—whether sewage irrigation to a vast extent can be carried on in the tropics, without injury to health, in the neighbourhood of so large a town as Bombay—the Commission consider that it would be wise to await the result of the great experiment about to be attempted in Calcutta.

For the reasons above stated, the Commission feel themselves unable, either on engineering or sanitary grounds, to recommend the adoption of Captain Tulloch's Project for the drainage of Bombay.

As, however, there is an impression abroad that the drainage of Bombay is miserably defective, and requires immediate alteration, the Commission think it will be useful to summarize the information they have obtained on the subject.

At Colaba there are few drains of any kind ; but waste and rain-water finds its way into the Harbour and Back Bay. There is halalcore service, and the night-soil is carried out to sea as far as possible. The drainage of Colaba was not included in Captain Tulloch's scheme.

For the Fort, a system of drainage on the combined principle, by which the rain is carried through the same sewers as the sewage matter, is being constructed, according to a design of the late Mr. Tracey, at an estimated cost of Rs.4,20,000. These works have been stopped for the present, but the

Evidence, p. 92. drains, so far as they have been constructed, are said by Mr. Aitken to work very well, both in fair weather and monsoon.

The Esplanade is drained chiefly by the absorbent power of the subsoil, but partly by connection with the drains of the Fort and Native Town.

The Native Town, wherein three-fourths of the inhabitants reside, drains partly into the Harbour and partly into Back Bay, but by far the greater portion of it drains towards the flats. The bulk of the sewage is carried off by the main drain to Love Grove Sluices, where it is pumped into the sea at all states of the tide. Every street has its drain, though the carts are badly supplied. The old drains are imperfectly constructed ; but in some districts, as at Camateepoora, new drains have been made with the happiest results. The houses are connected with the drains by means of gullies. The cost of cleaning the drains is about a lakh and a half per year.

The rest of the island is left very much to its natural drainage.

It is conceded by Captain Tulloch that "a careful examination of the map of Bombay can hardly fail to convince an engineer that the natural drainage line runs along" the streets in which the principal drains are now constructed. This is a great advantage, of which the most should be made in any efforts to improve the drainage of Bombay. But the Commission do not think it advisable to improve or maintain all those drains. The levels of low-lying districts are being raised

Report, p. 6.

every year, and Mr. Ormiston is inclined to believe that the island could be effectually, or nearly effectually, drained by gravitation.* With improved surface drainage, and an improved halalcore system, Dr. Lumsdaine thinks there is no necessity for a system of sewers to carry away the night-soil. The attention of the Municipality should, therefore, in the opinion of the Commission, be specially directed to constructing sewers having their outlets in the Harbour for draining by gravitation as much of the island as the levels will admit of, and to improving the present Halalcore Service.

With regard to the Fort drainage, as the scheme is complete in itself, and the money required for the execution has been raised by loan, the Commission consider that it should be proceeded with and completed without delay.† The Commission would, however, recommend that the house connections should be so constructed as to prevent, as much as possible, the admission of noxious gases into the buildings. A simple contrivance for achieving this object is described by Captain Tulloch.

The Commission desire also to draw attention to the night-soil reservoir at Carnac Bunder. It is insufficient in size, and the discharge-pipe is carried not only under the railway, but under the piers of the adjoining over-bridge. The Commission recommend that the reservoir should be enlarged, and the pipe relaid, so as to be easily accessible throughout its whole length in the event of any stoppage taking place in the pipe.

The Commission further recommend that the number of public necessities should be largely increased. There are at present only fourteen in Bombay—a very small number as compared with the wants of the population.

The Commission are aware that in recommending delay in undertaking any great scheme for the extension of water-supply or the reconstruction of the drainage of Bombay, they expose themselves to much adverse criticism, not only from the numerous class of persons interested in the execution of large projects, but from those who have the sanitary improvement of the city really at heart. But after careful consideration, the Commission have come to the conclusion that not one of the projects submitted to them fulfils these conditions of certainty and economy which would justify them in recommending it for adoption. They are unable to affirm that any of the works proposed is of indisputable necessity for the preservation of the health of the city of Bombay; and they do not think that a few years' further delay is likely to be productive of injurious consequences. If, in the interval, the recommenda-

* "I would endeavour," he says, "to induce the people, by assistance or otherwise, to raise the ground which is at present too low to be drained by gravitation. It is not a large area, only 170 acres altogether."—Evidence, p. 122.

† Captain Tulloch says:—"If the Government thought that the Fort was so small a place that the sewage might be discharged into the sea, I should not offer any objection. If this system were really hereafter to be a nuisance, nothing would be easier than to rectify it, for all you would have to do would be to extend the main drain and pick up [the Fort sewage]."—Evidence, p. 99.

tions of the Commission with regard to the extension and improvement of existing works are carried out, they consider that time will have been gained to ascertain the result of experiments now in progress, while provision has been made, without incurring any heavy liabilities, for the increasing requirements of the town.

A. R. SCOBLE.

W. KENDALL, COL. R.E.

J. S. TREVOR, LIEUT.-COL. R.E.

W. G. HUNTER, M.D., M.R.C.P.,

Surgeon, Bombay Army.

I. B. LYON, *Secretary.*

BOMBAY, *July*, 1869.

APPENDIX B.

MEMORANDUM ON GENERAL H. Y. D. SCOTT'S METHOD OF TREATING SEWAGE.

1. General Scott quotes in favour of his system the views and opinions of the most eminent authorities in sewage matters. These opinions are given by chemists, engineers, and even by the advocates of irrigation, and must undoubtedly carry great weight. It may be advisable to give some of this evidence in their own words, that full justice may be done to General Scott's invention.

2. Dr. Frankland, F.R.S., Professor of Chemistry at the College of Chemistry, and one of the River Pollution Commissioners, stated in his evidence on the Birmingham Sewerage Bill: "The process I would recommend to be carried on there (at Dunton, Birmingham), would be the treatment of the sewage some time before it comes there with a mixture of lime and clay. That produces a copious deposit from the sewage. It deodorizes the sewage very completely, so that it could flow on to the land afterwards without a trace of smell from it, and a trace of deposit is absolutely inodorous. That deposit would be first dried and then burnt in kilns, and then transformed into Portland cement. That appears to me to be the process of dealing with this sludge, which has always been a difficulty. It appears to me that this is the process least open to objection. I think it is very perfect in preventing nuisance. The sludge which is deposited, if a sufficient quantity of lime is introduced, such as is used in General Scott's Process, will remain for weeks without any smell."

Dr. Frankland stated in the same enquiry that sludge, treated as manure, would be nearly worthless. At a meeting at Stafford House, under the presidency of the Duke of Sutherland, he said:—"From what I know of the effect of lime (the chief precipitating ingredient in General Scott's Process) the sewage of 6,000 persons, after such treatment, may be run upon an acre."

Dr. A. Voelcker, F.R.S., Consulting Chemist to the Royal Agricultural Society, said that "having had an opportunity of visiting the works at Ealing, he wished to bear testimony to the fact that the process of drying and manufacturing the dried material into cement could be carried on in the immediate neighbourhood of the town where the sewage was obtained without creating the slightest nuisance. The subject, brought forward at this meeting in such an able manner by General Scott, was one of very great importance, not only to town authorities, but also to agriculturists; for he had come to the conclusion that agriculturists would never use sewage if they had to take it in the foul condition in which it had hitherto been delivered to them. But he was convinced that if sewage, properly clarified, were offered to the farmers, they would take it, and would find it a very useful liquid for irrigation

purposes. In all the clarification plans which had hitherto been put in practice, whether they were the lime, or the sulphate of alumina, or the Phosphate Sewage Process, very little, comparatively speaking, of the precipitating agents had been used, for obvious reasons—reasons of economy. Now, in General Scott's plan, a very large proportion of earthy matter—clay and lime—was used, because the object was to bring out a useful product, and it was mainly due to this circumstance that the sewage-slush did not enter into putrefaction. A little lime added to organic refuse matters hastened their decomposition, set up putrefaction, and created a very abominable nuisance. But in General Scott's plan a very large proportion was used, and with this was mixed clay, a material which possessed remarkable absorbing properties. The consequence was that any products of decomposition, which no doubt would be formed, were absorbed and retained by the earthy matter. Be this as it may, it was certainly a fact that the material which was obtained by precipitation, according to General Scott's plan, could be kept in a wet and pasty condition for two or three months. He had himself examined at Ealing some of the clay and lime sewage-mud which had been kept for nearly three months, and he found it had no disagreeable smell. This led him to the third point, on which he would just offer a remark which perhaps might not have occurred to General Scott. It was this—that the material from which he made cement might be dried in the open air without creating a nuisance. Indeed, he believed it would be found in practice that air-drying would be the most economical and probably the most efficacious plan of producing a material which could be burnt in a cement-kiln. There was a large quantity of earthy matter mixed up with the material which formed the sewage-slush, and the consequence was that it got penetrated by air and dried itself; whereas one of the most difficult things in the world was to dry the deposit obtained by simple subsidence of the sewage-slush obtained by the mixture of a small quantity of lime or sulphate of alumina. He knew of no substance which it was so difficult to dry, and, consequently, which it was so expensive to dry, as sewage-slush; but by General Scott's plan, the deposit, being mixed with much earthy matter, was at once rendered porous, so that by exposure to air it dried itself, and this was a matter of very great importance, for although, no doubt, sewage-slush could be dried artificially and burnt, yet there was a great objection to this artificial drying in the expense which had to be incurred. The simple evaporation of the water was by no means a guide as to the expense. These were some of the points which had forcibly struck him as being in favour of General Scott's plan."

In the Birmingham Sewerage Enquiry, Dr. Voelcker repeated much of the above evidence, adding that farmers will not use raw unclarified sewage, "on account of the sedimentary matters which form a deposit, choking up the pores of the soil, and therefore, in a great measure, neutralizing the fertilizing effects which the substances in solution would otherwise produce."

Dr. Voelcker also stated that the sedimentary matters contained only one-eighth part of the whole of the fertilizing substances in sewage, and that he considered them to have so little value that it is hardly worth the farmer's while to cart them away to any distance, if he can have them gratis.

Dr. Odling, F.R.S., Professor of Chemistry at the Royal Institution, gave it as his opinion before the Birmingham Sewerage Committee that sludge precipitated by milk of lime could be converted into cement without creating a nuisance, and that the effluent water "would be both clarified (and in the sense of no longer smelling) purified." He states that if the sewage is thrown on land with the suspended matters in it, "a very much larger area of land" is required for its purification, and that he does "not think there is any commercial value in the material that will be extracted at Dunton (Birmingham), unless they make it into cement."

Dr. Odling, at a discussion on General Scott's Process at the Society of Arts, also said "that he had seen General Scott's Process carried out at Ealing, and he must say that he was very much impressed with it. It appeared to him that, whatever might be the ultimate disposal of sewage, there must be a large number of cases in which it would be desirable to separate the sludge from the liquid matter, and the manner of separating the sludge adopted by General Scott was certainly most complete. There remained the question in what manner or for what purpose this sludge should be disposed of; and in dealing with that question General Scott had struck out a new line of work. He had availed himself of what Mr. Bramwell had called the 'fuel' in the material, and he had availed himself of its other most valuable constituents, and he had recovered the material with which he effected the process in a form more valuable than it was before it was used. Economically, the scheme seemed to him the most promising of all which had been introduced for the purpose of dealing with sewage, and throwing down the sludge from it, and then dealing with the solid portion so as to convert it into a useful marketable article."

Professor Abel, F.R.S., Chemist to the War Department, in discussing General Scott's Process at the Society of Arts, said: "He had looked carefully into the various points of the Process, and was particularly struck by the facility and the completeness with which it could be applied to the clarification and the precipitation of sewage. The process was at that time carried out certainly in no manner advantageous to its success, but the results which he (Mr. Abel) witnessed were conclusive in his mind, as far as the clarification and precipitation went. Further, he examined several of the products which were obtained by precipitating with a mixture, judiciously proportioned, of lime and clay. He examined them, not merely in regard to their power of being converted regularly into a species of cement, but also with regard to the quality of cement, and he found that it was equal to excellent Portland cement, or, in another case, to an excellent hydraulic cement of a different character, produced by another method."

Dr. Letheby, on the same occasion, said that, "in common with all who took any interest whatever in this question, he had had a good deal of satisfaction in listening to the paper read by General Scott, not merely because it seemed to offer a practical means of solving a great difficulty, but chiefly because it seemed to him to be the means whereby people of the most opposite inventions, and theories, and practices, might be brought somewhat into harmony. On the one hand, those who were advocates of the Precipitating

Process would find in it the means of carrying out all they wished ; and, on the other hand, those who were particularly anxious for the use of the sewage-water or effluent water upon the land, would find an opportunity of using it advantageously. One other point had struck him during the reading of the paper and the discussion which had arisen out of it, and that was as to the quantity of cement that would possibly be produced from a given quantity of sewage. Now, looking at the experience which we had during the days of the old Tottenham Works and of the works also at Leicester, it was found in practice that the proportion of solid matter that was obtained was invariably between four or five times that of the lime used. He calculated, therefore, that two tons and a half of this cement would be obtained from a million gallons of sewage. That would be about a ton for every 10,000 people per day. Well, he did not know what might be the demand for cement, but it did not strike him at first sight as being a very large quantity. Such a quantity might very well be used in building operations. He had listened with very great satisfaction to the account of the process, and he fancied and hoped that he saw in it a means by which we should get out of the great difficulty which pressed upon all the towns of England—namely, the economical disposal of the soil."

The following evidence, given on the Birmingham Sewerage Bill, embodies the opinions of Dr. Letheby on the importance of employing a Precipitation Process before throwing sewage on land :—

Was not that part of the farm which was used as a drying bed?—No ; I went on the farm on the 18th January, and I saw them ploughing it up, and it was so bad that I could hardly endure the smell.

What would be the effect of draining the land at Saltley and then putting clarified sewage upon it ; would not that do?—I should say yes, when the land gets into a proper condition. I do not believe that clarified sewage, under any circumstances, put upon good land would do any mischief.

If a farmer took it he would take it, not for the purpose of getting rid of the matters in the sewage for purification purposes, but for agricultural purposes?—Precisely. I say that sewage run upon land without being previously defecated by chemicals will be a nuisance wherever it is put on.

General Scott having brought forward, at the discussion on his process at Stafford House, the evidence given by Mr. W. Hope, Drs. Odling, Voelcker, and Letheby, Mr. Hawksley, and Mr. Bramwell, in support of the following proposition : "The sludge must be taken out of sewage-water before employing it for irrigation. If the sludge be allowed to deposit on the land, it chokes the pores of the soil and creates an intolerable nuisance." Mr. Morgan, Manager of Sewage Farm, Barking, said : "May I be allowed, my Lord Duke, to state that we have never found it necessary to remove the sludge. For the last seven years we have put the sewage on to the land in the condition in which it is delivered at the Barking Outfall. I do not deny that there may be occasions where it would be of advantage to allow the solid matter to precipitate ; but when it is stated on such high authority to be absolutely necessary, I feel called upon to say that we do not find it to be so."

Mr. R. Rawlinson, C.B., Government Inspector : "There is one point with

reference to Mr. Morgan's remarks about the Barking Farm which ought to be mentioned, and that is, that the grosser portion of the deposit remains at the bottom of the tanks, and the sewage is delivered upon the land by pumping-power. Of course, each case must be considered by itself. In some cases you have more deposit than in others. Then, again, you have some land more capable of receiving the grosser deposit than other land; but, as a rule, I think General Scott is right, viz., that land is better dealt with for having the solid matters extracted. The Manager of the Aldershot Sewage Farm, than whom there is no better authority on this subject, has a porous sandy subsoil, where it might be supposed the sludge could be put on with impunity, but he finds it better to remove the solid matters from the sewage. That gentleman has offered to the managers of solid manure manufactories to give an acre of land free of rent, in order that those who advocate the retention of the sludge as the most valuable part may have an opportunity of showing its value—the sludge, in Mr Blackburn's opinion, having no beneficial influence upon the land, as compared with the clarified sewage after the sludge has been extracted."

Mr. Morgan repeated that the sewage which was applied to the land at the Lodge Farm was taken from the main outfall sewer before it was delivered into the reservoirs, and therefore it was the North London Sewage in its raw state. The nature of the soil at the farm at Barking is most porous, but some of it is good land with some clay in it.

Mr. Hawksley, President of the Institute of Civil Engineers: "I think the instances quoted are not cases in point. In neither of these instances is farming conducted under sanitary obligations, and in neither case is more of the sewage used than is necessary for the purposes of the farm. The subject which is the important one to be here considered, is the case of the application of the sewage of towns, under all conditions, at all times, and in whatever volume it may be produced. These circumstances are so totally different from the circumstances of Barking and of Aldershot, that it is worth while for a moment to allude to the practical nature of the conditions in the case we have to consider, viz., the clarification of the sewage of towns. We have to put the sewage upon the land at all periods of the year, whether, for the purposes of cultivation, the ground requires the sewage or not. We have to put sewage upon the land when it rains as well as in dry weather; when there is frost on the ground, and when the ground is parched with heat. Now, the quantity of deposit coming down with the sewage of a large town is to be counted by thousands of tons per annum; and if that quantity is to be put upon a small area—inasmuch as by the very act of filtration, or by the very act of running over the surface, the whole of the matter is left upon the surface—a nuisance is produced, together with a clogging effect upon the soil that is injurious to the land. The question raised is one of the utmost importance, for to deal with sewage so that it shall not be a nuisance, and to deal with it so as to make it of practical utility in an economical sense, requires an enormous area of land, such as in general cannot be obtained in the United Kingdom for any such purpose. The question, therefore, arises—How, otherwise than by resorting to one or other of these processes, the effect of purification, which is so much desired, can be produced or attained? Now, General Scott proposes two

methods, resulting, to some extent, in the same end. The first method is to precipitate the organic matter, suspended in the sewage, and to use that organic matter as a fuel for the purpose of converting the other solid matters into a valuable product, viz., hydraulic cement; but General Scott does not stop there. He says by his process—and I believe in it—he can so clarify the sewage, that in general it may be admitted without injury into any running stream of competent magnitude. I believe in that; but again he says—Suppose you cannot, under the particular local circumstances of the case, effect that object *per se*, you may send the effluent water to the land, and to a small and possible area of land, without thereby occasioning a nuisance. These are the valuable results which General Scott proposes. I have myself seen a good deal of this process, and I am quite satisfied if it does not give us an entire solution of the problem, at all events it will help us nearer to it; and I am quite satisfied that by the means which General Scott proposes many of our large towns can escape from the difficulties with which they have now to contend.

The following are extracts from the evidence of Mr. Hawksley before the Birmingham Sewerage Committee in reference to the same subject :—

MR. THOMAS HAWKSLEY, Sworn.

3079. Were you appointed Engineer of the Sewerage Enquiry Committee in August, 1871?—Yes.

3115. I understood you to say that it (the sludge) was converted into something more solid than that? . . . It can be converted, by General Scott's Process, into a very useful and valuable cement.

3120. Now, my friend will ask, if I do not, whether you will venture to say that that process can be carried on over this land without any nuisance?—I am certain of it; if you kept off the untreated sludge, which is very offensive.

3123. You have said that sewage, when it is poured upon the land without any preparation of this kind, does make a great nuisance. You have often said that?—Yes; the nuisance varies in degree, according to the state of the weather—the comparative amount of water with which the sewage becomes mixed. . . .

3257. And where has that process been carried on of using the sludge for the purpose of manufacturing cement?—It is carried on at Ealing, where it may easily be seen.

3258. That is General Scott's Process?—Yes; it is very well described in a specification which I have brought with me, and if you will allow me, I will place it in the hands of the noble Lord. (Handing in specification.)

3261. That cement is manufactured out of that sludge so deposited?—Yes; and a very excellent cement it is.

3419. . . . I have already stated that as long as the sludge is deeply covered with water it gives off no offensive odour. It is only when afterwards it is got out of the tank, and, without being deodorised by chemicals in any way, it is spread upon the ground, that an offensive decomposition takes place, which, as has been observed, occasions a disgusting odour.

3433. What is your proposal? We have heard about burning this stuff.—I did not make the proposal, but it is practically done by General Scott, and done admirably. It is very combustible. It contains a very large amount of combustible matter; but you will hear all about that from Mr. Bramwell.

3575. . . . The sludge which is now formed in the basin at Saltley is not defecated in any way, and the moment it gets upon the land the organic matter in it begins to decompose and give off most offensive effluvia. It is a very abominable thing, no doubt.

3600. At what point in the conduit do you consider the sewage becomes innocuous?—At the point at which we add, and immediately we add, the milk of lime.

Mr. Bramwell, Vice-President of the Institution of Mechanical Engineers, and a member of the Council of the Institute of Civil Engineers, questioned on the same subject by the Committee, gave the following evidence :—

5767. As to the conversion of it (the sludge) into Portland cement, what do you say?—That process is carried on by General Scott, at Ealing, and from what I have seen of it, it appears to be an extremely satisfactory process, and I think would be suitable for the Birmingham sewage.

5769. Have you formed an opinion as to whether the process was a valuable one and likely to come into general use?—I think it is; I have the very highest opinion of it.

The same Engineer, at the Society of Arts, observed: He would say a word first of all in reference to an observation of Mr. White, although perhaps it would be doing what Mr. White had asked General Scott to do, viz., to answer a question. Mr. White put it, “Does the water contain lime, and does the water contain clay?” Now he supposed most sewage contained lime, but if it did not, it contained something which everybody was desirous of getting rid of, and that was the gluey, sticky, filthy sludge. That was a thing which everybody had decided ought to be got rid of before the water should go into any channel. That being so, supposing it contained no ingredient whatever to make Portland cement, but supposing that the materials to cause it to become inoffensive were such materials as made Portland cement, then you put those in, not because you wanted to make Portland cement, but because you wanted to make the sludge harmless and inoffensive; and if you could afterwards make Portland cement, why should not you do so? That he understood to be General Scott’s proposition.

Mr. W. Hope, V.C., Lessee of the Romford Sewage Farm, said: “He had listened with very great pleasure to the paper of General Scott, who had made a very original, and he hoped useful discovery. The sludge was always a great difficulty in dealing with sewage, no matter by what process or theory.”

Mr. Hope, examined before the Parliamentary Committee on the Birmingham Sewerage Bill, replied as follows :—

1935. Have you examined other systems which profess to deal with sewage chemically in the same way as the A B C?—I may mention that I am the Lessee of the Sewage at Romford. I always enquire into all these matters,

on the chance of my being able to do something with the sludge of Romford, to make a profit out of it ; at present it is a nuisance and a trouble.

2119. Do you provide for the exclusion of the ordinary excreta?
—I altogether approve of taking the sediment from the sewage.

2236. But with regard to the sewage of Birmingham, on the whole, it is really neither one thing nor the other? (That is, "not irrigation and not wholly filtration.")—I think it is very much the same as every other Sewage Scheme must be. As to the solid matter, it must be taken out.

2311. You see that you thought of the enormous strain (upon the purifying process of the land) at that time? (11th September, 1871.)—Yes.

2312. At that time, at any rate, you thought that, as a matter of course, a few years would produce an excess of organic matter in the filter? —I should be of the same opinion now, if it was proposed to run sludge on to the surface of the land.

2313. What do you mean by sludge?—Sewage-sludge.

2314. Detritus or fecal matter?—I mean sludge, not the detritus; the sludge arising from all kinds of sources: the sludge which at present creates a nuisance at Saltley. It is to be taken out, as I explained yesterday, at Dunton.

2324. You say that it is peculiarly offensive?—Yes; when it is allowed to stagnate and decompose, it stinks worse than anything I ever smelt out of Constantinople.

2501. There is always a certain amount of exhalation from a sewage farm, is there not?—There is a certain amount of smell from every farm.

2502. Not at present, certainly?—There is really so little smell about a sewage-farm except from the solid matter. I have on my own to take out the sediment. I have no use to put it to, and it accumulates.

2534. May the whole of the sewage be poured on to the land without any previous treatment?—Dr. Frankland's experiments proved that if the suspended matters were first taken out, the liquid sewage of 6,000 might be put upon one acre.

2539. Now be good enough to refer to your own Report, in p. 74, the passage to which you have referred. "It would not do to allow this solid matter to be exposed on the surface of the ground in hot weather in constantly accumulating quantities?"—Yes.

At the meeting at Stafford House, Mr. Hope appeared to somewhat qualify this evidence, but the qualification amounts to this—given a large area of land—that no regard need be paid to the question of purification—and that no storage is necessary (which he admits it to be), then, agriculturally, it is not necessary to take out the sludge before applying sewage to land; or, in other words, that land will not suffer from moderate doses of sewage-filth. His statement was as follows :—

In the first place, I am happy to say that no injury would arise to sewage for the purposes of irrigation from the previous process proposed by General Scott. There is no part of the process which could injure the sewage for use in that way; and, secondly, I am satisfied that the sewage would be so defecated as to admit of the effluent water being finally purified by the

smallest area of land. Having said thus much, which I am very happy to do, in support of General Scott's plan, I would like to qualify, in a small degree, one or two of the statements attributed to me in the Synopsis of the Birmingham Sewage Evidence. In the case of almost every town it is necessary that the sewage should be stored. The effluent water is stated to be pure. It is not. It is impure. A large portion of ammonia passes away in the effluent water precisely in the condition in which it arrived on the land. Therefore it is necessary that the sewage should be stored; but you cannot store it without having subsidence of the matters in suspension; therefore it is necessary that the solid matter in suspension should, in the bulk, be taken out. Agriculturally it is not necessary; that is, the statement in the Synopsis is not strictly accurate with regard to the agricultural application of sewage, though it is correct with regard to the purification of sewage on a limited area. In the latter case it would choke the pores of the soil and create a nuisance; but in the former case, in a more extended utilisation, it would not do so.

Both Mr. Hope and Mr. Bailey Denton, indeed, though earnest advocates of purification of sewage by irrigation, or irrigation combined with filtration through soil, are, it is stated, sufficiently impressed with the Cement and Lime Process for dealing with the sludge, to wish to employ it in towns of which the sewage is in their hands.

It certainly appears, therefore, that all the received authorities, almost without exception, speak in terms of praise of General Scott's System. No one authority of any note, whether chemist, engineer, or agriculturist, has disputed that it affords the best prospect of any of the numerous plans proposed for dealing with that part of the question which relates to the clarification of the sewage and disposing of the matters deposited without nuisance.

General Scott is now aiming at removing much of the dissolved impurities of sewage, and extracting a sufficient amount of ammonia and nitrogen compounds to meet the expenses of the process, and, as he states, he is fairly successful on the small scale. Since, however, no works have yet been erected to test these plans, no further remarks upon them are called for at present. They would come in aid of the Precipitation Process which he already employs. He has also the idea that much may be done towards the removal of noxious gases from the sewers of towns. The plan he proposes was explained at the Social Science Congress this year in the following terms:—

“An experiment, extending over seven or eight months, bearing upon the first head, has been carried out at Ealing. In lieu of introducing the precipitating materials at the outfall, as hitherto practised, they have been introduced into the sewer itself at a point nearly $1\frac{1}{2}$ miles from the depositing tank, and near the head of the village. As I have already explained elsewhere, the experiment was attended with the happiest results. All the slimy and sticky, black, decomposing filth, which usually furs the bottom and sides of drains, disappeared; the main-sewer was perfectly free from stinking sewer-gases, no deposit of any sort was left behind, and, owing to the thorough admixture of the chemicals with the sewage, the deodorization and precipitation

were more perfect than when the precipitants were introduced at the outfall. As the main-sewer alone was treated, the branch-drains to the side streets and houses were comparatively unaffected. Still, inasmuch as the great volume of the sewer-gases was disposed of, much benefit resulted, and directly the old system of introducing the chemicals at the outfall only was again resorted to, complaints of the smell of the drains re-commenced."

"It has occurred to me that the following plan might, to some extent, remedy the difficulty which there would be in subjecting the side-drains to similar treatment: Chlorine gas can now be manufactured very cheaply, and by passing such gas into a vessel in which milk of lime is being prepared, previous to its introduction into the sewer, all the advantages of chloride of lime would be obtained without incurring the heavy cost of that substance. The prepared mixture, on coming into contact with the free carbonic acid in the sewage, which would be constantly entering from the side-drains, would cause a continual formation of carbonate of lime and expulsion of chlorine. The main-drain would, therefore, never be without a certain amount of this disinfectant and deodorant, and so soon as, through the defective trapping in a side-drain, a rush of sewer-gas made for the opening, there would be drawn into the side-drain a certain amount of chlorine which would disinfect the gas subsequently discharged. The evil would, therefore, be of short duration, and continued breathing of the sewer-gases would be rendered impossible. Moreover, the natural tendency of gases to diffusion would gradually introduce notable quantities of chlorine into the side-drains—liable to absorption by the liquid sewage, doubtless, but still doing some good. Sulphurous acid gas might be similarly introduced, but it is certainly less efficient than chlorine. Carbolic acid might also be used in conjunction with the lime."

The various papers published by General Scott in reference to his process are sent in with this report. The process is about to be tried on a large scale at Birmingham and West Ham; and the towns of Chester, Norwich, Tunstall, Hanley, Darlington, and other places of importance, are in treaty for its use.





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