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SALUS GENERIS HUMANI.

Sewage Disposal Works.

With the Author's Compliments

SEWAGE DISPOSAL WORKS:

A GUIDE

TO

THE CONSTRUCTION OF WORKS FOR THE PREVENTION OF THE POLLUTION BY SEWAGE OF RIVERS AND ESTUARIES.

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SECOND EDITION, REVISED AND ENLARGED.

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PREFACE TO THE SECOND EDITION.

The fact that a Second Edition of this work has been deemed necessary, is good evidence that the Author's desire, as expressed in the original preface, has been, in some degree, attained.

With a view to increasing the usefulness of the work, some important new chapters—on the Sewage Disposal Systems of London, Berlin, and Margate respectively—have been added, and the information formerly given has been amplified and extended where necessary. In this revision the Author has endeavoured to meet the suggestions of the various reviewers who most generously noticed the First Edition, and he hopes, that with the new matter now presented, the reader may find the work of greater service. From the fact of his having, for some years, had charge of the Main Drainage Works of the Northern Section of the Metropolis, the chapter on London will be found to contain many important details which would not otherwise have been available.

In dealing with the question of the chemical treatment of sewage, the Author has been ably assisted by his partner, Mr. Midgley Taylor, F.C.S., to whom, and to others who have readily afforded him assistance in other directions, he desires to express his thanks.

THE AUTHOR.

27 Great George Street,
Westminster, *March, 1894.*

PREFACE TO THE FIRST EDITION.

Although many excellent works on the treatment of Sewage have been published, yet they are all without those plans and details so necessary to the proper appreciation of descriptive writing. The author has endeavoured to meet the want of an illustrated guide to the construction of Sewage Works, by bringing together in this volume some of the best examples of executed works. He has, however, been unable to obtain the particulars relating to some good examples, and this fact will account for their non-inclusion.

In preparing the first part of the work, the author has not hesitated to make such references to the various Commissions on River Pollution as he thought necessary. Such information may be "ancient history" to the older practitioners, but to the student it is indispensable.

During the long period in which the author was connected with the Wimbledon Works, he had opportunities of seeing Sewage treated under almost every condition, and he fully appreciates the difficulty of finding a universal solution to the "Sewage problem." Progress is, however, being constantly made, and it will be conceded that, especially in the treatment of sludge, means are now available, by the employment of which that troublesome material may be dealt with without causing offence. This in itself is of the first importance as regards works where the clarification of the Sewage is effected by means of tanks and chemicals.

The author has had the privilege of meeting many deputations from Sanitary Authorities about to carry out works, and he has been enabled to ascertain their views as to the direction in which information on Sewage Disposal is wanted. He can only hope that the present volume will in some degree meet an acknowledged want.

WIMBLEDON, *May*, 1890.

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SEWAGE DISPOSAL WORKS.

PART I.

CHAPTER I.—Introduction.

The reign of Queen Victoria will ever stand out as a most important epoch with regard to progress in sanitary science. At the time of her accession, the condition of the people was, from the sanitarian's point of view, deplorable in the extreme; during the earlier period of her reign matters became worse, as the town populations rapidly increased, and practically no steps were taken to remove the refuse matters constantly produced, nor to lessen the pollution of the rivers, of the soil, and of the air. As a consequence of the abuse of nature's gifts, dreadful outbreaks of cholera, of typhoid fever, and of other zymotic diseases occurred from time to time; it was seen by the early sanitarians that the root of the evil lay in the improper disposal of the fouled water, and the refuse generally from habitations and from factories, and the careless manner in which water-supplies were obtained from tainted sources.

The recent outbreak of typhoid fever at Worthing shows how slow is the rate of progress in some cases; whilst, on the other hand, the determination of Manchester, Liverpool, Birmingham, and other large centres to obtain their water-supplies from absolutely untainted sources is, to the sanitarian, gratifying evidence of the advances in the observance of the first principles of sanitation. Yet, that the ancients even knew of the evils attending the pollution of rivers is evident from

Herodotus, for he says—"The Persians, according to my own knowledge, observe the following customs:— . . . They neither make water, nor spit, nor wash their hands in a river, nor defile the stream with urine, nor do they allow any one else to do so, but they pay extreme veneration to all rivers." Would that every water-shed in the country had its conservators animated by the spirit of the Persians of a bygone age, and stopping with a strong hand the pollutions which, to this day, are allowed to convert once pellucid streams into putrid sewers, abominable alike to sight and smell, and it is no less than a disgrace to our civilisation that a year never passes but an outbreak of typhoid or other zymotic disease, directly traceable to a neglect of the first principles of sanitary science, fills, now the city cemetery, now the village churchyard, with its victims.

Insanitary Conditions.—The general question of the health of town communities was investigated by the Poor Law Commissioners of 1839-42, who found that the diseases principally prevailing amongst the working classes were those due to accumulations of decomposing refuse; to damp, close, and over-crowded dwellings; and to improper water-supply.

Remedies Proposed.—Some excellent suggestions were made by the Commissioners; they advocated the immediate removal of all decomposing refuse, and proposed, as an adjunct to better supplies of water, the construction of sewers, by means of which the foul matters could be cheaply transported to a distance from the towns, and then be applied to land, in order to prevent the pollution of the rivers, and to utilise the fertilising matters which they knew would be present in the sewage.

Public Health Acts, 1848 and 1875.—The Reports of the Poor Law Commissioners, and of the Duke of Buccleuch's Commission of 1843-45; the insufficiency of the Nuisances Removal Act of 1846, added to the fear of an outbreak of cholera, led Parliament, in 1848, to pass a resolution that—

"Further and more effectual provision ought to be made for improving the sanitary condition of towns and populous places in England and Wales, and it is expedient that the supply of water to such towns and places, and the sewerage, drainage, cleansing, and paving thereof, should, as far as practicable, be placed under one and the same local management and control, subject to general supervision."

It is unnecessary to refer at any length to the Act which was subsequently passed, and by means of which a General Board of Health was constituted.

The Act contained a large number of sanitary provisions, which were, however, inoperative, unless an exceptionally high rate of mortality enabled the Board of Trade to enforce their application, or unless the Act was petitioned for by aggrieved ratepayers.

Soon after the passing of the Public Health Act of 1848, towns began to carry out large sewerage schemes, using the streams and rivers as the receptacles of the liquid filth. As a natural consequence, the state of the rivers became worse than it was before, and men and animals suffered from the poisoned and polluted sources of water-supply.

The third great cholera outbreak of 1854 inspired the Legislature with renewed activity, and a comprehensive Nuisance Removal Act was passed in 1885.

Other legislation followed, until in 1875 the Public Health Act consolidated and simplified the various enactments in existence at that date.

Still, the Acts were permissive rather than compulsory, so far as the action of the various Local Authorities was concerned; and although towns readily availed themselves of some of the powers conferred upon them, particularly as regards the construction of sewers, they did not, as a rule, take steps to prevent the mischievous pollution of the rivers.

Rivers' Pollution Prevention Act, 1876.—In 1876 the Rivers' Pollution Prevention Act was passed, which Act has been amended during the present year, again, to a great extent, permissive in character, since an infringement of its provisions by local authorities simply renders them liable to proceedings, "on the part either of other sanitary authorities, or of any person or body of persons aggrieved by the commission of the offence" (*Local Government Board Circular, August*, 1877).

Having regard to the enormous expense involved in some of the law-suits of modern times in connection with the pollution of rivers, it is certain that few individuals will in future care to risk a contest with wealthy local authorities. The opinion of Mr. Michael, Q.C., is well worth quoting in this connection :—" The difficulty in applying to the authorities to carry out the law is that they are the very persons who are the greatest offenders. A small local authority in a district is, most likely, interested in polluting a river by the refuse of the manufactories, and it is called upon to institute proceedings against itself. *Quis custodiet ipsos custodes?* You cannot get an authority to act against itself officially. . . . We can never get any good until an authority is so constituted as to take under its charge the whole great features of the case, until some county or river authority, of sufficient extent, is appointed, with ample powers" (*Parkes Museum, February*, 1885).

The Local Government Act of 1888, Section 14, invested the County Councils with power to enforce the provisions of the Rivers' Pollution Prevention Act, 1876 (subject to certain restrictions in that Act contained), "in relation to so much of any stream as is situate within, or passes through or by, any part of their county, and for that purpose they shall have the same powers and duties as if they were a sanitary authority within the meaning of that Act, or any other authority having power to enforce the provisions of that Act, and the county were their district.

"Any county council shall have power to contribute towards the costs of any prosecution under the said Act instituted by any other county council or by any urban or rural authority."

The Local Government Board were empowered to constitute by Provisional Order, a Joint Committee to represent the administrative counties through or by which a river, or any specified portion, or any tributary passes, and to confer on such Committee (or other body) all or some of the powers of a sanitary authority under the Rivers' Pollution Prevention Act, 1876.

Here we find an earnest attempt on the part of the Legislature to cope with the evils produced by the somewhat lax, if progressive, sanitary measures of earlier administration.

Effects of River Pollution.—How wide-spread and disastrous are the effects of the pollution of the rivers of this country, the various reports of the Rivers' Pollution Commissioners of 1865 and succeeding years fully and conclusively show. The constant investigations by the Local Government Board, into the causes of the far too frequent outbreaks of zymotic disease, constantly result in such outbreaks being traced to a tainted water-supply. That the measures which have been passed have not definitely provided for all the requirements of the case, may be inferred upon a consideration of the conditions affecting river pollution.

The rivers themselves differ widely as regards their physical conditions. Some are large, others small; one river is exceedingly sluggish, another rapidly pursues its course; some are full of vegetation, others contain no plant-life; in some cases the water is used for drinking purposes, in others it is not. How then can a satisfactory standard of purity of the effluent water from sewage disposal works be established?

Up to a certain point, some rivers can most certainly complete the purification of sewage, and even free themselves entirely from their temporary pollution—solid refuse excepted. There is a proportion which a river may carry without being appreciably injuriously affected; it may be difficult to ascertain what that proportion is, but so long as it is not exceeded, no nuisance will arise. Legislation cannot solve the difficulty by fixing a hard and fast standard of purity of effluents, because the conditions vary in such wide degrees. What legislation can do is to say, "You have now reached the limit at which sewage may be turned into that stream. From that time forth no more shall be turned in." "This is what the law should be, if it is to be an effectual remedy for the pollution of rivers. See what that involves. You must first ascertain the volume of your river; you must then ascertain the density of your population, you must establish your just proportion, and then call on your towns to cease to pour in offensive matter" (*Mr. Pembroke Stephens, Q.C., Parkes Museum*, 1885).

Mr. Stephens might have added that a standard of purity for each different class of river should be established, in preference to the general standard of purity applicable to all sewage effluents suggested by the Rivers' Pollution Commissioners, because a careful consideration of the facts will make it clear that the condition of the river at the point where an effluent is to be discharged into it, must form an important element of the case. For instance, a river that has been deprived of the greater part of its dissolved oxygen by the various pollutions poured into it may already be in such a condition as to render it incapable of taking a further quantity of partly purified sewage even without becoming offensive.

The scientific investigations of recent years have established the fact that certain zymotic diseases—typhoid fever, cholera, &c.—are most readily contracted by drinking water which has become infected by the excretal discharges of persons suffering from those diseases. The utmost care should, therefore, be observed in the conservancy of those rivers from which supplies of drinking-water are procured.

"Diseases are the iron index of misery, which recedes before strength, health, and happiness, as the mortality declines" (*Dr. Farr*).

"Although the heaviest penalties of insanitary arrangements fall on the poor, who are themselves least able to bear them, yet no class is free from their dangers, or sufficiently careful to avert them. Where could one find a family which has not in some of its members suffered from typhoid fever or diphtheria, or others of those illnesses which are especially called "preventible diseases?" Where is there a family in which it might not be asked "if preventible, why not prevented?"*

CHAPTER II.

DETAILS OF RIVER POLLUTIONS AND RECOMMENDATIONS OF VARIOUS COMMISSIONS.

Sources of River Pollution.—"Physicians think that, the cause of the disease being discovered, they have also discovered its cure." This quotation from Cicero is peculiarly applicable to the question of River Pollution. The "Physicians" appointed to discover the cause of the diseases from which the streams and rivers of this country suffer, were the Rivers' Pollution Commissioners of 1865 and 1868. The various reports issued by them are full of the most valuable statistics and information, acquired by means of a vast amount of patient and careful investigation, and the conclusions arrived at by the Commissioners have, with few exceptions, been found to subsist on satisfactory bases. The materials forming the present chapter will, therefore, be largely drawn from the excellent stores of information provided by the Commissioners, in which the various reports prepared by them abound.

In the classification the Commissioners place "River Pollutions"† under two general heads, "Sewage" and "Manufacturing Refuse."

1. **Sewage** is a very complex liquid; a large proportion of its most offensive matters is, of course, human excrement, discharged from water-closets and privies, and also urine thrown down sinks and gully-holes; but, mixed with this, there is the water from the kitchens, containing vegetable, animal, and

* H.R.H. the Prince of Wales, Congress of Hygiene and Demography, 1891.

† *Report on the Mersey and Ribble Basins.* 1870.

other refuse, and that from wash-houses, containing soap and the animal matters from soiled linen. There is also the drainage from stables and cow-houses, and that from slaughter-houses, containing animal and vegetable offal. In cases where privies and cesspools are used instead of water-closets, and these are not connected with the sewers, there is still a large proportion of human refuse in the form of chamber-slops and urine. In fact, sewage cannot be looked upon as composed solely of human excrement diluted with water, but as water polluted with a great variety of matters, some held in suspension, some in solution, but both present in such a condition as to render it impossible, in the present state of our knowledge, practically to cleanse and purify sewage so thoroughly as to make it safe for drinking, even when largely diluted with unpolluted water.

2. **Manufacturing Refuse.** — The second class of river pollutions includes all kinds of "manufacturing refuse." In the towns of manufacturing districts, a considerable proportion of this waste is passed into the sewers, as being the readiest way of getting rid of it, and then it merely adds other ingredients to the dirty mixture flowing down these channels; but where the works are situated on or near a stream, and the water made use of in the process of manufacture is afterwards transferred directly to the river, polluted by admixture with the special matters made use of in the different technical processes, such refuse matters can be treated separately as manufacturing pollution. They may be classified generally under the following heads:—

Pollution by dye-, print-, and bleach-works,
" chemical works,
" tanneries,
" paper-making,
" woollen works,
" silk works.

3. **Street Drainage.**—Another class of pollution is the

drainage from street surfaces, which in towns with considerable vehicular traffic may be as impure as sewage. Table I. (below) shows the composition of London street water, during wet weather, taken as it flowed into the sewers. It will be observed upon referring to the Table that this liquid

TABLE I.—COMPOSITION OF LIQUID FLOWING FROM LONDON STREET SURFACES, 1892 AND 1893.

IN PARTS PER 100,000.

COMPOSITION.	J. W. DIBDIN, F.C.S.		MIDGLEY TAYLOR, F.C.S.	
	Wood Pavement.	Macadam.	Wood Pavement.	Asphalte.
Appearance, ...	Dark Colour	Slate Colour	Very Dark	Dark
Odour, ...	Strong Urine	Urine	Strong Urine	Faint
Chlorine, ...	54·0	24·4	2·43	2·57
Free Ammonia, . . .	6·89	3·54	5·67	3·66
Albuminoid do., . .	4·25	2·48	4·24	1·05
Oxygen absorbed by matters in solution in 15 minutes, . .	0 680	0·383	4·92	1·36
Ditto, in 4 hours, . .	4·948	2·811	6·03	2·42
Suspended Matter, Mineral, .	980·6	2020·6	170·70	55·90
Suspended Matter, Loss on Ignition,	83·4	77·7	157·90	52·40
Dissolved Solids, Mineral, .	462·1	178·6	42·16	10·80
Dissolved Solids, Loss on Ignition,	117·1	38·6	18·30	8·00

is highly charged with polluting matters, and whilst it must not be inferred that the drainage from suburban roads with little vehicular traffic is as impure, the advocates of the separate system should attentively study this aspect of the question before insisting upon its adoption, irrespective of the conditions obtaining. Then there is the liquid, remaining after rain, in the street gullies, which in dry weather rapidly putrefies and becomes most offensive. This foul liquid is displaced on the advent of a shower of rain, and it should in many cases be purified before being admitted into a stream.

In the Table, the samples analysed by Mr. Dibdin were taken soon after the commencement of rain, those by Mr. Midgley Taylor after rain had been falling somewhat heavily for two hours. In each case, the samples were taken from thoroughfares with much vehicular traffic.

On treating the samples with various reagents, Mr. Midgley Taylor found it most difficult to clarify them. Lime-water with Wardle's precipitant failed to produce any useful effect until carbonic acid gas was made to pass through the liquid, but when sufficient gas had been supplied to form with the lime a carbonate, clarification was rapidly and perfectly effected. The experiments were suggestive as to what might be necessary in dealing with sewage derived from soft water supplies, containing little or no carbonate of lime or carbonic acid.

The Commissioners next proceed to a consideration of the—

Chemical Difference between Polluted and Unpolluted Water.—"Absolutely pure water is not to be found in nature. Even at the moment of its condensation in the atmosphere from invisible vapour to visible cloud, water absorbs gases, and also becomes contaminated with a fine dust which is everywhere floating in the air. When it falls to the earth as rain, it percolates through strata or flows over surfaces more or less soluble, and dissolves, according to circumstances, quantities of solid matter, varying generally from about 3 lbs. to 50 lbs. in 100,000 lbs. of water. In addition to these inevitable impurities, natural and unpolluted water is not unfrequently turbid from insoluble substances suspended therein in a finely divided condition.

"The following are the chief characteristics of unpolluted water:—It is tasteless and inodorous, possesses a neutral or faintly alkaline reaction, rarely contains in 100,000 lbs. more than $\frac{1}{2}$ lb. of carbon and $\frac{1}{10}$ lb. of nitrogen in the form of organic matter, and is incapable of putrefaction even when kept for some time in close vessels at a summer temperature.

"Of the different kinds of pollution affecting rivers, **animal organic matter** as it occurs in sewage is that which renders water not only most offensive to the senses, but most likely to injure health both by its gaseous emanations, and by its deleterious effects when used as a beverage. Rivers so polluted frequently contain from 1 lb. to more than 2 lbs. of organic carbon, and from $\frac{1}{3}$ lb. to $\frac{3}{4}$ lb. of organic nitrogen in 100,000 lbs.

"Pollution by **vegetable organic matter,** such as that caused by dye- and print-works, stands next as regards offensiveness; water so polluted being excessively unpleasant not only to the sight, but also, in warm weather, to the sense of smell. . . . Chemical works contribute chiefly mineral impurities, which often communicate to the water extreme hardness and other disagreeable and even poisonous properties.

"**Necessary Analytical Determinations.**—Such being the nature of the most important kinds of pollution in these rivers, we have directed our chemical inquiries chiefly to the following particulars regarding them :—

"(*a.*) *The Total Amount of Solid Matters present in them in Solution.*—The most important constituents of these solid matters are :—

"1. *Carbon* in the form of organic matter.—Organic carbon.

"2. *Nitrogen* in the form of organic matter.—Organic nitrogen. . . . The determination of the two chief elements of the organic matter furnishes data from which its amount and character (animal or vegetable) may often be fairly inferred.

"3. *Ammonia* in the form chiefly of carbonate of ammonia.

"This ingredient is derived almost entirely from the decomposition of animal organic matters.

"4. *Nitrogen* in the form of salts of nitric acid and nitrous acid.

"Like ammonia, this ingredient is derived almost solely from the decomposition of sewage or animal matters. In determinations 3 and 4, chemical analysis becomes retrospective. Ammonia and the salts of nitrous and nitric acids do not in themselves contribute to the pollution of water, but their presence in considerable proportion denotes with certainty its anterior pollution by animal matters. . . .

"5. *Total Combined Nitrogen.*—This determination sums up the whole of the analytical evidence against the water as regards both past and present organic contamination.

"6. *Chlorine.*—The proportion of chlorine in water may often be used as an indication of the extent to which a stream has been contaminated with *sewage*, as distinguished from *solid* animal matters. The chlorine in river-water is almost always combined with sodium as common salt, which is a large and essential constituent of urine, and consequently of sewage, whilst it is present in only a comparatively minute quantity in solid manure. It is scarcely necessary to say, however, that the determination becomes valueless for this purpose in the neighbourhood of the sea and of natural deposits of salt. . . . The normal proportion of chlorine, as common salt, existing in this country in waters which have never been polluted by excrementitious matters, is about 1 part in 100,000 of water. . . .

"7. *Hardening Constituents.*—These consist chiefly of salts of lime and magnesia. As polluting agents they have no significance, unless the water be required for domestic purposes.

"(*b.*) *The Total Amount of Solid Matters in Suspension.*—In this it is very important to distinguish between organic and mineral matters. We have therefore determined—

"1. The organic matter in suspension.
"2. The mineral matter in suspension."

We may now proceed to an examination of the details of the pollution of rivers by sewage, and again draw upon the excellent materials contained in the Report on the Mersey and

Ribble Basins. The Commissioners directed a vast amount of attention to a comparison between the composition of sewage from midden towns and that from water-closet towns, the results being tabulated below:—

TABLE II.—AVERAGE COMPOSITION OF SEWAGE.

IN PARTS PER 100,000.

Description.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.
Midden Towns, .	82·4	4·181	1·975	5·435	6·451	11·54	17·81	21·30	39·11
Water-closet Towns,	72·2	4·696	2·205	6·703	7·728	10·66	24·18	20·51	44·69
IN GRAINS PER GALLON.									
Midden Towns, .	57·68	2·926	1·382	3·804	4·515	8·078	12·467	14·910	27·377
Water-closet Towns,	50·54	3·287	1·543	4·692	5·410	7·462	16·926	14·357	31·283

The figures given in the Table are averages of a large number of analyses of samples of sewage collected from upwards of thirty towns, and are fairly representative of its composition.

It is pointed out, however, in the Report, that the Preston sewage is really stronger than as indicated by the analysis, in consequence of the sample having been collected by taking one quart of sewage each hour during twenty-four hours, whereas the quantity taken each hour should be proportional to the flow. This question will be further considered in a subsequent Chapter, and in the meantime Table II. may be compared with Table XXI., p. 158, which gives the average composition of London sewage, which does not differ materially from that of the water-closet towns tabulated.

It must not be inferred that sewage from all towns will accord with the averages given, because, in the various towns tabulated by the Commissioners, its composition varies in wide degrees, and is very much affected by the dilution of sewage by subsoil water; even in dry weather, sewage from the same town will often vary in strength from week to week, as the subsoil water is lowered, and consequent dilution is lessened. As an instance of this, the author found that the average flow of sewage at Wimbledon, during seven consecutive dry days in the middle of August, 1888, was at the rate of 33 gallons per head; the flow for the corresponding week in September, 1888, was at the rate of 22 gallons per head only. The explanation of this difference lies in the fact that July was an exceptionally wet month, and heavy rain fell on the 1st of August, the subsoil being, in consequence, fully charged with water; by the middle of September the water had been drained off, and there was no dilution of the sewage. The character of sewage must also be greatly affected by the nature and volume of manufacturing refuse poured into the sewers.

In regard to the relative polluting effect of sewage from midden towns, as compared with that from water-closet towns, the Commissioners say:—

"These analytical numbers show a remarkable similarity of composition between the sewage of midden towns and that of water-closet towns. The proportion of putrescible organic matter in solution in the former is but slightly less than in the latter, whilst the organic matter in suspension is somewhat greater in midden than in water-closet sewage. For agricultural purposes, 10 tons of average water-closet sewage may, in round numbers, be taken to be equal to 12 tons of average privy sewage. The average quantity of chlorine in 100,000 parts of water-closet sewage is 10·66, while in midden sewage it is 11·54. This difference is very significant; it shows that, assuming (which is probably approximately the case) all the urine to reach the sewers in both classes of towns, a larger number of individuals contribute to a given volume of sewage in midden than in water-closet towns. . . . The retention of the solid excrements in middens is not, therefore, attended with any considerable diminution in the strength of the sewage, although the volume, even in manufacturing towns, is somewhat reduced; neither is the case substantially different where earth-closets are substituted for the Lancashire midden, for the sewage from Broadmoor Lunatic Asylum, in which these closets are partially used, exhibits no exceptional degree of weakness. . . . It seems hopeless, therefore, to anticipate any substantial reduction of sewage pollution by dealing with solid excrementitious matters only. It should, however, be noted that careful interception of excretal matter must tend to the lessening of the strength of domestic sewage."

In regard to pollution by manufacturing refuse, the results of the analyses by the Commissioners, as tabulated below, will be instructive.

The special means recommended for the purification of these classes of pollutions will be discussed hereafter.

Sewage Disposal in Relation to Health.—The influence upon health of the community by the improper disposal of

TABLE III.—ANALYSIS OF POLLUTION FROM MANUFACTORIES.

PARTS PER 100,000.

Description.	Total Solid Matter in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
							Mineral.	Organic.	Total.
Dye-, Print-, and Bleach-works, .	50·2	4·226	0·299	0·125	0·399	4·86	7·02	18·97	26·00
Chemical Works,	316·0	1·662	0·318	0·100	0·692	6·65	64·90	7·54	72·44
Tanneries, . .	848·5	79·48	5·37	5·18	9·64	Arsenic	...	...	...
Paper Mills, Esparto Liquor, .	4038·0	939·0	77·0	1·16	78·0	...	0	0	0
Woollen Works, Vat Liquor, .	103·10	14·92	0·925	1·144	1·867	0·012	...	...	...
Wool Suds, . .	1099·4	132·48	9·88	54·61	54·85	Traces	871·0	2611·6	3482·6
Silk Works, . .	26·50	1·489	0·153	0·026	0·174	0·012	...	...	...

sewage on one hand, and by the insanitary conservation of refuse matters on the other, is well known to be of the most pernicious nature.

The connection between some of the zymotic diseases—cholera, typhoid, &c.—and polluted water-supplies, has been firmly established by the various sanitarians of this and other countries, who have investigated outbreaks of those diseases. A large number of examples have been summarised by the Local Government Board, de Chaumont, Corfield, and others.

Water-supplies taken from rivers may be polluted by the direct discharge into them of sewage; those abstracted from the earth by means of wells, may be polluted by the leakage from cesspools, privies, and defective sewers.

Sewerage and Sewage Disposal.—The remedies for the first class of pollution are the interception and purification of the sewage; those for the second class are the construction of water-tight sewers, drains, cesspools, and privies. In the vocabulary of the engineer, "sewerage works" are distinct from "sewage disposal works." The first definition applies to the sewers and contingent works necessary for the *collection* and removal of sewage. Such works have been exhaustively described by Mr. Baldwin Latham,* and by other writers.

The second definition which has been adopted as the title of this work, applies to the land, filters, tanks, and other works necessary for the *treatment* and *purification* of sewage.

Modes of Sewage Disposal.—In this connection we may summarise the recommendations of the various Commissioners and others who have investigated the subject.

Conclusions of the Royal Sewage Commissioners appointed in 1857.

"1. The right way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided."

* *Sanitary Engineering*, by Baldwin Latham, 1878.

"2. The financial results of a continuous application of sewage to land differ under different local circumstances; first, because in some places irrigation can be effected by gravity, while in other places more or less pumping must be employed; secondly, because heavy soils (which in given localities may alone be available for the purpose) are less fit than light soils for continuous irrigation by sewage."

"3. Where local circumstances are favourable, and undue expenditure is avoided, towns may derive profit, more or less considerable, from applying their sewage in agriculture. Under opposite circumstances, there may not be a balance of profit; but even in such cases a rate in aid, required to cover any loss, need not be of large amount."

"Finally . . . the following two principles are established for legislative application:—

"First, that wherever rivers are polluted by a discharge of town sewage into them, the towns may reasonably be required to desist from causing that public nuisance.

"Second, that where town populations are injured or endangered in health by a retention of cesspool matter among them, the towns may reasonably be required to provide a system of sewers for its removal."

This report was made in 1865.

Conclusions of the Commissioners appointed in 1868 to inquire into the best means of Preventing the Pollution of Rivers.

". . . For the purpose of efficient legislation, an arbitrary line must be drawn between waters which are to be deemed polluting and inadmissible into streams, and such as may be considered innocuous, and, therefore, admissible into river channels. It will thus become easy, on the one hand, to convict reckless or careless corporations or manufacturers, and, on the other, which is equally important, to protect them from the incessant and uncertain litigation that must ensue if no definition of polluting liquids be adopted. . . . The following standards of purity . . . represent, in a concentrated form, our experience acquired by the incessant investigation for four years of the chief manufacturing processes carried on in this country, and the following liquids should be deemed polluting and inadmissible into any stream:—

"(*a.*) Any liquid containing, *in suspension*, more than 3 parts by weight of dry mineral matter, or 1 part by weight of dry organic matter in 100,000 parts by weight of the liquid.

"(*b.*) Any liquid containing, *in solution*, more than 2 parts by weight of organic carbon, or 0·3 part by weight of organic nitrogen, in 100,000 parts by weight.

"(*c.*) Any liquid which shall exhibit by daylight a distinct colour when a stratum of it 1 inch deep is placed in a white porcelain or earthenware vessel.

"(*d.*) Any liquid which contains, *in solution*, in 100,000 parts by weight more than 2 parts by weight of any metal except calcium, magnesium, potassium, and sodium.

"(*e.*) Any liquid which, in 100,000 parts by weight, contains, *whether in solution or suspension*, in chemical combination or otherwise, more than 0·05 part by weight of metallic arsenic.

"(*f.*) Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than 1 part by weight of free chlorine.

"(*g.*) Any liquid which contains, in 100,000 parts by weight, more than 1 part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.

"(*h.*) Any liquid possessing an acidity greater than that which is produced by adding 2 parts by weight of real muriatic acid to 1,000 parts by weight of distilled water.

"(*i.*) Any liquid possessing an alkalinity greater than that produced by adding 1 part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

"(*k.*) Any liquid exhibiting a film of petroleum or hydrocarbon oil upon its surface, or containing in suspension in 100,000 parts, more than 0·05 part of such oil."

With regard to sewage effluents, the Commissioners remark—

"There is in the case of town sewage, a condition of things which ought, in our humble opinion, to be taken into careful consideration in the framing of a legislative enactment. The condition to which we allude is that caused by excessive rainfall, or 'storm-water,' as it is technically called. To provide for the exceptional occasions when this condition prevails would entail in many cases an expenditure in sewerage works, many times greater than that necessary in ordinary weather. We are, therefore, of opinion that, however undesirable, it will be necessary to permit storm-water to flow directly into rivers without preliminary cleansing. Unfortunately, chemical analysis shows that storm-water, so far at least as its earlier portions are concerned, is more polluting than dry-weather sewage, owing to old deposits in the sewers being then swept to the outfall; and it will be important to guard against any unnecessary use of this exceptional permission."

Conclusions of the Committee appointed by the Local Government Board in 1875 to inquire into the various methods of sewage disposal.

"1. That the scavenging, sewering, and cleansing of towns are necessary for comfort and health. . . ."

"2. That the retention . . . of refuse and excreta . . . in cesspools . . . or other places in the midst of towns must be utterly condemned; and that none of the (so-called) dry earth or pail-systems or improved privies can be approved other than as palliatives for cesspit-middens. . . ."

"3. That the sewering of towns, and the draining of houses must be considered a prime necessity. . . ."

"4. That most rivers and streams are polluted by a discharge into them of crude sewage, which practice is highly objectionable."

"5. That, as far as we have been able to ascertain, none of the existing modes of treating town sewage by deposition and by chemicals in tanks appear to effect much change beyond the separation of the solids and the clarification of the liquid. That the treatment of sewage in this manner, however, effects a considerable improvement, and, when carried to its greatest perfection, may in some cases be accepted."

"6. That, so far as our examinations extend, none of the manufactured manures made by manipulating town's refuse, with or without chemicals, pay the contingent costs of such modes of treatment; neither has any mode of dealing separately with excreta, so as to defray the cost of collection and preparation by a sale of the manure, been brought under our notice."

"7. That town sewage can best and most cheaply be disposed of and purified by the process of land irrigation for agricultural purposes, where local conditions are favourable to its application, but that the chemical value of sewage is greatly reduced to the farmer by the fact that it must be disposed of day by day throughout the entire year, and that its volume is generally greatest when it is of the least service to the land."

"8. That land irrigation is not practicable in all cases; and, therefore, other modes of dealing with sewage must be allowed."

"9. That towns, situate on the sea-coast, or on tidal estuaries, may be allowed to turn sewage into the sea or estuary, below the line of low-water, provided no nuisance is caused; and, that such mode of getting rid of sewage may be allowed and justified on the score of economy."

Conclusions of the Committee appointed by the Society of Arts in 1876, to inquire into various subjects connected with the Health of Towns.

"In certain localities where land at a reasonable price can be procured with favourable natural gradients, with soil of suitable quality and in sufficient quantity, a sewage farm, if properly conducted, is apparently the best method of disposing of water-carried sewage.

"It is essential, however, to bear in mind that a profit should not be looked for by the locality establishing the sewage farm, and only a moderate one by the farmer.

"With regard to the various processes based upon subsidence, precipitation, or filtration, it is evident that by some of them a sufficiently purified element can be produced for discharge, without injurious result, into water-courses and rivers of sufficient magnitude for its considerable dilution, and that for many towns where land is not readily obtained at a moderate price, these particular processes afford the most suitable means of disposing of the water-carried sewage.

"It appears, further, that the sludge, in a manurial point of view, is of low and uncertain commercial value; that the cost of its conversion into a valuable manure will preclude the attainment of any adequate return on the outlay and working expenses connected therewith; and that means must, therefore, be used for getting rid of it without reference to possible profit.

"For health's sake, without consideration of commercial profit, sewage and excreta must be got rid of at any cost."

In regard to the question of the interception of excretal matters, generally referred to as the "dry" system, as distinguished from the "water-carriage" system, the Committee passed the following resolutions:—

"1. That the pail system, under proper regulations for early and frequent removal, is greatly superior to all privies, cesspools, ashpits, and middens, and possesses manifold advantages in regard to health and cleanliness, whilst its results in economy and facility of utilisation often compare favourably with those of water-carried sewage.

"2. That hitherto no mode of utilising the excreta has been brought into operation which repays the cost of collection.

"3. That the almost universal practice of mixing ashes with the pail products, though it applies these as a convenient absorbent, and possibly to some extent as a deodorant, is injurious to the value of the excreta as manure.

"4. That for use within the house, no system has been found in practice to take the place of the water-closet."

"8. That all middens, privies, and cesspools in towns should be abolished by law, due regard in point of time being had to the condition of each locality."

Conclusions of the Commissioners appointed by the Minister of Public Works, to propose measures for remedying the pollution of the Seine, 1874.

"To prevent the pollution of the Seine by the waters of the intercepting sewers, the most economical, practical, and efficacious means consists in using them in the irrigation of a sufficiently permeable soil. Different kinds of tillage (above all, that of kitchen gardens) will find in these waters the moisture and manure necessary for them.

"The experiments, made in the plain of Gennevilliers, are entirely conclusive in showing, not only the luxuriant vegetation which may be produced by irrigations, but their harmlessness in respect of health, as well as the perfect purification of the waters, which return to the river after having traversed a subsoil naturally permeable or sufficiently drained. . . .

"It is important in every respect to put promptly in execution the project submitted to the Municipal Council of Paris for the employment of a volume of water of at least fifty million cubic metres (sixty-five million cubic yards) per annum on a surface of 1,000 hectares (2,471 acres) in the Commune of Gennevilliers. . . .

"As to purification by chemical processes, and in particular by sulphate of alumina, the Commission are of opinion that it will not constitute a complete and practical solution of the question; the application of these processes to the entire sewage waters would involve an expenditure, and difficulties in working, which are altogether disproportionate to the results obtained either from a sanitary or agricultural point of view. . . ."

Extracts from the Report of the Committee appointed by the Corporation of Glasgow, in 1880, to inquire into the various methods of sewage disposal.

"Probably the only proposition of universal acceptance is that *crude* sewage cannot be disposed of anywhere, by any means, without nuisance or risk of nuisance. Whether poured into a running stream, a tidal river, or the open sea, or distributed on an extended area of land, it is certain, that at some time or other, it will make its presence felt. Some clarifying process whereby the whole of the suspended impurities, at least, shall be removed, seems to be an indispensable preface, even to discharge into the sea or to irrigation.

"There are processes of precipitation now in operation which give an effluent capable of being discharged into a river with perfect inoffensiveness, and without sensibly destroying its purity, provided always that the volume of sewage is small compared with that of the river.

"The success or otherwise of a precipitation process depends largely upon details in the arrangement, construction, and management of the various parts of the works. The best process may fail by neglect of these details.

"Whatever be the process of chemical purification to which the sewage is subjected, the effluent is still impure, and will putrefy and give off noxious gases if kept for some time; and we know of no way in which the purification can be completed but oxidation. Filtration through cultivated land—*i.e.*, irrigation—is probably the best means. But oxidation of the effluent may in most cases be effected by the simple and natural process of running it into the nearest water-course, when, if the proportion of clean water be sufficient, the organic matter will be gradually oxidised, and the effluent water will not become putrid or offensive in any way even in warm weather.

"The sewage-sludge is the troublesome, not to say dangerous, element in all such processes, especially that from lime precipitation, which changes more rapidly than that produced by the action of alumina or oxide of iron. The first, and absolutely essential preliminary to the adoption of any method of treatment by precipitation, is to arrange for the systematic removal of the sludge from the works. To begin sewage treatment without this is to end in the creation of a gigantic nuisance, and become involved in an almost hopeless struggle to suppress it."

"Sewage-sludge may be disposed of in four ways--it may be compressed into portable cakes; or it may be conveyed in a semi-fluid condition to the open sea; or it may be used to make up waste land; or it may be dug into ground, so producing a highly fertile soil."

The Committee recommended :—

"1. That the system of having water-closets for public works, jails, workhouses, infirmaries, and railway stations, should be forbidden, so as to reduce the quantity of water-closet sewage now turned into the river; water-closets in small houses should also be discouraged.

"2. That the ordinary privies and ashpits be altered to the tub and pail system, to be cleansed daily, as it has been carried out in Manchester and other important English cities and towns; and that special accommodation be provided for children. . . .

"In the event of it being found necessary to purify the river :—

"7. That the whole drainage of the city be taken into main intercepting sewers, and conducted to a suitable point, and, after being rendered clear by precipitation and filtration, passed into the Clyde.

"8. That the sludge obtained in the precipitation process be got rid of in the cheapest possible manner. A part of it might be utilised in making up waste land, and a certain quantity might be taken away by farmers; but the greater part would probably require to be disposed of in the same manner as the dredgings of the river."

The case of "The Lower Thames Valley Main Sewerage Board" is most instructive as an example of the difficulties which beset the question of sewage disposal. A number of suburban districts and towns, located on both banks of the Thames between London and Windsor, joined in a common endeavour to sewer their districts, the Joint Board bearing the above-named title.

After three schemes of sewerage and sewage disposal had been considered, and a very considerable sum of money had been expended, by both the promoters and the opponents of the schemes, the Joint Board was dissolved, and some of the towns have since constructed the necessary works.

The third scheme of the Joint Board, only, was approved by the Local Government Board in 1884, and a provisional Order was issued, but, on application being made to Parliament to confirm it, the Order was rejected by the House of Commons' Committee, on the ground that it was inexpedient that the sewage should be combined and treated at one spot. The Committee also recommended that the districts should be sub-divided. The scheme, to which those proceedings referred, was that of Messrs. Mansergh and Melliss, in which it was proposed to chemically treat the sewage near Mortlake, and to pass the effluent into the Thames, regarding which, the Committee observed—" Your Committee believe that in these cases the process of filtering the chemically purified effluent through earth, ought, if possible, to be adopted, which was not provided for in the scheme under their consideration."

The district has now been sub-divided ; in some cases each town has carried out its own work; in others, two or more have combined for that purpose.

Conclusions of the Commissioners appointed by the Municipal Authority of the City of Turin, to inquire into the methods adopted for the disposal of refuse in various European towns.

"1. That the chemical or precipitation methods for the treatment of sewage, which have been tried up to the present time, do not succeed in separating the manurial ingredients, are costly, clarify, but do not purify the water, which, moreover, remains liable to undergo putrefaction afresh if the process is not followed by some method of oxidation.

"2. The only method recognised up to the present time as really efficacious for the purification of sewage is irrigation, carried out in a proper way, upon suitable soil; after the separation of the suspended matters, this method is deprived of danger and of inconvenience, and in our districts would give the best agricultural results."

Conclusions and Recommendations of the Royal Commissioners on Metropolitan Sewage Discharge, 1884.

"FIRST REPORT.

"1. That the works of the Metropolitan Board, for the purpose of carrying the sewage of London to the respective outfalls at Barking Creek and Crossness, have been executed in a highly creditable manner, and have been of great benefit to the Metropolis.

"2. That the storm-overflows allow the occasional discharge into the river, within the Metropolis, of considerable quantities of solid fæcal matter accumulated in some of the sewers; but this has not caused, under present circumstances, serious damage or offence.

"3. That the sewage from the northern outfall is discharged partly over the foreshore, and not, as was originally intended, 'through submerged pipes terminating below low-water mark;' this arrangement increasing the risk of nuisance from the discharge.

"4. That the discharge of the sewage in its crude state, during the whole year, without any attempt to render it less offensive by separating the solids or otherwise, is at variance with the original intention, and with the understanding in Parliament when the Act of 1858 was passed.

"5. That the sewage discharged from the main outfalls becomes very widely distributed by the motions of the water, both up and down the river, being traced in dry seasons through the Metropolis and almost as high as Teddington; and that it oscillates for a long period before getting finally out to sea.

"6. That the dilution of the sewage by the land and sea water, aided by the agitation produced by the various motions in the river, effects a partial purification of the sewage by oxidation; and that this purification is carried farther by the action of animal and vegetable organisms.

"7. That the sewage, which becomes distributed to the higher and to the lower portions of the river, thus gradually loses its offensive properties. The limits above and below the outfalls where this purification becomes efficient, vary with the meteorological conditions; but it may be stated that, in general, above Greenwich and below Greenhithe the river does not afford ground for serious complaint.

"8. That between these limits the effects of the sewage discharge are more or less apparent at all times.

"9. That in dry seasons the dilution of the sewage is scanty and ineffective, especially at neap tides.

"10. That it does not appear that hitherto the sewage discharge has had any seriously prejudicial effect on the general healthiness of the neighbouring districts. But that there is evidence of certain evil effects of a minor kind on the health of persons employed upon the river; and that there may reasonably be anxiety on the subject for the future.

"11. That in hot and dry weather there is serious nuisance and inconvenience, extending to a considerable distance both below and above the outfall, from the foul state of the water consequent on the sewage discharge. The smell is very offensive, and the water is at times unusable.

"12. That foul mud, partly composed of sewage matter, accumulates at Erith and elsewhere, and adheres to nets, anchors, and other objects dropped into it.

"13. That sand dredged near the outfalls, which used to be obtained in a pure state, is now found to be so much contaminated with sewage matter as to be unusable; compelling the dredgers to go farther away.

"14. That for these reasons the river is not, at times, in the state in which such an important highway to a great capital carrying so large a traffic ought to be.

"15. That in consequence of the sewage discharge, fish have disappeared from the Thames for a distance of some fifteen miles below the outfalls, and for a considerable distance above them.

"16. That there is some evidence that wells in the neighbourhood of the Thames are affected by the water in the river; and, although there is no proof of actual injury due to the sewage, that anxiety may be felt in that point.

"17. That there is no evidence of any evil results to the navigation of the river by deposits from the sewage discharge; but that this discharge adds largely to the quantity of detritus in the river, and so must increase the tendency to deposit.

"18. That the evils and dangers are likely to increase with the increase of population in the districts drained.

"19. That it is desirable we should inquire further 'what measures can be applied for remedying or preventing' the evils and dangers resulting from the sewage discharge."

"Second Report.

"1. Our opinion of the evils described in our first report, as resulting from the present system under which sewage is discharged into the Thames by the Metropolitan Board of

Works, is much strengthened, and we believe these evils imperatively demand a prompt remedy.

"2. We are of opinion that it is neither necessary nor justifiable to discharge the sewage of the Metropolis in its crude state into any part of the Thames.

"3. We are of opinion that some process of deposition or precipitation should be used to separate the solid from the liquid portions of the sewage.

"4. Such process may be conveniently and speedily applied at the two present main outfalls.

"5. The solid matter deposited as sludge can be applied to the raising of low-lying lands, or burnt, or dug into land, or carried away to sea.

"6. The entire processes of precipitation and dealing with the sludge can be, and must be, effected without substantial nuisance to the neighbourhoods where they are carried on.

"7. The liquid portion of the sewage remaining after the precipitation of the solids may, *as a preliminary and temporary measure*, be suffered to escape into the river.

"8. Its discharge should be rigorously limited to the period between high water and half-ebb of each tide, and the top of the discharging orifice should be not less than 6 feet below low water of the lowest equinoctial spring tides.

"9. By these means much of the existing evil will be abated.

"10. But we believe that the liquid so separated would not be sufficiently free from noxious matters to allow of its being discharged at the present outfalls as a *permanent* measure. It would require further purification; and this, according to the present state of knowledge, can only be done effectually by its application to land.

"11. In the case of the Metropolis, the best method of applying the liquid to land with a view to its purification would be by intermittent filtration. We have reason to believe that sufficient land of a quality suitable for this purpose exists within a convenient distance of the northern outfall. The liquid portion of the sewage would be pumped up to this land from the separating works, and after filtration would be conducted to the river.

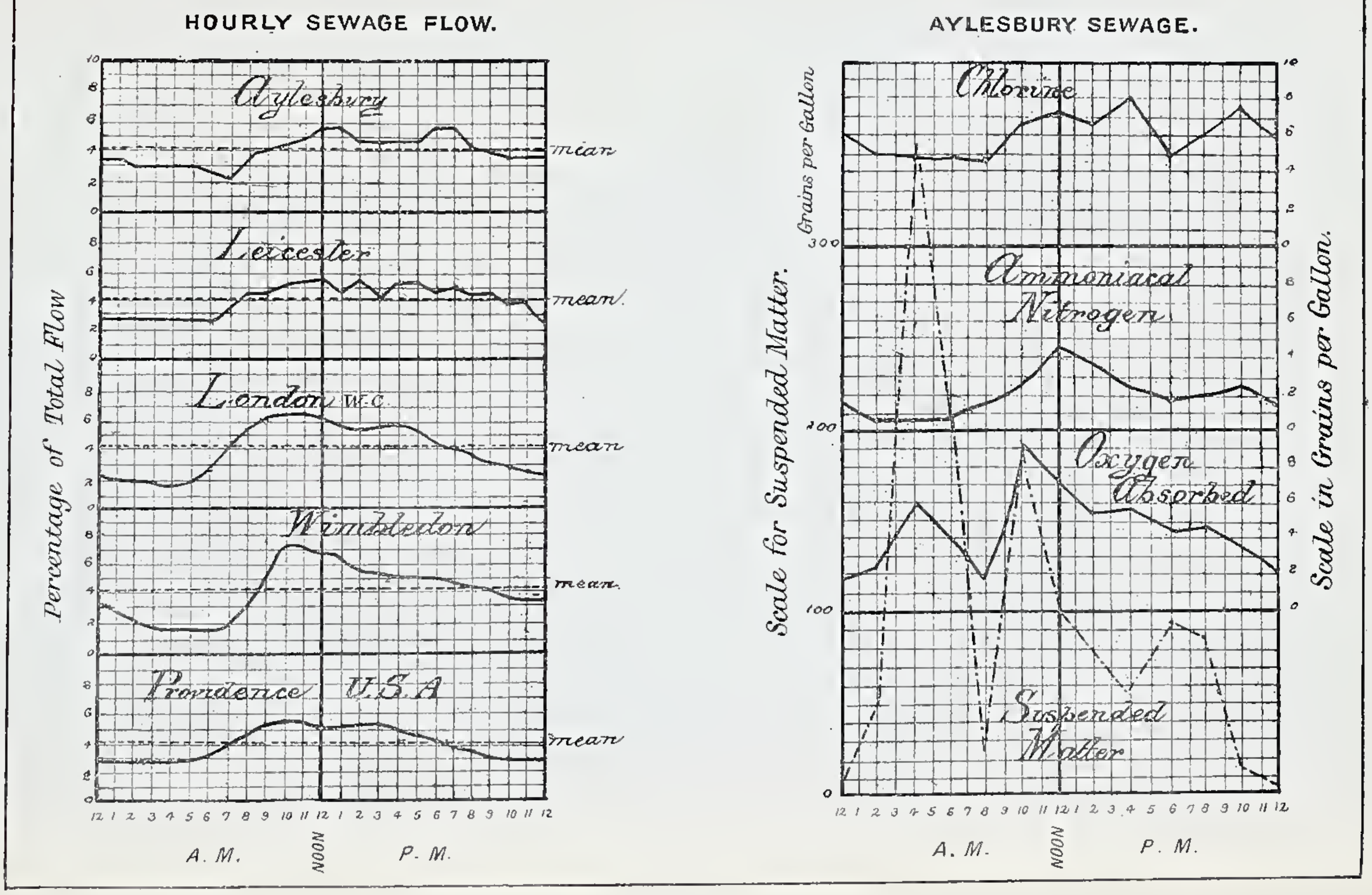
"12. We do not know whether suitable land in sufficient quantity can be found in convenient positions near the southern outfall. If not, the liquid must be conveyed across to the north side by a conduit under the river.

"13. If suitable land in sufficient quantity and at reasonable cost cannot be procured near the present outfalls, we recommend that the sewer liquid, after separation from the solids, be carried down to a lower point of the river, at least as low as Hole Haven, where it may be discharged. In this case it will also be advisable that the liquid from the southern sewage should be taken across the river, and the whole conveyed down the northern side. It may be found that the separating process can be effected more conveniently at the new than at the present outfalls; this will depend on various considerations of cost and otherwise.

"14. If the outfalls are removed farther down the river, the main conduit or conduits may, if thought desirable, be made of sufficient capacity to include a general extension of the drainage to the whole of the districts round London, as recommended by Sir Joseph Bazalgette and Mr. Baldwin Latham. In new drainage works the sewage should be, as far as possible, separated from the rainfall."

In summarising the foregoing conclusions and recommendations of the various Commissioners and Committees, who have investigated the subject of sewage disposal on different occasions, in this and in other countries, during the past 30 years, it will be observed that perfect unanimity obtains in regard to the purification of sewage by means of land. Notwithstanding the fact, that during that period the chemical treatment of sewage has received the concentrated attention of the most eminent chemists, it is still recognised that, in order to produce a sewage effluent of any substantial degree of purity, and must be employed in some form or other, or the effluent must be passed through artificial filters.

Pl. 1.



West, Newman photo-lith.

In certain cases, and under conditions to be discussed in a subsequent chapter, sewage may be sufficiently purified by means of chemicals to admit of the liquid portion being discharged into streams of rivers.

In the case of sea-side towns, sewage may, under favourable conditions, be discharged, in its crude state, into the sea.

CHAPTER III.

HOURLY AND DAILY FLOW OF SEWAGE.

Having described the general character of River Pollutions, and having presented a brief summary of the recommendations and conclusions of the various eminent bodies that have investigated the subject, we may, before examining the remedies as applied, properly inquire into some of the conditions which affect their employment.

This division of the subject will be considered under three heads as follows:—

1. The hourly and daily flow of sewage.
2. The separation of rainfall.
3. Partial interception, by "dry" methods.

Rate of Sewage Flow.—With regard to the first of these questions, on examining the diagrams given on Plate 1, it will be seen that the hourly flow of sewage and its composition, as may be expected when the nature of its source is considered, varies to a very large extent throughout the twenty-four hour period.

From Houses.—The principal source of sewage is the house, and in consequence of the domestic habits of the people being more or less uniform in character, so far as each particular class of the community is concerned, and, as many of those habits involve the fouling of larger or smaller volumes of water, which are then discharged into the sewers, as moreover, certain of these operations are performed with tolerable regularity day by day, it is certain that their influence will be observable in the sewers.

In the case of houses provided with baths that are used regularly day by day, the early morning sewage will, until its entry into the sewer, be simply soiled water, which will dilute the sewage with which it mixes. During the forenoon, the scullery sinks, the water-closets, and the house-maids' sinks, will be freely discharging various foul matters, more or less diluted; in the afternoon and evening the scullery sink is the principal contributor.

From Factories.—At all hours of the day and night manufacturing refuse is poured into the sewers in towns where manufactories exist, and the joint effect of these several operations is to produce important fluctuations in both the flow and the chemical composition of sewage.

The variations in the hourly flow of sewage have necessarily been recognised by engineers, who consequently make provision for them in designing outfall sewers.

Upon the design and construction of settling tanks, and the application of chemicals, for the purpose of sewage treatment, this hourly fluctuation of flow exercises an important influence.

The question was most fully and carefully examined, in connection with the drainage of London, by Mr. Haywood, by Sir Joseph Bazalgette, and by the Referees who reported upon the scheme for the main drainage of the Metropolis.

A very large number of gaugings of various main sewers were taken by the Referees, and the following general results were obtained:—

(1.) Area sewered 75,251 acres.

(2.) Population on that area 2,656,000.

(3.) Population per acre 35.

(4.) Daily flow of sewage (dry weather) 15,208,083 cubic feet.

(5.) Maximum average flow of sewage per acre 1·402 cubic feet per minute.

(6.) Flow of sewage per head per day 36 gallons.

These details will be again referred to in the chapter on London.

According to Population Density.—It should be remarked that the density of population varied from 253 persons per acre to 7·3 persons, and that the flow of sewage from each acre varied from 0·83 cubic foot per minute to 0·04, accordingly as the relative districts were of an urban or a suburban character. These figures indicate that the sewage flow per head in the suburban districts was much higher than in the urban, the quantities being 50 gallons and 30 gallons per head per day respectively. The difference is no doubt partly owing to the fact that in most towns the crowded parts are inhabited by the poorest members of the community, who use water very sparingly; and secondly, that in sparsely inhabited districts, leakage into the sewers of subsoil water is proportionally greater per head, since the population per mile of sewer is less than in densely populated districts. These wide variations must necessarily be borne in mind when considering the design of sewage disposal works.

Maximum Rates of Discharge.—The hourly rate of flow of sewage again fluctuates so widely, that a neglect of its consideration must result in improperly designed works when these have as their object the treatment or purification of sewage.

In the subjoined Table, the details as regards the Metropolis have been prepared from the data contained in the report of the Referees, but the author checked the results when he had charge of the system, and found them to be substantially correct; those relating to Leicester are from a report by Mr. Gordon, M.Inst.C.E.; those to Aylesbury from a report by Dr. Tidy; those to Providence from a report by the City Engineer, Mr. Gray; while those relating to Wimbledon are the results of the author's gaugings.

From these details we may construct an empirical rule, after making due allowance for contingencies, which will fairly apply to most sewage disposal works—

1. Seventy per cent. of the daily flow may be discharged in twelve hours.

TABLE IV.—PERIODICITY OF FLOW OF SEWAGE.

Town.	Maximum Percentages Discharged.				Excess of Maximum over Mean Discharge, per Cent.	Gallons per Head per Day.
	7 a.m. to 7 p.m.	During 8 Hours.	During 6 Hours.	During 1 Hour.		
Aylesbury, .	56	42·2	31·4	5·90	42	60
Leicester, .	60	42·8	31·3	5·70	37	42
London, . .	68	49·0	37·0	6·34	60	36
Providence, .	61	42·0	33·0	5·63	35	...
Wimbledon,	66	48·2	39·5	7·40	78	29
Averages, .	62·2	44·8	34·44	6·25	50·4	...

2. Eight per cent. may be discharged in one hour, during the period of maximum flow. This last provision may appear to be high, but, as a matter of fact, upwards of 7 per cent. of the Wimbledon sewage has frequently been discharged in one hour.

An explanation of the differences observable in regard to the sewage flow of the various towns, may be found partly in the configuration of the districts, in great part in the leakage into the sewers of subsoil water, and not least, in the influx of large volumes of manufacturing refuse.

According to Physical Aspect.—As regards the physical aspects of the districts sewered, in cases where the houses are spread over wide areas in which the sewage may occupy from a few minutes to as many hours in reaching the common outfall, the hourly fluctuations will be smaller in extent than where the opposite conditions obtain. Flat districts, again, will be productive of conditions similar in character, but less in degree, to those having a low density of population.

Influence of Leakage.—The leakage into sewers of subsoil water, being nearly constant in volume throughout the day, tends to modify the hourly fluctuations; the leakage into the subsoil of sewage, when sewers are defective and the subsoil is of a dry, open character, has the same tendency, since the leakage is greatest during the period of maximum flow. The effect of the influx into sewers of large volumes of liquid manufacturing refuse at uncertain periods, is to accentuate the hourly fluctuations. In applying the rule, therefore, these various details must be carefully considered.

Hourly Variation of Composition.—The analyses, by Dr. Tidy, of Aylesbury sewage are of great value, as showing the varying character of the sewage at different periods of the day. The details of some of the chemical constituents of sewage, with the hourly fluctuations of flow, are shown in a diagrammatic form on Plate 1.

It is desirable to point out that in cases where it is necessary to pump the sewage, the hourly volume discharged into the tanks, or other receptacles, will depend upon the capacity of the pumping machinery, and the mode of working. As some kind of storage reservoir for the sewage is usually provided in these cases, its effect is to equalise the hourly variations in the composition of the sewage.

CHAPTER IV.

THE PAIL SYSTEM, AS AFFECTING SEWAGE.

Composition and Value of Sewage.—As a result of the experiments conducted by Röderer, Eichhorn, Letheby, Tidy, and other chemists, it may be taken that the liquid and solid excreta yielded by a mixed population of adults and children amounts to 2½ lbs. (17,500 grains) per head per diem, of which one-twelfth consists of fæcal matter, the remainder of urine; of the fæcal matter about 260 grains are insoluble in water, thus, of the suspended matters in average sewage, about 7 grains per gallon are due to fæcal matter.

The components of urine and fæces have been thus tabulated by Dr. Tidy*:—

* *Journal of the Society of Arts*, October 8, 1886.

TABLE V.—COMPOSITION AND ESTIMATED VALUE OF THE SOLIDS OF URINE AND FÆCES, AND OF THE MIXED EXCRETA OF A POPULATION.

Constituents per Ton.	Ammonia (=7d. per lb.)	Phosphoric Acid.		Potash (=3d. per lb.)	Estimated Value per ton.
		Soluble (=4d. per lb.)	Insoluble (=2d. per lb.)		
NATURAL STATE.	Lbs.	Lbs.	Lbs.	Lbs.	£ s. d.
Urine, ...	23·94	2·94	...	3·39	0 15 10
Fæces, ...	35·45	...	26·62	9·46	1 7 6
Mixed Excreta of Population, ...	23·13	2·70	1·93	3·83	0 15 8
1,000 tons of Average London Sewage, . .	219·37	27·61	24·20	50·65	0 0 1¾

The annual value of the excreta of an adult person has been variously estimated by different authorities at from 6s. 6d. to £1.

Lawes and Way value it at . . .	8s. 5¾d.
Voelcker values it at	9s.
Hofmann and Witt value it at . . .	11s. 9¼d.
Thudichum values it at	20s.

The ammonia in urine voided by an average person per annum is said to be worth about 7s., while that contained in the fæcal matter is valued at 1s. 3d. (*Tidy*).

Compared with the manure yielded by animals usually found on farms and with guano—

1 lb. of human excrement
= 13 lbs. of horse-dung.

1 lb. of human excrement
= 6 lbs. of cow-dung (*Macaire* and *Marcet*).

Excreta (solid and liquid) of one adult
= droppings from one sheep (*Mechi*).

Yearly excreta (solid and liquid) of one adult
= 75 lbs. Peruvian guano (*Voelcker*).

The pail system has been evolved from the old midden and cesspool systems, regarding the evil effects of which latter, the Blue Books and Official Reports issued from time to time since the date of Chadwick's first researches, give numberless examples. It is unnecessary to enter into the details of such an abominable system of conservation of foul matters, since it is universally condemned by all sanitarians.

As an example of the enormous mass of pollution at one time existing in the large northern cities, Manchester may be quoted, where, in 1868 no fewer than 60,000 open middens and cesspools, covering an area of 16 acres, were in existence. The abolition of these centres of infection and disease, and the substitution of pan, or pail, or improved closets, has led to an improvement in the health of the people of inestimable value. A large amount of attention has been bestowed upon the sanitary arrangements generally, and as a result of the labours of the Health Committee, the annual death rate has been reduced from 33 to about 24 per 1,000.

Compared with London, where there is no conservation of excretal matters, water-closets being universal, the rate is high; but with a proper system of main drainage and sewage disposal, as about to be carried out, Manchester may yet, with the advantages of its splendid water supply, surpass in healthiness London itself.

As recently as 1877,* the aggregate population of 37 large towns, amounting in number to 4,028,882, were provided with 341,928 middens, ashpits, privies, or cesspools, and with 100,350 pails or tubs; the cost of collection and disposal amounted to £337,232, while the receipts were £95,942 per annum. There were in addition upwards of 200,000 water-closets in use.

It will be conceded that the pail system is a vast improvement upon the old midden and cesspool, the question we have

* Conference on Health and Sewage of towns. *Society of Arts*, p. 127 of Report.

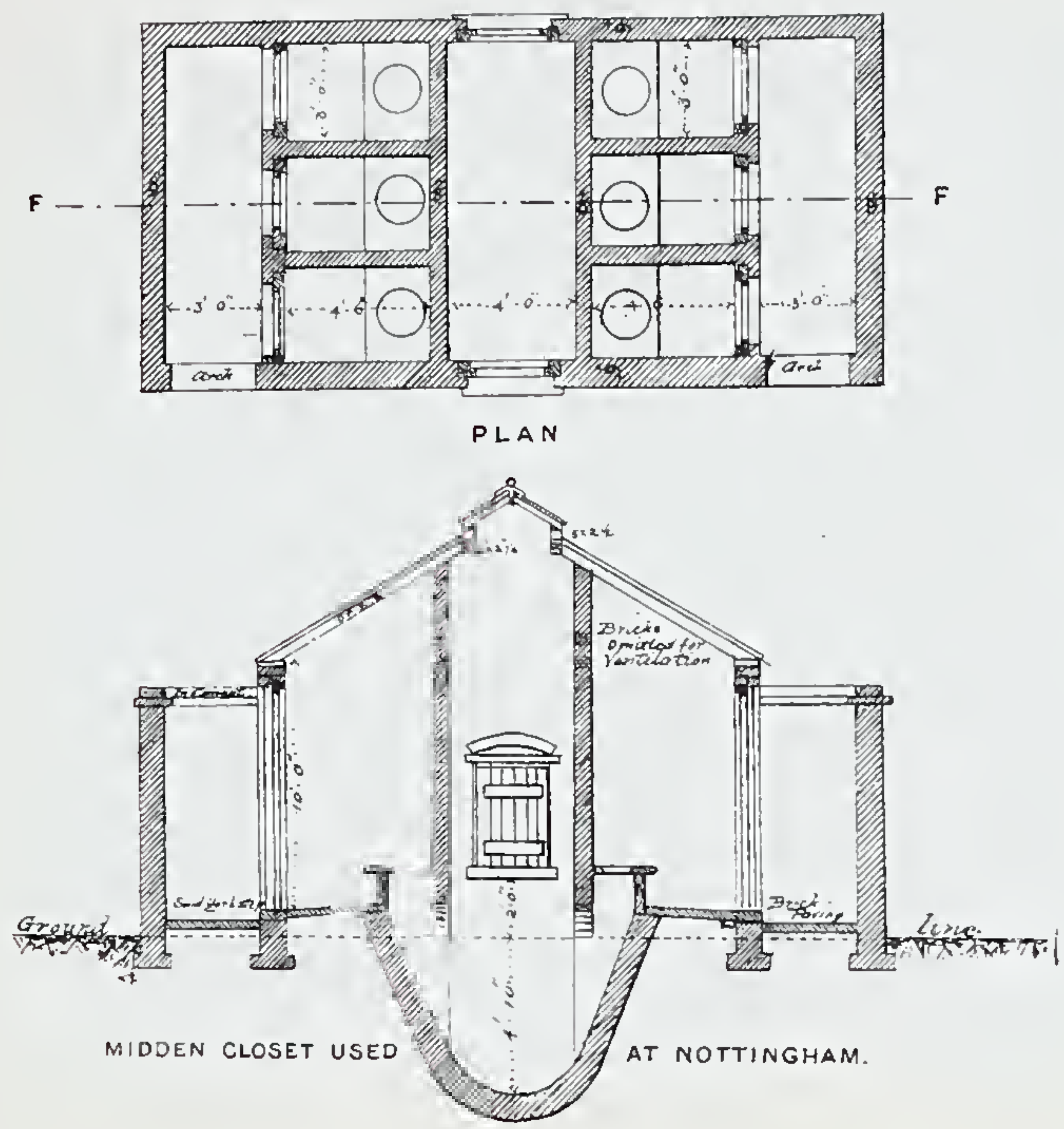
to consider is its effect upon the sewage of the town in which it is in general use.

The analyses of the River Pollution Commissioners showed little difference between the sewage from water-closet towns and that from midden towns. As, however, by the use of the pail, or by the substitution of the improved closet of the Manchester and other types (see Plate 2), the liquid drainage, as from the old midden, no longer enters the sewers, these analyses would probably give different results if they were made anew.

It is known that a large proportion of the urine never enters the pail or closet, but is received in chamber vessels, and in public urinals, from which it is discharged into the sewers where it mixes with the fouled water from sinks and other sources. The opponents of the pail system use this fact with much force.

In the Report by Mr. Gilbert R. Redgrave,* it is stated that at Rochdale, at the date referred to, one-fourth only of the excreta was received by the pails; at Halifax two-fifths were collected; while at Birmingham, the proportion was as high as one-half. As an average, Halifax fairly represented the proportion collected, so that apart from the houses provided with water-closets, and in which no pails were used, two-fifths only of the excreta were accounted for by the pails in the districts in which they were in use. On an average one-fourth of the population of the northern towns use water-closets, so that, as a matter of fact, two-fifths of three-fourths, or three-tenths only of the excreta is intercepted by means of the pail system; but if the washings from the pans and pails, and the excrements from sick persons, which are disposed of by other means than pails, be deducted, it will not be inconsistent with the facts of the case to state generally, that one-fourth only of the total excrements of a population using the pail system, is intercepted from the sewers. But, as in the pail system, no attempt is made to intercept the liquid refuse from sculleries,

* *Society of Arts*, 1877, "Health and Sewage of Towns."



PLAN

MIDDEN CLOSET USED AT NOTTINGHAM.

SECTION F. F.

MANCHESTER CORPORATION DRY ASH CLOSET.

West, Newman photo-lith

Pl. 3.

THE PAIL SYSTEM.

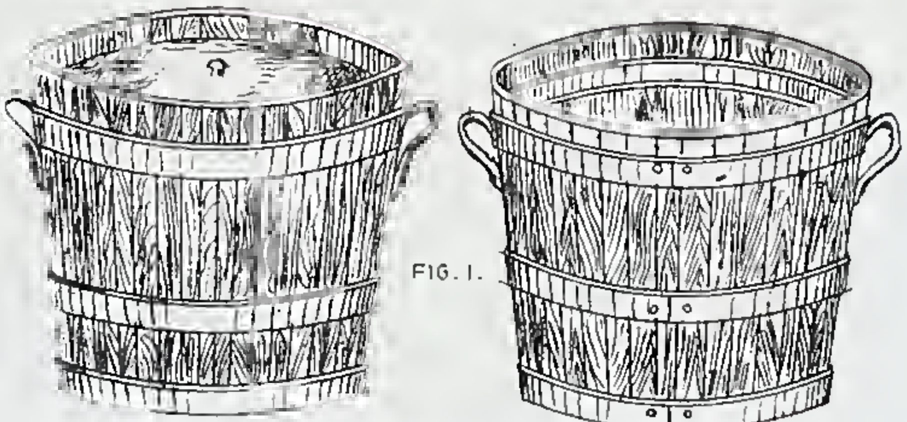


FIG. 1.

Excrement Pail with lid on full to return to Works. *Excrement Pail empty ready for use.*

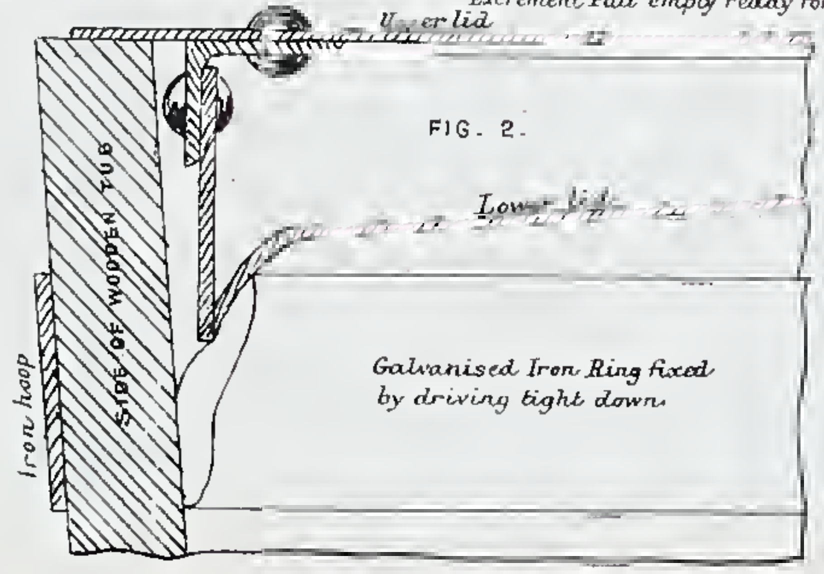


FIG. 2.

Part Section of the Rochdale Pail and Cover.
½ Full size.

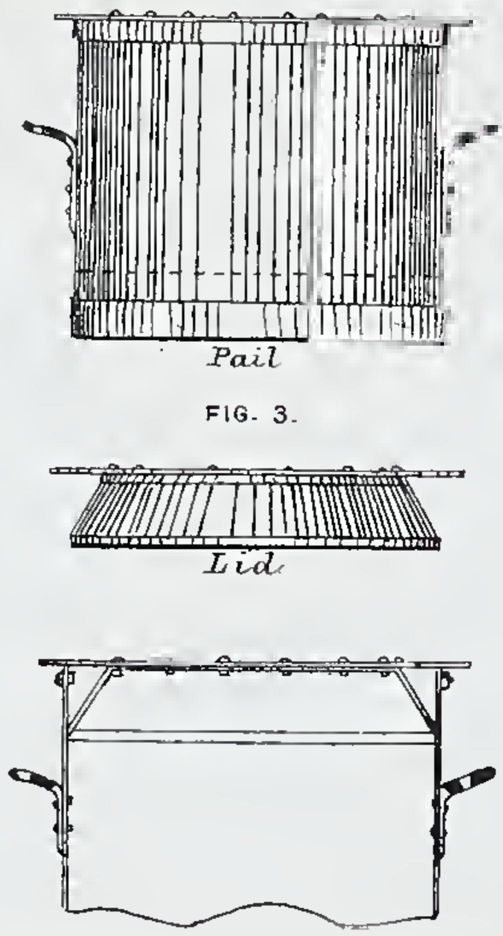


FIG. 3.

Section showing the lid in position Birmingham pail and Cover.
Scale, 1½ inch = 1 Foot

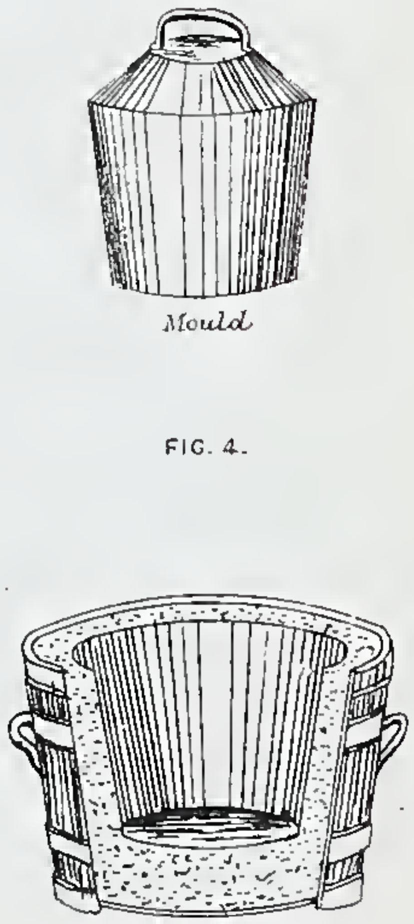
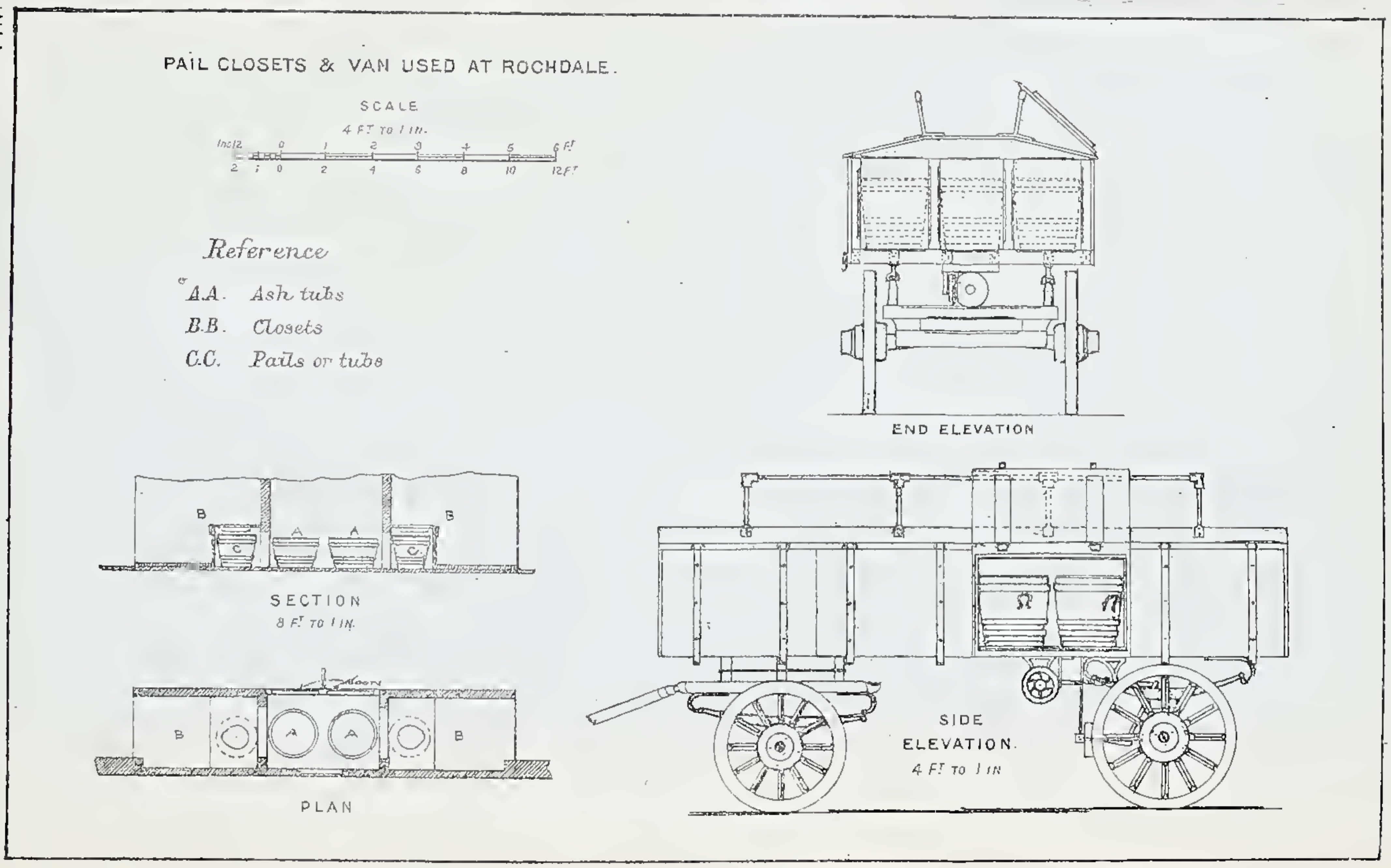


FIG. 4.

Absorbent Receptacle Lined Pail used for "Goux" system, employed at Halifax.

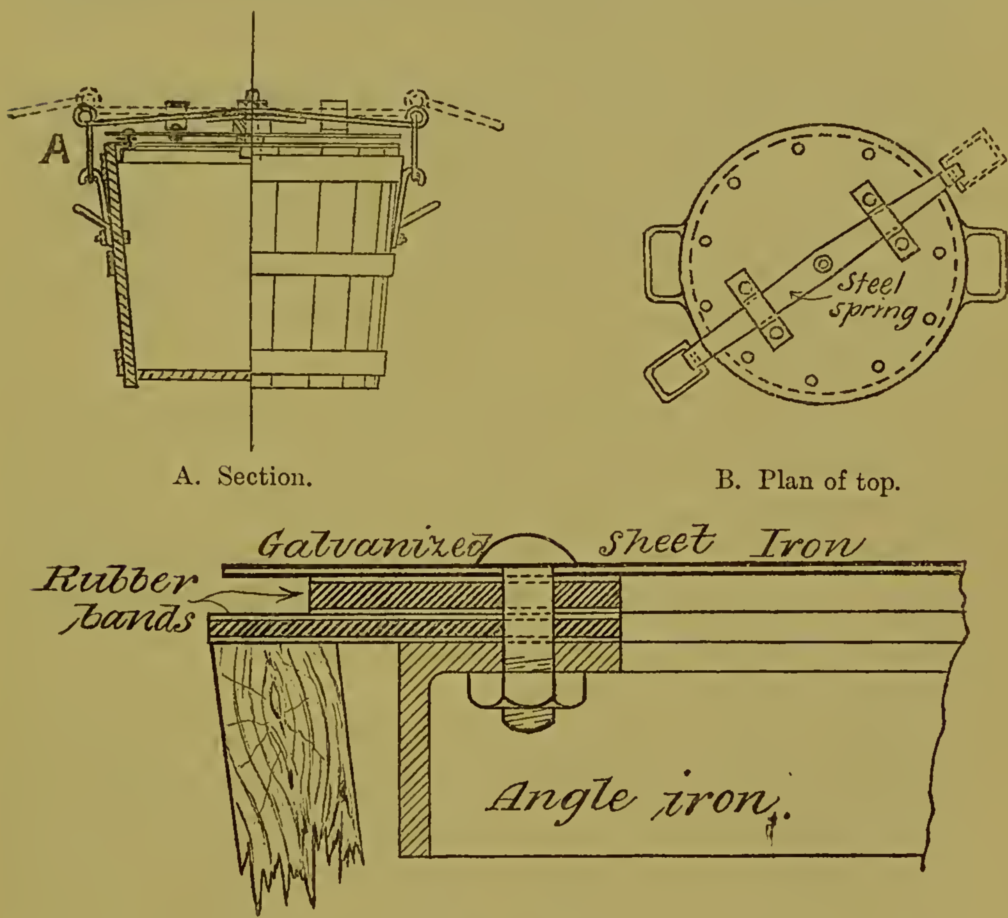
TUBS USED IN THE PAIL OR TUB SYSTEM.

Pl. 4.


PAIL CLOSETS & VAN USED AT ROCHDALE.
SCALE
4 FT. TO 1 IN.
Reference
A.A. Ash tubs
B.B. Closets
C.C. Pails or tubs
B
A
A
B
SECTION
8 FT. TO 1 IN.
B
A
A
B
PLAN
END ELEVATION
SIDE
ELEVATION.
4 FT. TO 1 IN

laundries, stables, slaughter-houses, and other sources, which forms part of the "complex" liquid *sewage*, the fraction of polluting matters intercepted is small compared with the whole.

Pails.—The machinery for effecting this partial interception of excretal matters has perhaps been most fully developed at Rochdale. The details of the pails and collecting vans are



A. Section.

B. Plan of top.

C. Part section. Full size at A.

Fig. 1.—The Rochdale excreta pail—Scale $\frac{1}{10}$th full size.

given in the accompanying figures and on Plates 3 and 4. The pails are made from petroleum oil casks cut in two, and then restaved and rehooped; the pails when finished are 18 inches in diameter at the top, 15 inches at the bottom, and about 16 inches in depth. The first cost is 3s. 9d. per pail, whilst their life is said to be about two years.

According to Mr. Platt, the Borough Engineer of Rochdale, the cost of collecting both excreta and house-refuse during the year ending March 25, 1893, amounted to £7,278, there being 13,279 pails. The whole of the Borough is on the pail system, and at the date mentioned there were only 115 ash-pits, 138 privies, and 24 cesspools in the town.

"The disposal, *i.e.*, manufacture, of excreta into a concentrated manure, and the disposal of the ashes, &c., just clears the expense of disposal" (*Platt*).

At Nottingham the old midden was in the first instance replaced by the improved ashpit, but more recently the pail has been introduced. In the year 1883 there were about 25,000 pails in use, 5,000 of which were collected each night. A pail coloured in a special manner is supplied to houses in which infectious diseases or enteric fever exist, and these pails are supplied with a special disinfectant.

At Halifax the pails are used with an absorbent lining of dry refuse on the Goux principle, see Plate 3.

At Birmingham and at Manchester iron pails are used, and their contents, after acidification with sulphuric acid, are placed in revolving cylinders where evaporation is effected by means of the heat derived from burning the town refuse, and a concentrated manure is produced.

Relative Costs of the Pail and Water-closet Systems.— During the years 1879-1883, the cost of the pail system was investigated by Mr. Councillor Tuke of Bury, and according to his experience in that town, where in 1883 the number of pail closets was about 3,600, "the average cost of each pail closet (per annum) was 12s. 5d., with an average servitude of 1·12 houses per pail. . . . If the pails were properly washed, and the vans employed, the cost of the complete system would be raised by the addition of 4s. 5d." By raising the servitude of the pail to that of the midden, for the purposes of comparison, Mr. Tuke found the total annual cost of each pail to be 20s. 6d. By the adoption of sewers, Mr. Tuke estimated that the saving in cost of collection would be as follows :—

"2,758 barrels of excreta, now conveyed from pails and costing 5s. 9¾d. each, would go down sewers, ...	£801 10 10
"4,469 loads of ashes, now costing 3s. 3d. per load, would, if removed in bulk and in daylight, cost only about 2s. or a saving of 1s. 3d., ...	279 6 3
"4,083 loads of excreta, now carted from the midden privies at a cost of 2s. 6d. per load, would go into sewers, . .	510 7 10
"8,092 loads of rubbish, now removed at night at a cost of 2s. 6d. per load, would then be removed in daylight. This would save two-ninths of the wages of the men, the whole cost of lamps, oil, carbolic powder, &c.; besides, the fact that the men could, and would, do much more in daylight than they do in the dark, save say 20 per cent., or 6d. per load, ...	202 6 0
Total saving, ...	£1,793 10 11"

As a set-off to this estimate, the cost of treating the additional sewage at the outfall must be considered. It is urged by the advocates of the pail system that the total volume of sewage would be much increased by the substitution of water-closets, but the trough water-closets at Leeds consume but 3 gallons per head per day, whilst it is possible, by the use of Fowler's, or Duckett's, or the Crewe slop water-closet, to utilise the waste from sinks for the purpose of carrying away the excretal matters, thus adding nothing but these matters to the sewage.

It is said also that water-closets in poor districts are liable to be thrown out of order by the introduction of large solid bodies, such as old boots, tins, &c., but there are hundreds of thousands of these closets in London alone, and the difficulties attending their use are found to be easily surmountable.

The author has had some years' experience of Fowler's closet, in conjunction with Field's syphon flush-tanks, which latter receive the waste from the sinks, and he is able to confirm the experience of others as to the satisfactory working of these appliances.

TABLE VI.—GENERAL DETAILS OF SEWAGE DISPOSAL (1889).

Name of Town.	Population, 1889.	Closets, &c.			Sewers and Sewage.		
		Water-closets.	Pails.	Middens, Privies, and Ashpits.	Sewage Flow per Twenty-four Hours.	Gallons per Head.	Disposal of Manufacturing Waste.
					Gallons.		
Accrington,	37,000	700	3,600	2,200	925,000	25	Into Sewers.
Aylesbury,	7,795	...	...	...	464,000	60	Do.
Bedford,	25,000	...	...	...	1,000,000	40	
Birmingham,	606,000	...	...	...	15,000,000	25	
Blackburn,	116,000	2,510	11,090	5,500	3,500,000	30	
Bolton,	110,000	1,252	6,000	8,632	4,000,000	36	
Bradford,	224,507	6,000	...	18,000	8,000,000	35	Into Sewers.
Brentford,	12,500	2,400	...	...	350,000	28	
Burnley,	78,000	5,000	...	...	1,950,000	25	
Burton-on-Trent,	44,500	850	2,795	4,300	4,500,000	101	Into Sewers.
Buxton,	15,000	2,600	...	250	850,000	57	
Chester,	37,000	...	...	...	2,500,000	68	
Chiswick,	20,000	...	...	...	700,000	35	
Coventry,	48,000	8,000	...	...	2,200,000	46	Into Sewers
Crewe,	31,000	500 and 499 with tipping flush pans.	...	4,200	1,000,000	32	
Derby,	94,000	4,604	4,418	10,143	2,350,000	25	Part to Sewers.
Dudley,	47,000	100	...	4,900	600,000	13	

Ealing,	20,000	4,000	...	...	600,000	30	
Edinburgh,	262,733	40,000	...	...	10,750,000	41	
Grantham,	17,000	3,240	...	...	1,000,000	59	Into Sewers.
Leeds,	327,324	15,889 and 4,392 trough water-closets	3,384	...	10,000,000	30	Do.
Leicester,	143,153	15,000	6,500	100	7,000,000	42	Do.
Leyton,	40,000	...	...	...	1,500,000	37	
Lincoln,	43,000	3,108	...	5,932	1,000,000	23	Into Sewers.
Maidstone,	30,000	7,500	...	...	878,000	29	
Northampton,	55,000	...	...	...	750,000	14	Into Sewers.
Norwich,	93,000	3,500	...	15,000	4,000,000	43	Do.
Oswestry,	10,000	700	..	...	390,000	39	Do.
Oxford,	44,000	8,000	...	...	1,200,000	27	
Penrith,	9,000	850	...	281	316,800	35	
Reading,	59,000	9,890	...	...	1,200,000	20	Into Sewers.
Rugby,	12,000	2,400	...	12	600,000	50	
Salford,	177,000	...	...	...	...	...	
Salisbury,	15,000	...	...	...	2,500,000	166	
Sheffield,	310,000	3,500	...	...	10,000,000	32	Into Sewers.
Southampton,	63,000	12,500	...	...	2,500,000	39	
Wigan,	54,500	700	5,400	774	1,250,000	23	
Wimbledon,	25,928	6,000	...	15	725,000	28	No Manufactories.
Wolverhampton,	80,000	2,000	11,000	...	2,000,000	25	Into Sewers (after Treatment).
					Average,	34·61*	

* Not including Burton-on-Trent or Salisbury.

TABLE VII.—GENERAL DETAILS OF SEWAGE DISPOSAL (1889).

NAME OF TOWN.	SEWAGE TREATMENT.				Tanks, Continuous or Intermittent.	Acreage of Land.	Years in operation.
	Mode of Disposal (1889).	Chemicals used.	Annual production of Sludge in tons.	Disposal of Sludge.			
Acton,	Precipitation and filtration.	"International" process.	...	... ...	... ...	...	2
Aldershot,	Precipitation, irrigation, and filtration.	Alumino ferric and lime.	...	Given away.	... ...	...	...
Aylesbury,	Precipitation.	... ...	...	... ...	Continuous.	6	10
Banbury,	Irrigation.	... ...	...	... ...	... ...	136	...
Bedford,	Do.	... ...	...	... ...	... ...	...	...
Birmingham,	Precipitation and irrigation.	Lime.	...	Dug into ground.	... ...	...	...
Blackburn,	Do.	Do.	640	Sold.	Continuous.	689	16
Bolton,	Precipitation.	Lime and iron water.	...	Dug into ground.	Continuous (Burnden); Intermittent (Hacken).	25	15
Bradford,	Precipitation and filtration.	Lime.	6,000	... ...	Intermittent.	$7\frac{1}{2}$	12
Brentford,	Precipitation.	Lime and alumino ferric.	1,145	Sold.	Do.	4	4
Burnley,	Precipitation and filtration.	Lime.	22,000	Given away.	... ...	65	...
Burton-on-Trent,	Irrigation.	... ...	...	... ...	... ...	572	...
Chester,	Precipitation.	Lime.	1,200	Sold.	Continuous.	6	...
Chiswick,	Do.	Lime and sulph. alumina.	2,600	Given away.	... ...	...	...
Coventry,	Precipitation and filtration.	Do.	5,720	Sold.	Continuous.	13	15
Crewe,	Irrigation.	... ...	40	Dug into ground.	Intermittent.	268	14

Derby, . . .	Filtration.	... ...	...	Sold.	Continuous.	...	...
Doncaster, . .	Irrigation and filtration.	... ...	...	Dug into ground.	... ...	264	...
Dudley, . . .	Irrigation.	... ...	...	... ...	... ...	...	...
Ealing, . . .	Precipitation and filtration.	Lime and sulph. alumina.	11,000	Burnt in destructor.	Continuous.	3½	20
Edinburgh, . .	Discharged direct into the Firth of Forth.	... ...	...	... ...	... ...	...	...
Grantham, . .	Irrigation.	... ...	...	... ...	Continuous.	230	6
Leeds, . . .	Precipitation.	Lime.	9,000	Given away.	... ...	26	17
Leicester, . .	Do.	Do.	...	Do.	Intermittent.	13	30
Leyton, . . .	Do.	Lime and black ash.	5,200	Pay for removal.	... ...	...	...
Lincoln, . . .	Do.	Lime.	...	Sold.	Intermittent.	68	...
Maidstone, . .	Do.	Do.	9,000	... ...	... ...	...	...
Northampton, . .	Irrigation.	... ...	...	Sold.	Continuous.	327	16
Norwich, . . .	Do.	... ...	...	... ...	... ...	500	17
Oswestry, . .	Precipitation.	... ...	...	... ...	Intermittent.	3½	...
Oxford, . . .	Irrigation and filtration.	... ...	...	... ...	... ...	330	7
Peterborough, . .	Irrigation.	... ...	500	... ...	Continuous.	300	5
Reading, . . .	Do.	... ...	...	... ...	Do.	770	13
Rugby, . . .	Do.	... ...	200	Sold.	Do.	80	35
Salford, . . .	Precipitation.	Lime.	...	... ...	Do.	...	4
Salisbury, . .	Do.	Do.	988	Sold.	... ...	...	...
Sheffield, . . .	Precipitation and filtration.	Do.	20,000	Do.	Intermittent.	22½	2
Southampton, . .	Precipitation.	Carbon and sulp. acid.	...	... ...	... ...	...	...
Tunbridge Wells, .	Irrigation.	... ...	...	Sold.	... ...	...	...
Wigan, . . .	Do.	... ...	...	... ...	... ...	272	...
Wimbledon, . .	Precipitation, irrigation, and filtration.	Lime, sulphate of alumina, ozo, &c.	3,250	Part sold, rem. ploughed in on farm.	Both.	74	14
Wolverhampton, .	Irrigation.	... ...	...	... ...	... ...	...	...

At Crewe, the London and North-Western Railway Company provide their workmen's cottages with the tumbler slop water-closet, shown on Plate 2, and wilful interference with its proper use is punished by charging the tenant with the cost of removing the obstruction.

With regard to the financial aspects of the question, circumstances differ in each town, and no absolute rules can be formulated as being applicable to all cases. We have, however, seen that in the case of Bury, the estimated saving by the adoption of water-carriage would amount to £1,800 (in round figures) per annum. If ordinary water-closets were adopted, and the sewage was increased by 3 gallons per head per day, and the cost of treatment at the outfall was increased in a corresponding ratio, the additional volume at Bury would amount to about 50 million gallons per annum, and the cost of chemically treating this volume would, at 40s. per million gallons, amount to £100 per annum. In order to complete the comparison, we must, on the one hand, estimate the whole cost of collection and disposal, with the costs of the various depôts and machinery that might be necessary for dealing with the pail contents, with the returns due to sales as a set-off; whilst, on the other hand, the cost of the substitution of the water-closet, and of any additional tank accommodation at the outfall, with the additional working expenses, would have to be considered.

Experience teaches that at Manchester, at Birmingham, at Blackburn, and in other towns, where part of the excretal matters are intercepted from the sewers, the same measures have to be adopted for treating the sewage as in those towns where water-closets are in universal use; from a sanitary point of view, therefore, the pail closet must be admitted to be but a slight palliative of the ever increasing pollutions which are poured into the streams and rivers of this country.

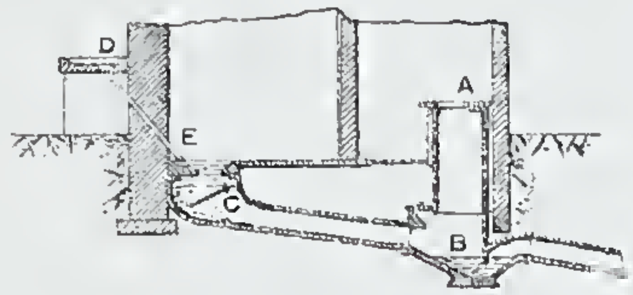
The Tables, pages 42-45, contain some useful details relating to the pail system, and to sewage disposal generally, as in

TUMBLER WATER CLOSETS AT GREWE & BURY.

SCALE, 8 FT. TO 1 IN.

Ins. 12 0 1 2 4 6 8 10 12 14 16 18 20 Ft.

SECTION

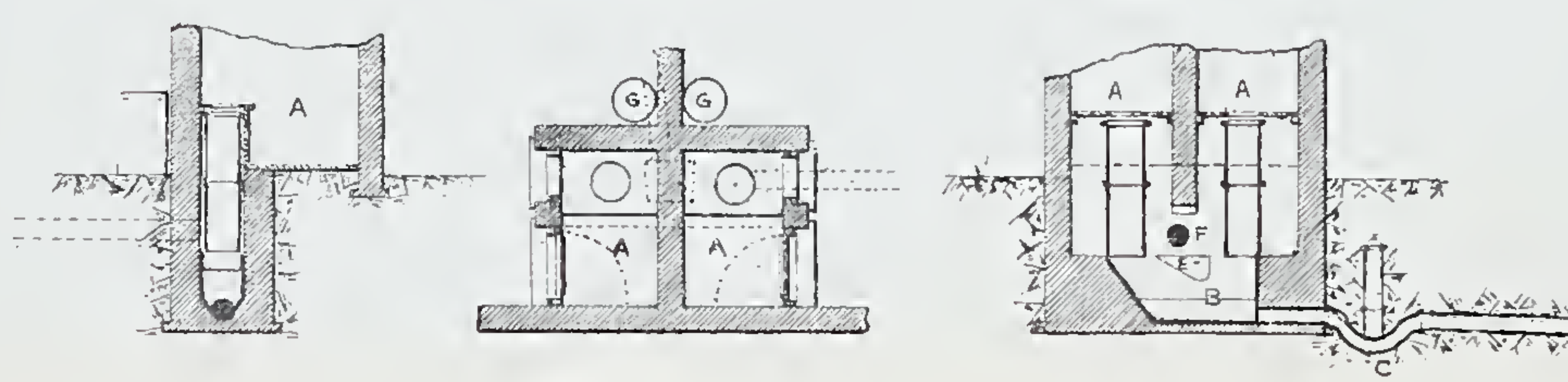


DUCKETT'S W. C.

Reference

DUCKETT'S W.C.		CREWE CLOSET	
a	*Closet*	*A.A.*	*Closet*
B	*Trap*	*B*	*Cemented Channel*
C	*Tumbler*	*C*	*Trap*
D	*Sink*	*E*	*Tumbler*
E	*Waste pipe*	*F*	*Waste pipe from sink*
		G.G.	*Ash Receptacles*

SECTION. PLAN SECTION



THE CREWE W. C.

West, Newman photo-lith

operation in 1889. As, however, changes in the method of dealing with sewage constantly take place, the table must be accepted as being solely for the purpose of illustration.

CHAPTER V.

THE SEPARATION OF RAIN-WATER FROM THE SEWAGE PROPER.

Should Rain-Water be Separated from Sewage?—This question is beset with difficulties, as regards both its theoretical and practical aspects.

The question is sometimes considered from one point of view, at others from an entirely different one. One writer takes as his theme the relative costs of the combined and separate systems, whilst another considers the prevention of the pollution of rivers as being of the first importance. There is, however, a consensus of opinion in favour of generally excluding rain-water from the sewers, so far as may be practicable, more particularly in suburban districts and in those cases where sewage is utilised on land, or is chemically treated in tanks.

The author's experience in connection with the disposal of sewage leads him to endorse most thoroughly that conclusion, although the object may often be quite satisfactorily attained by one system only, provided with proper storm-overflows. London is an example of this kind.

Practical Difficulties.—But a practical difficulty often arises; for reasons which may be briefly given, it is inadvisable to separate the whole of the rain water from the sewage; to what extent then should the operation be carried out?

Separate Drainage of Back Areas.—Those having the charge of large sewerage systems know that the stoppage of house-drains is of constant occurrence, more particularly in the case of small houses built in terraces, where back drainage is allowed. If, for the purposes of separation, two sets of drains are carried to the backs of these houses, the temptation to connect the blocked sewage drain with the rain-water drain would in many cases be too strong to admit of the risk being run; and those only who have charge of large systems of sewers in duplicate can know the amount of trouble and expense involved in the detection of improper connections with the rain-water sewers. We must generally be prepared, therefore, to take the drainage from the backs of the houses and from back-yards into the sewage sewers.

Separate Drainage of Paved Surfaces.—We may now consider the area of the paved surfaces which, in the author's opinion, it is desirable to drain into the sewage system. From measurements of about 4,000 houses at Wimbledon, one-half of which are cottages with a frontage of about 16 feet, the remainder, shops and villas of ordinary sizes, and including also a fair proportion of large residences, the author found that 250 persons were fairly representative of 1 acre of roof surfaces, of which area about one-half drains to the back. Where separation is carried out, therefore, to the extent suggested, 1,000 persons would be the index of 2 acres of roof surfaces. If sewers are constructed in duplicate, and all the street-water, with that from the fronts of the houses and from paved fore-courts, be excluded from the sewage, it may be shown that this partial separation still involves the provision of accommodation at the sewage disposal works for a largely augmented volume of sewage with the occurrence of every fall of rain, if no further means are provided for diverting the excess. A rainfall 1 inch in depth over 1 acre is equal in volume to 3,630 cubic feet, and it is by no means unusual for the rate of fall to exceed $\frac{1}{100}$ inch per minute; where the fall is equal to a rate of $\frac{1}{100}$ inch per minute, the rate of flow to the sewage disposal works will be at the rate of $\frac{3630}{100} = 36{\cdot}30$ cubic feet per minute, from each acre, or from each 500 persons, and twice that volume from 1,000 persons, if we adopt the data suggested. The sewage proper from the latter number of people, would, at the rate of 5 cubic feet per head per day, amount to 5,000 cubic feet, 8 per cent. of which might be discharged per hour during the period of maximum flow, which rate is equal to 6·66 cubic feet per minute per 1,000 persons. As a rainfall of $\frac{1}{100}$ inch per minute would, in the case under consideration, amount to 72·60 cubic feet per minute, or eleven times the volume of the sewage proper, it may be inferred that the effect of the sudden influx of such largely increased volumes of liquid into the sewage disposal works, would, in the absence of storm-overflows, be to throw entirely out of gear all the machinery in operation for the treatment of the sewage proper.

If, to the volume derived from the backs of houses only, we add the whole volume of rain-water descending upon the paved surfaces, and the impervious soils that are present in many towns, the quantity would be increased to such dimensions as to become practicably unmanageable, and the cost of the construction of works capable of dealing with it would be out of all proportion to the requirements of the case.

An estimation of the volume of rain falling upon street-surfaces and paved fore-courts, must be of an approximate character, since the width of streets, and their other features, differ to such an extent in various towns. It will, however, be found that, in the majority of cases, 1 mile of street will be representative of 6 acres of paved surfaces; but it is difficult to determine the relation this area bears to the unit of 1,000 persons, because the density of population varies in such wide degrees. We have seen in the preceding chapter that in the case of the Metropolis, the Referees found that the density varied from 7·3 persons to 253 persons per acre, accordingly as the districts examined were of a suburban or an urban character. According to a table prepared by Sir J. Bazalgette,* the population per mile of sewer in the Metropolis in 1884 was 1,800. In a rural district drained under the superintendence of the author, the population amounted to about

* *Min. Proc. Inst. C.E.*, vol. lxxvi., 1884.

400 per mile of sewer. These wide limits do not admit of an average being struck; the street-water must, therefore, be estimated for in each particular case.

Drainage from Impermeable Areas.—The water falling upon the impermeable strata sometimes forming the site of the town must also be dealt with, and its volume can be estimated only when the physical characteristics of the particular case are considered.

The author gauged the volume of water flowing from a large clay district forming part of the Wandle Watershed during the years 1879-81, and was fortunate in being able to include in the returns the results due to the exceptionally wet year 1879. The largest flood discharge amounted to slightly less than 2·6 cubic feet per minute per acre. The area was but sparsely occupied by buildings. In another case, an area on a porous formation, fully built upon, was found to discharge upwards of 10 cubic feet per minute per acre.

The Government Referees on gauging the Metropolitan sewers on the morning of the 20th June, 1857, when ·9 inch of rain fell between 12 midnight and 1.45 a.m., found that the Norfolk Street sewer discharged 3·05 cubic feet per minute per acre, while the Savoy Street sewer discharged as much as 20·50 cubic feet per minute per acre: in both cases the figures refer to the maximum discharge. It is right to add, however, that the engineers who designed the main drainage system did not agree with these results.

As a general result of the observations in relation to the sewage flow in the Metropolitan sewers, the Referees suggested that the proposed intercepting sewers should be capable of carrying off ·05 inch of rain per hour, from the urban districts, during the period of maximum sewage flow. The density of population in the urban districts was estimated at about 80 per acre.

The Metropolitan sewers, as constructed, contemplated the removal of the sewage produced by a prospective population of 3,413,000 persons, with a discharge of 5 cubic feet per head per day, to which was added a rainfall of ·01 inch per hour in the urban and one-half of that quantity in the suburban districts.

The total volumes to be removed were—

Sewage, ...	106,623,000	gallons per diem.
Rainfall, ...	324,594,000	,, ,,
Total, ...	431,217,000	,, ,,

It should be mentioned that, as a proportion only of each fall of rain reaches the sewers, the estimate of ·01 inch per hour (really $\frac{1}{4}$ inch per day) was based on the assumption that with a rainfall of ·40 inch per day, five-eighths only of the total volume would reach the sewers, the remainder being absorbed, evaporated, or utilised.

Storm-waters.—It was found from the records of rainfall that there were only from 14 to 21 days in each year, on the average, when the daily fall exceeded a quarter of an inch, and in this connection Sir J. Bazalgette * said, "if we can divert the sewage from the river in dry weather altogether on all those days excepting the 14 to 21, according to the season (a very wet season has been 30 days), we shall sufficiently divert the sewage from the river to make it clear."

It is not proposed to consider the question of rainfall as affecting the size of outfall sewers, in this work, but rather as affecting the operations connected with the treatment of the sewage; and it is obvious from a consideration of the foregoing details that some means must be adopted to relieve the sewage disposal works from volumes of water, which may be enormously in excess of the normal rate of sewage flow. The rain-water, or at least a part of it, must be diverted into the natural water-courses without passing through the sewage works. Whether the sewage sewers are relieved from the excess by means of storm-overflows, or a separate set of rain-water sewers is provided, the end to be attained is the same, the means only differ.

* *Royal Commission on Metropolitan Sewage Discharge*, Q. 9.

The principal objections to the separate system, or provision of sewers in duplicate, are raised on the score of economy on one hand, and on the fact that in urban districts where there is great vehicular traffic, the first washings of the streets are very foul, and on analysis may show the presence of as much putrescible organic matter as sewage itself. But it must be conceded that the sewage would be the more dangerous liquid to mix with water used for drinking purposes, since it might contain the dejections from persons suffering from typhoid fever or other zymotic diseases, which are known to be communicable to persons drinking the polluted or infected water. All the sewage of those towns situated upon rivers which supply water for domestic purposes should, therefore, be purified to the fullest extent practicable; and, in those cases, the passing of flood waters through the sewers, in order that they may be discharged by means of storm-overflows into the nearest available water-courses, cannot be in accordance with the principles of sanitary science, if the water so discharged mixes with that which may be used for domestic purposes.

In cases where it is desirable to admit the first scourings from the streets into the sewers, a simple weir arrangement may be constructed as shown in Baldwin Latham's *Sanitary Engineering*, page 48 (2nd edition). When the volume of water passing down the storm-water sewer—which sewer is some feet higher than the sewage sewer—is small, and is probably very foul in character, as at the commencement of rain after a period of drought, or when the surfaces of the streets are artificially washed with small volumes of water, the polluted liquid passes down a small opening communicating with the sewage sewer; but, when the volume increases, and the water is consequently in a comparatively unpolluted condition, it is, in consequence of its higher velocity, projected across the opening, and, falling into the storm-water channel, is conveyed to the river.

In the case of the Metropolis, the separation of rain-water from the sewage would, as Sir J. Bazalgette stated, "involve the redraining of every house (400,000 in number). You must put a drain into the house to take the sewage from the water-closets and the sinks, in fact, from the inside of the house, and you must carry the water from the roof by another drain, separating the two from each house from the very commencement. Now putting that reconstruction of all the drains of all the houses at £20 per house upon the average, would make £8,000,000 to begin with in the house-drainage Then it is not merely a question of money, but I think you would have a very powerful resistance to any such proposal. I think that every house in London having to be redrained would, both on account of the expense and of the immense disturbance that would arise from it, be very strongly objected to. Then that is not all. You would have to use the present system of sewers for the storm-water, and to lay an entirely separate set of sewers through the streets for the sewage, with pumping establishments, and so forth. That, we came to the conclusion, could not be done, that, as applied to London, was an impracticable suggestion."

The excessive volumes due to rain are allowed to escape into the river by means of 48 storm-overflows, while, for the relief of certain low-lying districts, there are four auxiliary pumping stations for the purpose of lifting the storm-water when the overflows are closed by high tides.

With regard to these means of disposing of the storm-waters, in their Report, the Royal Commission on Metropolitan Sewage Discharge, 1884, observe—

"The weakest points of the present system are, the necessity for a large provision of storm outlets, and the discharge of the sewage in its natural crude state.

"The *storm outlets* are a necessary consequence of the limited general capacity of the intercepting system, and of the sewers having to carry off the sewage and the storm-water combined. The question of capacity was argued at much length before the present designs were adopted, as will be seen in our historical notice. The Government Referees urged that a larger system would be necessary, but the advisers of the Metropolitan Board considered their proposals needlessly expensive.

"The objection to the capacity has been renewed in evidence before us. Some of the complainants' scientific witnesses have expressed the opinion that the provision for interception is too limited, and that, consequently, the discharges from the storm-overflows within the Metropolis are already more frequent and larger in amount than they ought to be; an evil which, if it exists at present, must increase as the population extends.

"It is asserted that there is an error in regard to the estimation of the rainfall to be provided for. For even assuming there were only 14 to 21 days in the year in which over a quarter of an inch of rain fell in the 24 hours, there would be more than that number when the rainfall would exceed one-eighth in 12 hours, or one-sixteenth in 6 hours, either of which would tend to produce overflow.

"These allegations are denied by the scientific witnesses of the Metropolitan Board, who contend that the system, with the proposed addition, affords ample provision, not only for the present, but also for the prospective drainage.

"We cannot, however, lose sight of the important fact, that an expenditure is now going on of the large sum of £1,500,000 for additional 'relief sewers' with storm-overflows discharging within the Metropolis.

"We are of opinion that the discharges of sewage from the storm-overflows, within the Metropolitan area, are frequent and considerable, and that they are occasionally of very offensive character."

"*Mr. Phillips,* formerly surveyor of the Metropolitan sewers, states that 'there are hundreds of miles of sewers now in the Metropolis in which the sewage does not flow at the velocity ($2\frac{1}{2}$ feet per second) necessary to prevent the sewage matters from depositing, and which are called 'deposit sewers.' In these and many other sewers large accumulations take place in dry weather; and when sudden heavy rains occur, as in thunderstorms, great masses of filthy material are washed out, and, as the intercepting sewers are gorged by the sudden rain, find their way by the storm outfalls directly into the urban reaches of the river. . . .

"It is probable the noxious matters which these discharges contain are so speedily oxidised and destroyed by the fresh river-water as to become inoffensive and imperceptible. But in this process the free oxygen is abstracted from the water, which is thus rendered less capable of acting efficiently on the larger sewage discharges met with below. . . .

"But though the storm discharges are locally offensive and disgusting at times, there is no evidence of any injury or serious inconvenience resulting from them above the reach of the influence of the main outfalls."

The history of the working of the Metropolitan main-drainage system in times of heavy rainfall is most interesting and will be referred to in the chapter on London, and although the original estimate of the Government Referees, even, has been exceeded, the carrying out of the work in detail from time to time as the exigencies of the case demanded, may, on close examination, prove in the end to be the most economical mode of draining such an enormous city as London has now become.

Drainage of Suburban Districts.—In regard to such districts, true economy may best be observed by constructing small sewers for the sewage, and for a small proportion of the rainfall only. In such districts, means, such as old covered or open water-courses, or old and often badly-constructed sewers, are always in existence for the disposal of rain-water, and it is the practice of, possibly, all engineers in this country to sewer suburban or rural districts in accordance with these principles.

The case of Wimbledon is interesting, because of its rapid transition from a sparsely-inhabited district to a thickly-populated one. The new streets laid out up to 1885 were provided with one sewer only, and at that date the outfall sewers had become quite inadequate to carry off heavy falls of rain, and much flooding took place. It was necessary, therefore, either to enlarge the outfalls, or to provide a separate system for rainfall, and after carefully considering all the features of the case, the author decided to recommend the separate system, which was forthwith inaugurated, and the main outfalls were completed by him in 1886. All new streets laid out since that date have been provided with two sewers, and the street water, with that from the fronts of new houses, is discharged into the rain-water sewer provided for it, whilst the sewage, with the roof water and washings from back yards, goes into the sewer proper. The general effect of these operations may be gathered from an inspection of the following Table :—

TABLE VIII.—WIMBLEDON SEWERS AND RAINFALL.

Year ending Dec. 31st.	Million Gals. Pumped.	Population Draining to Low Level Sewer (Sewage Pumped).	Million Gals. Pumped per 1,000 Persons per Annum.	Rainfall in Inches.	Million Gals. Pumped per 1-inch of Rainfall.	Mean of Million Gals. Pumped per 1,000 Persons and per 1-inch Rainfall.
1885	190	12,000	15·8	21·5	8·8	12·3
*1886	227	13,460	16·8	24·0	9·5	13·15
1887	216	14,040	15·4	21·0	10·3	12·85
1888	228	14,604	15·6	26·0	8·7	12·1
1889	186·6	15,324	12·2	24·0	7·7	9·95
1890	175·7	15,500	11·3	21·41	8·2	9·8
1891	218·4	18,023	12·1	29·76	6·8	9·45
1892	237·4	18,500	12·8	25·2	9·5	11·15

* Separate system commenced.

If the figures relating to rainfall are examined, it will be observed that in 1885 a total rainfall of 21·5 inches was registered, and in that year the figures in the last column, relating to sewage pumped, are 12·3. In 1890, with an almost equal rainfall, the figures in the last column are 9·8, showing a reduction of about 20 per cent., due to the adoption of the separate system. Again, in 1886 and 1889 the same amount of rain is registered—namely, 24 inches. The figures in the last column are 13·15 and 9·95 respectively, the reduction being about 24 per cent. These figures indicate approximately the extent to which the sewage works have been relieved of rain-water; but, as before stated, the main object the author had in view, in carrying out the system, was the prevention of flooding.

With respect to the volume of rain-water to be admitted to the sewage disposal works with the sewage proper, no definite rule can be laid down. The question must be considered in conjunction with the requirements of each particular case. The volume of each river, its nature, and the uses to which the water is applied, must be accurately examined before the final decision is arrived at.

As an instance of what has been deemed necessary in a particular case, it was laid down in the Provisional Order of the **Lower Thames Valley Main Drainage Board,** that provision should be made with all such machinery and appliances as may be requisite for lifting and disposing . . . "of a volume of sewage equal to 250 gallons per diem for each *inhabited* house in the united district." Taking the population of Wimbledon per house as a basis, fairly representative of the united district, the volume per head per day would be $\frac{250}{6}$ = 42 gallons (very nearly).

In the case of works recently carried out at **Kingston-upon-Thames,** the Corporation have agreed with the A. B. C. Company that any excess over 45 gallons per head per day shall be diverted into the Thames by means of a storm-overflow.

Where the sewage is disposed of on a comparatively small area of land, as by intermittent filtration, it is of the greatest importance to the crops that they should not be subject to inundations and submersion by foul sewage, which has the effect of rendering them totally unfit for the market.

When it is necessary to pump sewage, or when it is chemically treated in tanks, the exclusion of as much rain-water from the sewage proper is, on the score of economy in first cost of works and in the subsequent working expenses, an important matter.

General Conclusions.—The following general conclusions may, probably, fairly indicate the requirements of the case:—

First.—That towns situated on sea-coasts, on estuaries, and on rivers, the water of which is not used for domestic purposes, may be satisfactorily drained by means of one system of sewers provided with storm-overflows.

Second.—That where a town is situated upon a river or stream, the water of which is used for drinking purposes, the exigencies of the case demand that the best "practicable and available" means shall be adopted, in order to render the sewage harmless before being admitted to the river.

Third.—That the means for the attainment of this last-mentioned object will be most effective when the separation of rain-water from the sewage is carried out to the fullest practicable extent.

With regard to the admission of rain-water to the sewers for the purpose of flushing, no system can be sanitarily perfect which depends for its cleanliness upon the uncertain volumes of rain-water which may periodically enter the sewers, since in dry weather when flushing is most needed, the means are altogether wanting; and unless special flushing tanks are provided and are regularly used, or other means for flushing are adopted, accumulations of foul deposits will take place in the sewers, which will not only render the sewage putrid and offensive, but will be brought to the sewage disposal works with the occurrence of the first heavy shower, and most probably cause much inconvenience. Moreover the liquid escaping from the storm-overflows on such occasions will contain an undue amount of polluting matters in suspension, to the possible detriment of the stream into which it is discharged.

CHAPTER VI.

SETTLING TANKS.

The primary object of the settling tank at sewage disposal works is the separation of the suspended matters from the liquid sewage, together with a certain proportion of the dissolved impurities. The design of the tank should be such as to bring the sewage to rest or nearly so in the shortest time practicable, and admit of the solid matters being removed with the minimum of labour.

Continuous *v.* Absolute Rest System.—The details will to some extent depend upon the mode of treatment of the sewage, and whether the "continuous" or "absolute rest" method is adopted. In the former case, the sewage is allowed to pass continuously through the tank, but the forward movement is sufficiently retarded to admit of the solids being deposited, while in the latter case a tank is filled with sewage, and after a certain period of quiescence the liquid is drawn off, leaving the solids on the floor of the tank. At first sight it would appear that the absolute rest system is the preferable, since the deposition of the solids would more likely be perfectly affected; but after trying both systems, the author found that the continuous system possesses certain advantages which more than compensates for the absence of absolute rest; indeed, in the case of the London works—which will be further referred to—the absolute rest system proved to be an expensive failure.

Cleansing of Tanks.—When a tank has been filled, and, after deposition of the solids, the clarified water has been drawn off, the sludge remains on the floor of the tank, and unless this is removed with each operation, the re-admission of the sewage is attended with a stirring up of the sludge—it is washed in short—and the sewage becomes unduly charged with the dissolved matters contained in the sludge. The cleansing of the tank after each time of filling is an expensive operation.

When the continuous system is adopted, the sewage quietly flows through the tank, or series of tanks, and if the forward rate is such that two hours elapse between the time of its entry and exit, the suspended solids will be effectively removed, provided suitable chemicals have been properly used in the treatment of the sewage. In this system the tanks should be cleansed at least once in three days, as the decomposition of the settled sludge is attended with the production of foul gases, principally carburetted hydrogen (marsh gas), which causes the sludge to rise to the surface in great masses, slowly to subside again on the liberation of the gases. The effect of the second admixture of the sludge with the sewage is to cause the latter to become very foul, and as the lightest and most offensive matters are the last to settle and the first to rise again, and as these matters subside near the outlet of the tank, the importance of keeping the tanks clean cannot be too strongly urged.

Form of Tanks.—Settling tanks as generally constructed in this country are rectangular on plan, and a series of tanks of that shape will be very effective if cross walls and floating scum-boards be also used.

DIAGRAM OF SETTLING TANK.

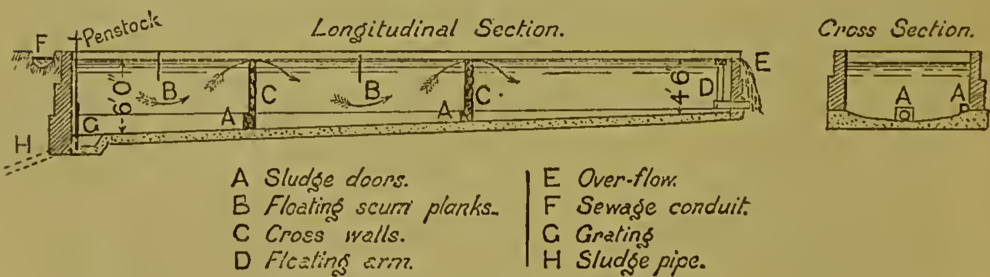


Fig. 2.

The bottom of the tank should be segmental in cross-section, the width being about one-fourth of its length, whilst the longitudinal section should show a fall of about 1 in 80, the deepest end being at the inlet; the sludge will be readily removed from tanks constructed in this manner (fig. 2).

Capacity of Tanks.—With regard to the capacity of the settling tanks compared with the total volume of the sewage flow, provision should be made for 8 per cent. of the total flow per hour. Taking a case where the daily flow amounts to 100,000 gallons, we must provide for 8,000 gallons per hour during the period of maximum flow, and as two hours are necessary for the deposition of the solids, the tank should contain 16 per cent. of the total daily volume; but, as one tank is necessarily idle whilst being cleaned, a second tank of the same size will be needed, and as some provision must be made for ordinary rainfall, a third tank will also be necessary. so that, altogether, about 50 per cent. of the total dry-weather flow will be good measure of the total tank accommodation required, the average capacity of the tanks of Birmingham, Burnley, Coventry, and Leicester is 48 per cent. of the daily flow. In large works it will be convenient to provide a number of small tanks, rather than three large ones, since in the former case the sludge may be more easily removed, and a smaller proportion of the tanks will be out of use during cleansing operations. At Barking, for instance, although the tank accommodation is only about 20 per cent. of the daily dry weather flow, there are so many tanks—thirteen in all—that only about one-sixth of the total capacity is not available for settling purposes during cleansing operations.

Valves and Filters.—The tank should be provided with a floating-arm outlet-valve for the purpose of drawing off the water from the surface, thus leaving the sludge undisturbed when it is necessary to empty a tank for cleansing purposes (see fig. 3, page 64).

If the sludge is to be filter-pressed, it is of importance to provide at the sludge outlet a grating of about 1-inch mesh, in order to intercept large substances which might otherwise damage the presses.

Small coke filters are sometimes added to the tanks at the outlet end; these are not necessary if the effluent is to be applied to land after tank treatment. Further, it is questionable if any advantage accrues to the effluent in its passage through these filters when they are very small; indeed under certain circumstances, as for instance when the filters are allowed to become very filthy, the effluent will be deteriorated by this process of filtration.

The Kniebühler Tank.—We may now briefly consider an entirely different type of settling tank as designed by Herr Carl Kniebühler, in use at Dortmund, and communicated to the author by Mr. Emil Kuichling, M. Am. Soc. C.E.

Experiments upon the flow of sewage through ordinary settling tanks showed that the velocity at the surface was very considerable compared with that lower down, and Herr Kniebühler determined to try tanks constructed upon an entirely different principle (see Chapter on Dortmund).

On referring to the diagram of the Dortmund works we may see that the tank is of considerable depth, and it is circular on plan. The sewage—after treatment with chemicals—is conveyed to a large tube fixed vertically in the centre of the tank, down which it passes until on arriving at the "distributor" it commences its upward course, but at a very low velocity. The heavier particles of suspended matter at once fall to the bottom, whilst the lighter are carried some distance upwards forming a kind of floating filter; these particles of floating matters constantly aggregate together and eventually fall to the bottom also; the clarified water overflows at the top, and is conveyed to the river. A small pipe passes down the central tube to near the bottom of the tank, and being connected with a pump, the sludge is removed as soon as formed. Full details of the system may be found in the Chapter on Dortmund.

Tanks designed on this principle are much in advance, as regards scientific design, of the English tanks; but there are certain difficulties with regard to the removal of the sludge, and in practice the results are not so good as might be anticipated.

The chief advantages appear to the author to consist in (*a*) small area of ground required for tanks, (*b*) more equable velocity of sewage through the tank and better clarification, (*c*) less tank-capacity is required, as each tank may be in continuous use. On the other hand, as the tanks are nearly always full, the sides tend to become very foul, and this is certainly a disadvantage; and, as before stated, difficulties are experienced in removing the sludge.

The Essen Tanks.—The settling tanks at Essen are also of novel construction. The following details are given in the *Minutes of the Proceedings Inst. C.E.*, vol. xcvi., p. 397:—"The scheme prepared for the whole town involved the erection of four cylinders 7 metres in height above the water-line and 4·2 metres in diameter. The sumps were each to be 5·8 metres in diameter, and 6·5 metres in depth. It was intended that the water should rise 3 metres high in the sumps; and this, added to the vertical rise in the cylinders, gave a total lift of 10 metres. For the purpose of the experiment, one cylinder and one sump were constructed capable of dealing with one-fourth of the sewage of the town. The total dry-weather sewage flow (exclusive of the sewage from Messrs. Krupp's works, which is treated separately) is from 10,000 to 11,000 cubic metres. The four cylinders were estimated to have a joint capacity of 18,000 cubic metres; and thus the volume capable of being dealt with per diem in the one actually erected was 4,500 cubic metres. After experiments, extending over ten months in the course of 1885-86, which were considered to be favourable, it was resolved to adopt this process for the whole of the town, and works, costing £12,508, were completed in September, 1887, and have been in operation ever since." The population is said to be 68,000, of whom 11,000 are employed by Messrs. Krupp.

It would appear that experiments with this system were first made at Dortmund (see *Min. Proc. Inst. C.E.*, vol. lxxix., p. 412). "The mechanical treatment of the sewage consists in its introduction into a simple apparatus, in the form of an upright cylinder about 7 metres (22·96 feet) high, whose diameter is regulated by the volume of liquid to be treated in a given time. This vessel has certain pipes connecting it with a small air-pump, the dimensions of which for the

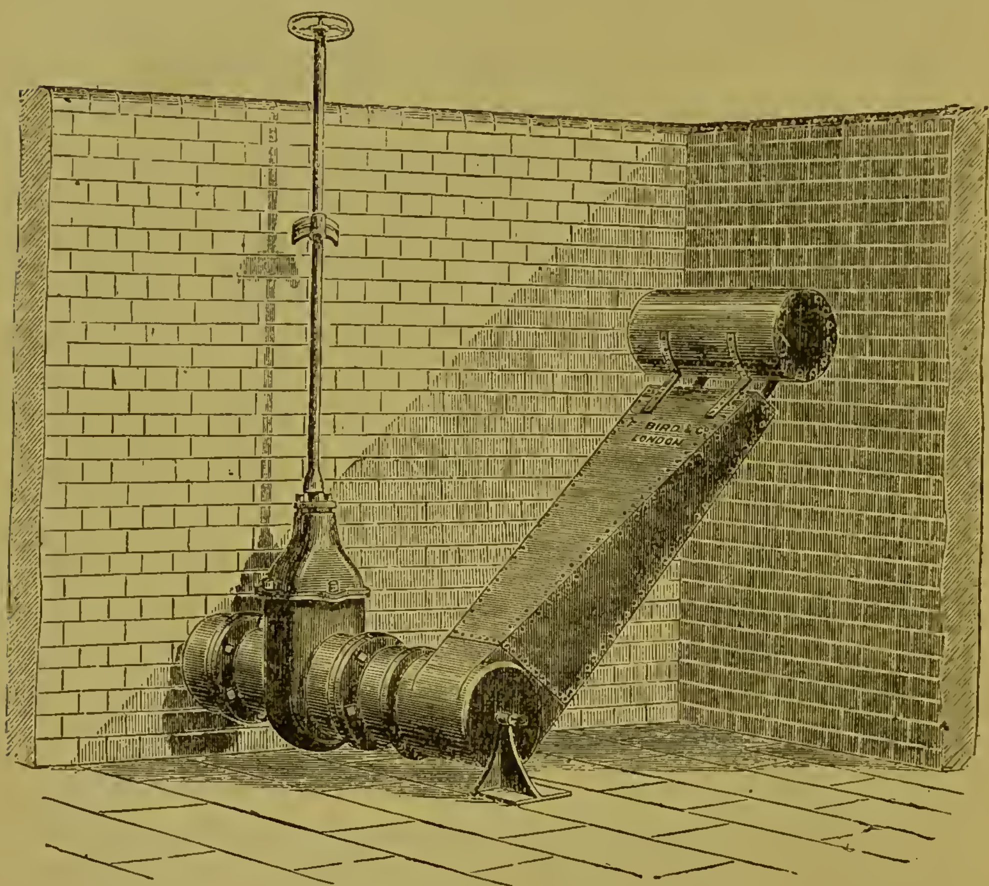


Fig. 3.—Floating arm used in settling tanks.

treatment of 200 cubic metres (44,000 gallons) per diem were as follows:—Cylinder, 75 millimetres (2·95 inches) in diameter; stroke, 210 millimetres (8·26 inches). It was found practicable in eight minutes with this pump to exhaust the air entering the receiver in the course of five hours; so that a similar pump, used continuously, would suffice for the daily purification of upwards of 7,000 cubic metres of sewage. Owing to the vacuum produced in the receiver, the external atmospheric

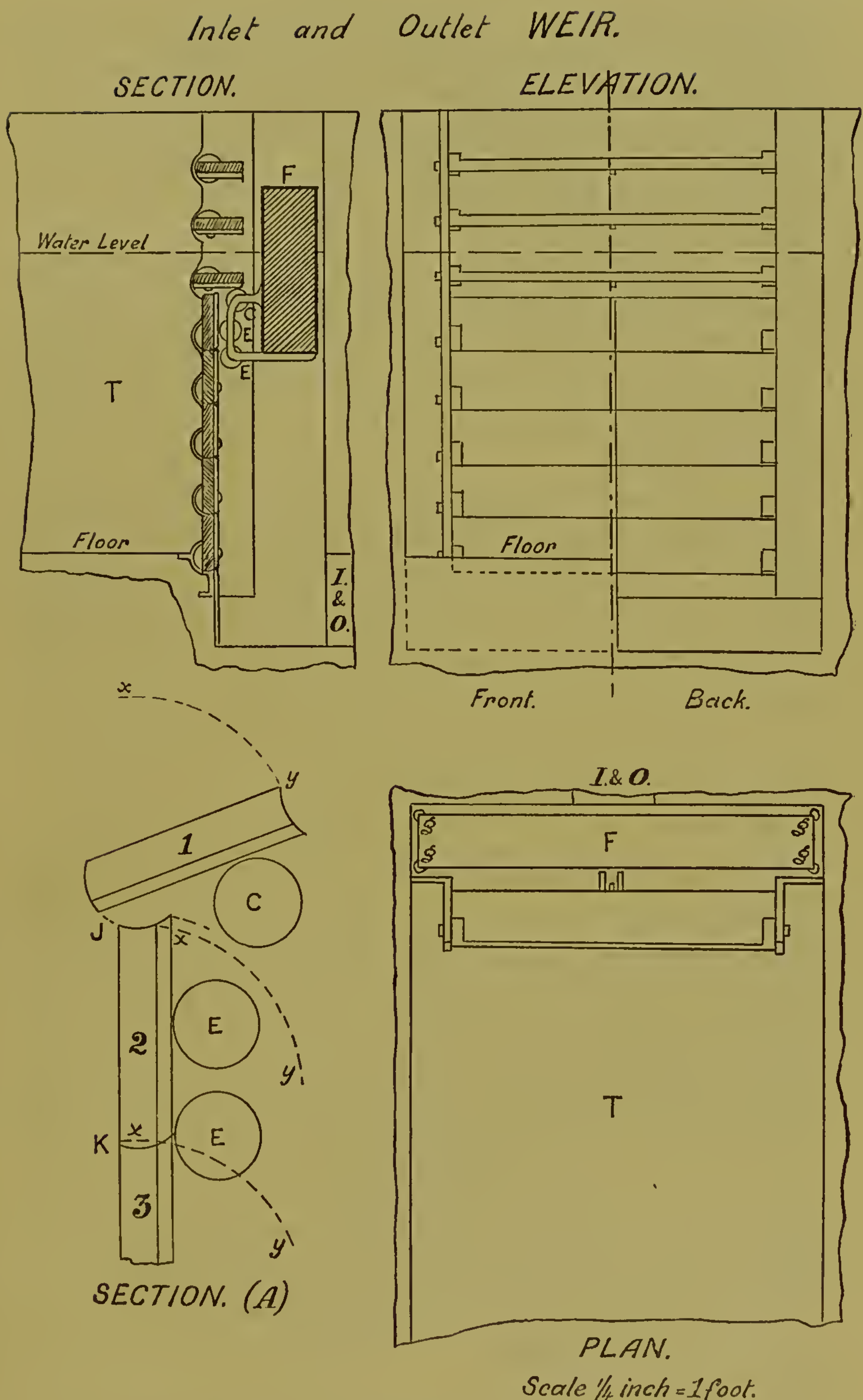


Fig. 4.—Weir designed by Mr. Houghton.

pressure slowly forces up the sewage, together with the precipitate, and this mixture undergoes complete separation of the liquids from the solids. Then by a syphon-like contrivance, which is entirely self-acting and continuous in its operation, the purified liquid is caused eventually to flow away at the top of the vessel."

The works at Essen are a combination of this apparatus with the Dortmund tanks, of which a diagram has been given. The arrangement seems to possess many advantages where a limited space, near populous places, is only available for the construction of works; or in cases where extremes of climate are experienced.

The engraving above shows a form of floating arm now much used in settling tanks. A sluice-valve regulates the volume to be drawn off, whilst the hollow vessel near the mouth of the floating arm, keeps the mouth submerged to the depth of about 9 inches, thus the effluent water is drawn off without disturbing the sludge (see fig. 3).

The following particulars relate to an ingeniously devised weir by Mr. Houghton (fig. 4):—

The weir consists of a series of flaps, pivotted at their ends, and fitting between vertical side frames, placed either against the wall of the reservoir in front of the inlet and outlet openings, or in a trunk or case placed in the reservoir. As the reservoir fills, these flaps are closed successively from the bottom upwards by a float which rises at the back. The uppermost flap in closing, securely locks the one immediately beneath, thus cleaning the contact surface and always bringing the inlet flow to the sewage level for the time being. For the withdrawal of the effluent the process is reversed. As the liquid level falls, the float drops, and each successive flap falls over from the top downwards. Direct control of the rate of inflow and outflow is maintained by means of the ordinary sluices. Stops are provided to prevent any chance of the flaps falling forward.

Fig. 4 shows one of these weirs fitted at the end of a tank, T. In the section the float, F, has a projecting frame attached below the liquid level, carrying three rollers, the top one, C, being the lifting and closing roller, and the two beneath, E, E, being easing rollers to prevent the flap just closed from moving back before it is securely locked by the closing of the one above. The enlarged section (*A*) shows this more clearly, the dotted lines, x, y, showing the path taken as the flap falls over or closes, as the case may be. In filling the tank, the flap marked *1* is being lifted by roller, C (attached to frame on float), and will soon lock flap *2* at J, as flap *2* does flap *3* at K, and at the same time thoroughly clean the opposite contact surface of any filth or obstruction thereon. In emptying the tank, the flap *1* is falling over as C descends with float, and, as shown, leaves flap *2* free to fall over when the float further descends with the liquid level.

CHAPTER VII.

CHEMICAL PROCESSES.

Clarifying Reagents.—The purification of sewage by means of one or more reagents has occupied the attention of eminent chemists since the commencement of the present century; indeed, the first patent in connection with this matter was taken out in the year 1762 by Deboissieu, since which date about 500 patents have been obtained, an enumeration of which cannot be entered upon in this work.

It will be conceded that the solution of the "sewage problem," so far as the employment of chemicals is concerned, is now placed upon a satisfactory basis, since the vast number of failures or negative results which have been obtained in the use of chemicals, have served to reduce the question to one of comparative simplicity.

The exact position may be briefly recapitulated in the words of Dr. Dupré,* F.R.S.:—"As regards processes of precipitation, I will merely remark that inasmuch as no proportion of chemicals which can practically be employed will do much more than clarify the sewage, the proportion of chemicals employed should be kept as low as is consistent with the object to be attained, namely, clarification, and that, more particularly, the use of large quantities of lime should be avoided."

In the design of settling tanks, the engineer has at length arrived at some definite conclusions as to capacity and general arrangement, and it is improbable that any great improvement will be made upon some of the best modern works.

In the disposal of the sewage-sludge, again, the filter-press has rendered possible the construction and successful operation of works, which, but for its adoption, would have been impracticable.

The chemical processes in general use are few in number, lime, either alone or in conjunction with other chemicals, being most frequently used.

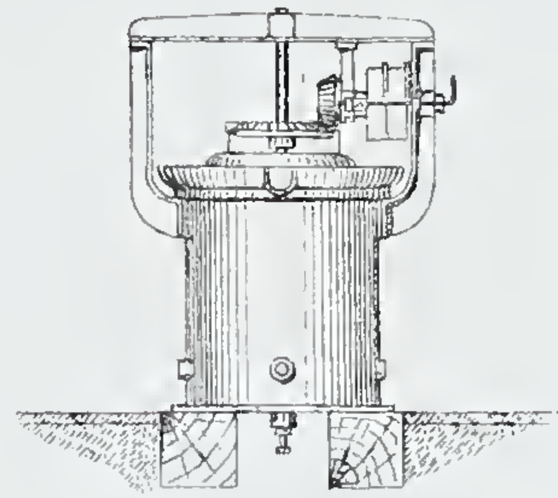
The Lime Process.—The efficiency of this, as compared with other chemical processes, together with the economy attending the use of so cheap an agent as lime, must be the explanation of so wide an adoption of the process.

The purest lime should be used—*i.e.*, that containing a very high percentage of calcium. Strong limes, such as those produced from grey chalk, are not nearly as efficacious as those yielded by the upper chalk (flare lime), and by the crystalline limestone of Derbyshire and other counties.

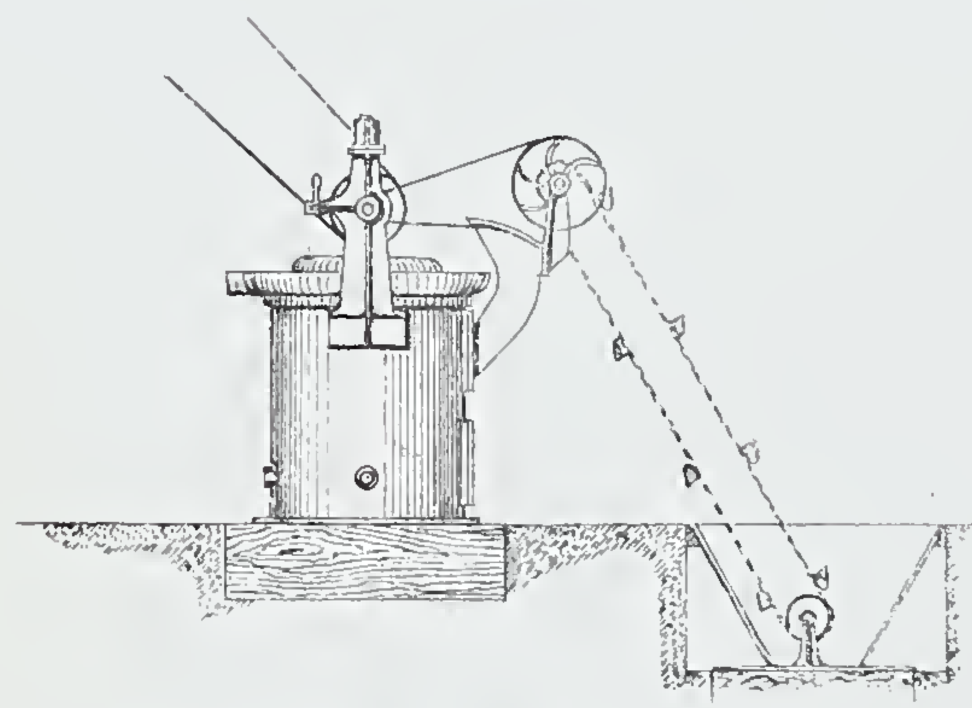
The lime should be thoroughly slaked before being used: if possible, the day's supply should be weighed out and slaked on the day preceding that of its intended use. Before being added to the sewage, it must be reduced to the "milky" condition, and this may be accomplished by means of the ordinary mortar mill, or better, by the lime-mixer shown on Plate 6. The quantity of lime necessary to the volume of

* *Transactions of the Sanitary Institute of Great Britain*, vol. ix., 1887-88, p. 368.

BOWES SCOTT & READ'S LIME MIXER.



FRONT ELEVATION.



SIDE ELEVATION SHOWING ELEVATOR.

West, Newman photo-lith.

sewage under treatment can be nicely adjusted by regulating the supply of water to the mixer, or, if the endless-chain feeding-arrangement be adopted, by varying the speed of the chain or the number of buckets.

If the sewage is pumped, the milk of lime might be conducted into the pump-well, when in passing through the pumps it will be thoroughly well incorporated with the sewage; but if the sewage gravitates into the settling tanks, a salmon-ladder mixing-arrangement may be constructed in the portion of the tunnel adjacent to the tanks, or a small chamber with mechanical stirrers may be constructed. In many cases, sufficient fall may be obtained at the works for operating a turbine by means of the sewage, in order to provide the necessary motive power, or the simple but effective "sewage clarifier" of Messrs. Bradley, as shown in fig. 5, and in operation at Ilford and elsewhere, may be adopted.

In treating London sewage, lime-water is employed, and experience has fully confirmed Mr. Dibdin's views as to efficiency of a small dose of lime when used in that form, one-third of a ton of lime per million gallons of sewage, being fairly effective in clarifying the sewage.

The usual dose is one ton of lime to each million gallons of sewage (15·68 grains per gallon), but the tendency is to reduce the quantity of lime to the smallest effective amount,* since an alkaline effluent mixing with organic matters such as abound in the muds of many rivers, is liable to enter into putrefaction of a most offensive nature. Indeed an excess of lime in an effluent may cause it to act as a precipitant of the suspended organic matters present in the river-water, thus producing deposits which in hot weather become exceedingly offensive. The most notable example of the unsuitability of the lime process in certain cases is that of Leicester. The effluent water falls into a comparatively small and very sluggish river, and in hot weather, in consequence of

* Dr. Tidy recommends "not less than 10 grains per gallon to a sewage that does not exceed 30 gallons per head."—*Journal Society of Arts*, 1886.

'secondary" or deferred-decomposition setting up and creating a nuisance, a very large area of land (about 1,375 acres) is now used for sewage disposal purposes. In this case, however, lime has merely failed in company with possibly every prominent chemical process known.

In towns such as Wolverhampton, Sheffield, Birmingham, and others, in which the galvanising of iron goods and the manufactures generally yield abundance of acid metallic salts to the sewage, the lime process might, "if judiciously managed,

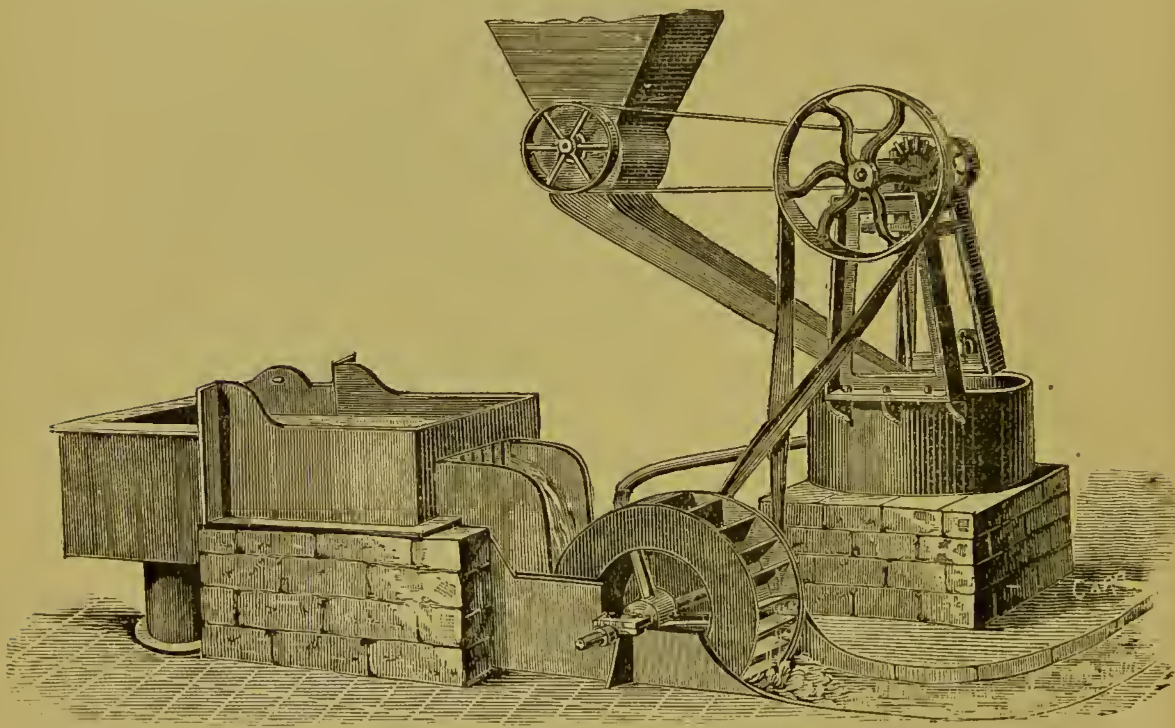


Fig. 5.—Bradley's sewage clarifier.

produce excellent results" (*Crookes*). Further reference to Birmingham will be made in the proper place.

In many modern sewage works the effluent from the settling tanks is made to fall over a series of steps, the aeration thus attained tending to neutralise its alkalinity by absorption of carbonic acid from the atmosphere, whilst any oxygen absorbed becomes available for the micro-organisms, which are now known to play an important part in the final purification of sewage.

Lime and Chloride of Lime.—This process has been in operation at Hertford, where, in consequence of leakage of subsoil-water, the sewage is very weak. Dr. Tidy * speaks favourably of the process, and stated that one-third of a grain of chloride of lime per gallon of sewage prevented the growth of sewage fungus. Further, "my experience enables me to speak favourably of the employment of chloride of lime with lime, especially in hot weather. About 56 lbs. per million gallons of sewage will be found, as a rule, fully sufficient for a sewage represented by 30 gallons per head of the population."

Hillé Process.—The formula for the mixture in this process is lime 100 lbs., gas-tar 3 lbs., chloride of magnesium 17 lbs., made into a paste with 180 lbs. of water. The proportions to be varied if necessary. This process was tried at Wimbledon (1870-76), but being found to be not more efficacious than lime, its employment ceased. At Edmonton the process was in operation for some years, but has been superseded by land.

The dose necessary "varies from $\frac{1}{4}$ lb. to 1 lb. of paste per 100 gallons" (*Tidy*). The smaller dose supposes subsequent filtration of the effluent.

Lime and Sulphate of Alumina.—This process has been employed at Wimbledon, and will be further referred to in the chapter descriptive of the Wimbledon works.

Dr. Tidy † says of this process, "My experience leads me to speak very highly indeed of the combined use of lime and sulphate of alumina. The quantity of lime, which is to be added first, should be such as to render the sewage faintly alkaline. Probably at the rate of from 5 to 7 grains per gallon will be needed for this purpose. It should be added as milk of lime, and should be thoroughly stirred in by means of a paddle-wheel, or other efficient mixer. A flow of a few yards should now be allowed, to permit the aggregation of the precipitate. This having taken place, a solution of crude

* *Journal Society of Arts*, 1886. † *Ibid.*

sulphate of alumina is to be added, and the sewage again actively stirred. In the alkaline condition of the sewage, the alumina will be precipitated, and will then combine with a portion of the organic matter, forming together an insoluble precipitate. Thus treated, the sewage should be allowed to flow into tanks for the precipitated matters to collect."

Dr. Angus Smith, F.R.S., has devoted a considerable amount of attention to the question of **aeration of sewage,** and the summary of his experiments is given in a Report to the Local Government Board, 1882, page 51 :—

"In all cases putrefaction is delayed by aeration. The oxygen recovers itself in the aerated specimens better than in the non-aerated. Nitrates are formed more readily in the aerated than in the non-aerated specimens.

"'Ammonia is lost by agitation, but specially by the previous addition of lime. The amount of lime added was ·171 grain per litre, or 12 grains to the gallon.'

"When mechanical means for effecting aeration are necessary, the aquarium or jet-system is found to be most effective, since the air is injected into the liquid in finely divided particles.

"A portion of the lime will be at once converted into carbonate of lime, by combining with the carbonic acid present in the sewage, and serve as a weighting material to aid in the deposition of the lighter flocculent materials. This mechanical action of the lime carbonate is of great importance. The flocculent suspended matter is no doubt one of the most important materials to remove, because it is this ingredient of the sewage which readily putrefies, and in this way causes a nuisance.

"It is, moreover, so light that unless weighted it is difficult to precipitate. A second portion of the lime combines with some of the organic matter in solution producing an insoluble precipitate (of uncertain composition) of a compound of lime and organic matter, the subsidence of which is again assisted by the formation of the carbonate of lime previously described.

A third portion of the lime renders the sewage faintly alkaline.

"The alumina salt is now to be added. The alumina is precipitated, owing to the alkalinity effected by the slight excess of lime. This alumina combines with some of the organic matter in solution, not precipitated by the action of the lime. The power of alumina in combining with dissolved organic matter, and so removing it from solution, is taken advantage of in many commercial processes."

In experimenting with London sewage, Mr. Dibdin * found that, as in the case of iron salts, the percentage reduction of dissolved organic matter was not materially increased by the use of sulphate of alumina beyond that due to the lime alone.

When the effluent is applied to land in close proximity to houses, as at Wimbledon, it is of importance that it should not be liable to deferred decomposition, and this condition is in great measure attained by the use of sulphate of alumina.

Lime and Phosphoric Acid.—In the patent of Mr. Forbes, F.R.S., and Dr. Price, an acid solution of native phosphate of alumina is employed, either with or without lime. The phosphate of alumina, as procured from the West Indies, is said to consist of 38 per cent. of phosphoric acid, 25 per cent. alumina, with about 2·5 per cent. of peroxide of iron (*Tidy*).

This natural production is submitted to the action of sulphuric or muriatic acid, by means of which the phosphates are converted into a soluble condition. Dr. Tidy experimented with London and with Coventry sewage, employing 33 grains of phosphatic material dissolved in an equal weight of commercial sulphuric acid, in the treatment of each gallon of sewage.

Dr. Tidy † says—"The effluent was clear and without smell, much soluble organic matter being removed. The process however, is peculiar in this respect, that if no lime be added

* *Minutes of the Proceedings, Institution of Civil Engineers*, vol. lxxxviii., 1887.
† *Journal Society of Arts*, 1886.

after the precipitating material, much soluble phosphate will remain in solution. The effluent may then be used for irrigation, no nuisance being likely to result from the use of the clarified water, the manurial value of which will be considerable. In other words, we strengthen (the patentees would say) the manurial value of the sewage, and purify it by the same operation."

With regard to the application of the process, the patentees say, "Whilst the sewage is contained in a cistern or reservoir, or whilst it is in the act of flowing thereinto, the requisite amount of the soluble phosphates of alumina is to be added thereto, and after thorough admixture with the sewage by the use of agitators, or other well-known means, the sewage so treated may be allowed to remain tranquil in the reservoir in order that subsidence of the resulting precipitate may be effected, or after having added to the sewage the requisite amount of the soluble phosphate of alumina, lime (by preference in the form of milk of lime) is to be added in such quantity as that the phosphates in solution shall be precipitated. The result will be known by the sewage acquiring a neutral or alkaline reaction, or the lime may be firstly added, and the solution of the phosphates of alumina added subsequently, but we prefer the former process; or the soluble phosphates of alumina may be firstly decomposed by means of the lime or carbonate of lime, and the resulting precipitate may be employed for the purpose of effecting the separation of certain constituents of sewage."

The price of the commercial phosphate of alumina is at the present time about £4, 10s. per ton, whilst sulphuric acid costs about £1, 15s. per ton, and if any approach to the quantity used by Dr. Tidy is necessary, the cost of the process would be prohibitive. It was employed at Hertford in the years 1876-7.

Lime and Proto-Sulphate of Iron (or **Green Copperas**).—This process has been recently prominently brought before the public in connection with the Metropolitan sewage disposal problem. After making an exceedingly valuable series of experiments, and carefully considering the general results obtained, Mr. Dibdin, F.C.S., F.I.C., the Board's chemist, finally recommended the use of 3·7 grains of lime *in solution*, and 1 grain of proto-sulphate of iron per gallon, in the treatment of the London sewage; in addition, in hot weather Mr. Dibdin uses permanganate acid in order to destroy any offensive odour remaining after chemical precipitation. The results of the experiments by Mr. Dibdin were communicated to the Institution of Civil Engineers in January, 1887.* In the use of lime Mr. Dibdin was led to suggest the use of the minimum dose found to be effective, because of the solvent property of lime upon organic matters when brought in contact with them. He says—"The use of an excessive quantity of lime, while affording a rapid settlement of the sludge, and a more or less clear effluent, dissolves a by no means inconsiderable quantity of the offensive matters previously in suspension, and this is apt to render the last state of the liquid worse than its first."

The reason given for the adoption of the fraction (3·7 grains) is that it "had so come out from the calculated quantities used." It will be observed that this fraction is a close approximation to a quarter of a ton per million gallons, which is equal to 3·92 grains per gallon.

Mr. Dibdin says further, that "if the whole of the chemically effective strength of the lime is to be utilised, it must be in solution and not in suspension. Whether this is brought about by first adding the lime to the sewage in the form of 'milk,' and afterwards agitating the sewage for a period sufficient to ensure the whole of the lime entering into solution, or first dissolving it in water, and then adding the lime-water so obtained to the sewage, matters not, the result is the same. The point being that the whole of the lime must be dissolved. If this precaution be observed, a far less quantity

* "Sewage Sludge and its Disposal," J. W. Dibdin. *Minutes of the Proceedings Inst. C.E.*, vol. lxxxviii., 1887.

of lime will be required to effect precipitation, and a few grains of lime will effect as much work as three or four times the quantity when used in the usual form of 'milk of lime,' without sufficient subsequent agitation of the sewage."

With regard to the process generally, the following passage occurs in the Report of the Metropolitan Board of Works, 1887.—"Careful experiments made, first with small and afterwards with larger and larger quantities of sewage, showed that chemical precipitation of the matter held in suspension could be satisfactorily effected by adding to the sewage certain proportions of lime and proto-sulphate of iron, and then allowing it to remain for an hour or two in settling tanks. The Board submitted the results of the process to four independent chemists of the highest standing, viz., Sir Frederic Abel, Dr. William Odling, Dr. A. W. Williamson, and Dr. A. Dupré, one of whom (Dr. Williamson) was a member of the Royal Commission of 1882. Those gentlemen advised that the method of precipitation adopted was a good one, and that it produced a fairly clear liquid, but that it left a sufficiently unpleasant smell to prohibit the effluent water being discharged into the river during warm weather at all states of the tide. It appeared, in fact, that the clarification of the sewage would not be sufficient to secure complete immunity from smell arising from secondary fermentation and fresh development of offensive gases in hot weather. Such immunity, however, it was deemed desirable to attain.

"The Royal Commissioners seem to have been of opinion that the only effectual way of attaining it was, after precipitation of the solid matter, to further purify the liquid by a process of filtration through earth, and they advised that such a process of filtration should be adopted if it were decided to discharge the sewage effluent into the Thames in the neighbourhood of the present outfalls.

"The acquisition of sufficient land, however, in the neighbourhoods of Barking and Crossness, to enable the vast quantity of London sewage to be effectually filtered through soil, was found upon examination to be attended with such great difficulty, to say nothing of cost, that the Board conceived it to be its duty to endeavour, under competent advice, to find some other method sufficiently effective to obviate the necessity of earth-filtration. What was required seemed to be an oxidising agent, which should not only effect the immediate destruction of any offensive odour still remaining after chemical precipitation, but which would at the same time prevent the development of noxious gases. It was found that permanganate acid was effectual in accomplishing both these objects. . . . The Board again sought the opinion of the four eminent chemists who had advised upon the method of precipitation. They all, after careful observation of the experiments made, gave it as their opinion that, if the liquid resulting from precipitation with lime and proto-sulphate of iron were subsequently treated with manganate of soda and sulphuric acid, it would be deodorised and purified to such an extent as to render its discharge into the river unobjectionable at all states of the tide."

It appears from the Report that, in 1877, the quantities used were—of manganate of soda 2,173 tons, and of sulphuric acid 865 tons.

In a letter to the author Mr. Dibdin stated that, in order to obtain the best results, "the manganate is first dissolved in water, thus making a green solution of manganate; sulphuric acid is then run in, in quantity sufficient to give the solution a strongly or distinct acid reaction to test-paper. The acid run in will convert the green colour into the well-known red one of the *per*-manganate, which is the substance actually required." Further reference to the employment of this material will be made in the chapter on London.

Messrs. Tennant & Co. of Mincing Lane now supply the material ready prepared for use under the name of "Ozo," quantities of which have been used at Wimbledon by the author with excellent results. The late Mr. Gordon, M. Inst. C.E., also tried the manganate at Leicester, after first treating the sewage with about 16 grains of lime per gallon. He found that "the application of from 1 grain to 1¼ grain of manganate of soda, with about ¾ grain of sulphuric acid, per gallon to the effluent before it passed into the river, practically stopped further decomposition in the river, and satisfied the complaining local authorities." The conditions at Leicester are exceedingly trying as regards any process, since in very dry weather the sewage effluent greatly exceeds the volume of the river, which is canalised, thus adding to the difficulties of the situation.

Lime and Black-ash Waste.—In this process the black-ash waste, produced in great abundance at alkali works, is prepared by Mr. Hanson, and used in conjunction with lime. When tried at Wimbledon the results were not encouraging, as the sludge was greatly increased in quantity whilst the effluent was not appreciably affected.

Professor Corfield * mentions this process as being in operation at Leyton and at Tottenham, with good results. "At Tottenham . . . black-ash waste is used. We took a sample of the effluent from the tanks, and found it to contain 20 parts per million of free ammonia and 8·6 parts per million of albuminoid ammonia. Although this effluent is similar in composition to a weak, crude sewage, and has been kept in an open bottle for over a month, no putrefactive changes have taken place in it. Its sediment has contained, during the whole of the period, numbers of infusoria, which are as abundant and active now as on the day the sample was taken. It thus appears that although black-ash waste may prevent the formation of purtrefactive organisms (Bacteria) when used in sufficient quantities, it does not interfere with the growth of those microscopic organisms, which, by feeding on organic matters, are capable of purifying foul waters, without the production of foul gases of putrefaction" (*loc. cit.*) The Tottenham works are now no longer in operation, the Lee, which received the effluent, having become so foul that in

* *Treatment and Utilisation of Sewage*, 3rd edition, 1887, p. 490.

1891 an agreement with the London County Council was entered into, and the sewage of Tottenham is now discharged into the metropolitan system, and is treated with the London sewage at Barking.

A large amount of information regarding waste from alkali works may be found in the Report to the Local Government Board, 1882, by Dr. Augus Smith, F.R.S. A great number of reagents—other than those referred to—have been employed with lime, but the list cannot be further examined in this work. It is doubtful if any great improvement upon the processes described will be found.

A. B. C. Process.—In this process a distinct departure is made from those in which lime is used. The materials have been varied from time to time, but the mixture consists, as a rule, of alum, charcoal, or refuse from prussiate of potash works, and clay. Blood was at one time employed, but is not found to be necessary.

The clay and charcoal are first ground together in a mortar-mill, and then added to the sewage, sufficient water being used in the mill to cause the mixture to flow to the sewage, the alum is dissolved and the solution is also added to the sewage. *"Here, now, were two imperfect processes; on the one hand, sulphate of alumina, or some analogous salt which clarified but did not perfectly deodorise, and gave a precipitate which was apt to rise up; on the other hand, clay and charcoal, which deodorised but did not clarify, and which, *per se*, remained floating in the liquid with their cargo of impurities. But put these two classes of bodies together and combine their action, and the 'sensational' A. B. C. process resulted."

In the original specification, the patentee, Mr. Sillar, states that for the treatment of ordinary sewage the following ingredients should be employed:—

* W. Crookes, F.R.S., *Minutes of the Proceedings, Institution of Civil Engineers*, vol. xlvii., 1877.

Alum,	600	parts.
Blood,	1	,,
Clay,	1,900	,,
Magnesia,	5	,,
Manganate of potash,	10	,,
Burnt clay,	25	,,
Chloride of sodium,	10	,,
Animal charcoal,	15	,,
Vegetable ,,	20	,,
Magnesian limestone,	2	,,

Dose to be employed, 4 lbs. per 1,000 gallons of sewage, or 28 grains per gallon.

In the paper by Dr. Tidy, printed in the *Journal of the Society of Arts*, of October 8, 1886, the details of the quantities used in treating the sewage of different towns are given, which varied from 28 grains per gallon at Leicester in 1868 to 224 grains per gallon at Crossness in 1873. An unusual quantity of sludge is produced in consequence of the use of insoluble precipitants in large quantities, but it is claimed for the system that the sludge thus produced is, when dried and ground, an excellent manure, and that its market price is £3, 10s. per ton. In this respect the A. B. C. process may be said to stand alone.

The process was in operation at Aylesbury for upwards of 12 years, it has been adopted at Wellington College under the advice of Mr. Baldwin Latham, M. Inst. C.E., and towards the close of the year 1888 was adopted at Kingston-upon-Thames. Like other processes, it has been "tried" at many other places without having been finally adopted.

Ferozone and Polarite Process.—In this process—which is of somewhat recent origin—the introduction of the precipitating material, ferozone, is followed by filtration of the effluent through a filter containing polarite, employed in the manner shown in fig. 6.

The following is an analysis of the precipitant by Professor Roscoe:—

Ferrous sulphate,	26·64
Aluminium sulphate,	2·19
Calcium sulphate,	3·30
Magnesium sulphate,	5·17
Combined water,	8·20
Moisture,	24·14
Silica,	11·35
Magnetic oxide of iron,	19·01
	100·00

Analysis of polarite by Professor Roscoe :—

Magnetic oxide of iron,	53·85
Alumina,	5·68
Magnesia,	7·55
Water, with a trace of carbon,	5·41
Silica,	25·50
Lime,	2·01
	100·00

The process has been in operation at Acton during the past four years with satisfactory results. In a report by Professor Roscoe, who examined the process in detail, the following passage occurs :—

"Samples of the effluent have been kept in absence of air for nearly two months, and have still retained their good qualities. They exhibit no trace of putrefactive change, but have rather undergone improvement, inasmuch as in most cases a slight green growth has taken place, showing that the effluent is in a condition to be acted upon by the natural influences which will tend further to improve the water whilst flowing along a stream."

Ferozone has been employed at Wimbledon, the material being ground in an ordinary mortar mill, and added to the sewage in a semi-fluid condition. When used at the rate of about half a ton per million gallons, the deodorisation was very effective, but fine particles of the precipitant remained suspended in the sewage, and the appearance of the effluent was not good. A small experimental filter of polarite was also used, through which the effluent from the settling tanks was passed at the rate of 500 gallons per square yard per day, the effluent issuing being of the nature described by Professor Roscoe. In order to prevent the suspended matters from

SECTION OF POLARITE FILTER.

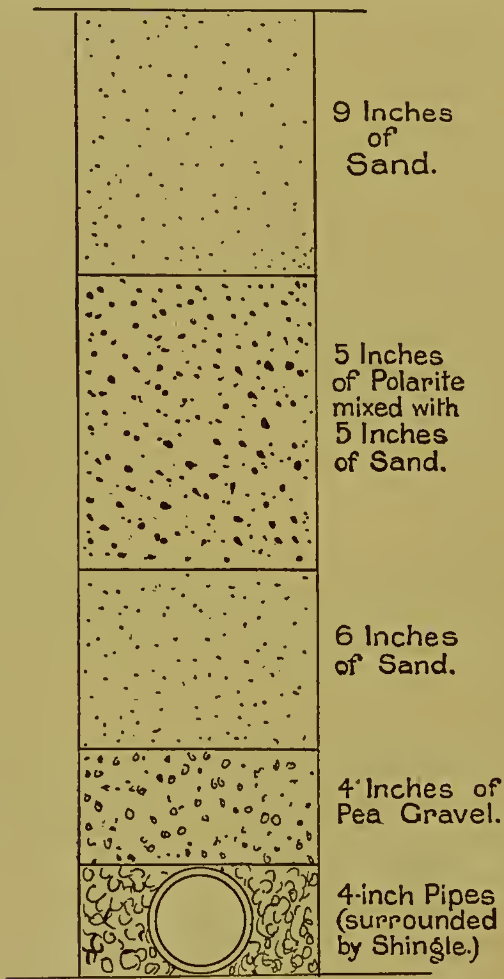


Fig. 6.

passing into the body of the filter, a layer of washed sand, 8 inches in thickness, was placed upon the polarite, but this became clogged and impervious when about 1,000 gallons per square yard had passed through, and in order to obviate the expense of renewing the uppermost layer, the sand was removed and good surface soil was substituted, which proved quite satisfactory, although frequent surface cleansing was necessary. The filter was constructed by first placing on its floor burnt ballast 6 inches in thickness, upon this a layer of washed sand 3 inches in thickness was placed, then a bed of polarite and washed sand, mixed together in equal proportions, and 18 inches in thickness, and, finally, surface soil 8 inches in thickness.

The following description of the process is by Dr. Arthur Angell, Ph.D., F.I.C. :—

"Ferozone contains a large proportion of ferrous iron salts, and for that reason alone cannot fail to be a powerful chemical disinfectant; further than this, however, it contains salts of alumina and of magnesia, both of which assist as deodorants and precipitants. The remaining part of ferozone is made up principally of very finely-divided porous magnetic oxide of iron, and this serves both as a further oxidising agent, and as a weighting material which accelerates the subsidence of the suspended matter, and keeps the sludge down as it accumulates at the bottom of the tank.

"The insoluble portion of the ferozone is composed of finely-powdered polarite, the newly invented material, to which the filter beds containing it owe their very remarkable oxidising powers; this powder, therefore, keeps the sludge sweet during subsequent disposal, either by pressing or drying, or by both, and thus a part of the process which is so offensive at sewage works, where lime forms one of the ingredients used, is carried on without committing a nuisance.

"The ferruginous effluent from the tanks is passed through a filter composed of polarite mixed with sand, which will filter sewage effluents at the rate of 1,000 gallons per square yard per 24 hours, with better results than can be obtained by land, which filters about 1½ gallons per square yard per 24 hours; or, in other words, one acre of filtering area containing a layer of 'polarite' will do more efficient work than 666 acres of land.

"The value of this discovery can scarcely be over-estimated, as by the use of these small but powerfully-active filter-beds, it is entirely unnecessary to acquire large areas of land for expensive sewage farms; the polarite in these beds never requires to be changed, or to be removed, a slight rest of a few hours occasionally being all that is needed to effect revivification, and to admit of the top of the filter being cleansed.

"The action of the filter-bed is entirely independent of any property inherent to the polarite itself, which remains the same in weight and in bulk after an indefinite amount of oxidising work has been done. Polarite is simply a carrier of oxygen and a means of bringing about a contact between that element and the foul matters in the filtering fluid. It derives its oxygen from the air and also from the tank fluid, and as these sources are inexhaustible, so also is the life and power of the filter-bed."

Although the author is not in accordance with Dr. Angell, as regards the relative efficiency of land and polarite, since the quality of land, and its power of purifying sewage varies enormously, there can be no question as to the value of ferozone and polarite, and the entire process may be regarded as an important addition to the list of workable methods of sewage disposal.

Spencer's System.—The filters constructed by Spencer's Company are on the same principle as those described above, but instead of polarite, a compound of carbon and magnetic oxide of iron is employed. The material has been used with remarkable success since 1864 in purifying River Calder water before it is supplied to Wakefield for domestic purposes, and was highly praised by the late Thos. Hawksley. Mr. Wardle * states that it has been tried for purifying sewage at Salford, and effected a remarkable reduction in the amount of dissolved impurities. According to the tables in Mr. Wardle's book, albuminoid ammonia was reduced from ·14 part per 100,000 to ·065 part, on passing clarified sewage through the filters.

Amines Process.—This has been tried at Wimbledon, and consists in the employment of from 30 to 50 grains of lime

* *Sewage Treatment and Disposal*, by Thomas Wardle. John Heywood, Manchester, 1893.

per gallon and about 3 grains of herring brine. The clarification is very rapid and complete, and a heavy, nearly inodorous sludge, which does not become putrescent, is produced. Some samples of wet sludge examined by the author only contained 86 per cent. of moisture. So far as could be observed, the crops on the sewage farm were unaffected by the effluent water from the tanks. The object sought to be attained by the inventor, Herr Wollheim, is the complete sterilisation of the effluent, and according to reports by Dr. Klein, F.R.S., the process is successful in that respect. Where, however, the effluent is to be discharged into a chalk-water stream from the tanks direct, it would be well to ascertain the effect of effluent, which is very alkaline, by experimenting on a small scale.

Persulphate of Iron, Wardle's Process.—This is a new precipitant brought out by Mr. Thomas Wardle, the well-known chemist and silk dyer, of Leek. In describing the new system in his work, "The Treatment and Disposal of Sewage," just published, Mr. Wardle says, "This is a precipitation process discovered by the author after several years of experimental research with persulphates and other salts of iron. The object was the construction of a persulphate of iron in such a basic and delicately existing state as would most readily combine with the organic matter in solution in sewage. . . . I had for some time known that several salts of iron possess the property of precipitating the organic matter of sewage to a greater or less degree, and I thought it might be worth while to follow up the idea and endeavour to discover such an iron salt as would attain the maximum power of the precipitation of such organic matter, with or without additions, which would answer all the requirements desired in the treatment of sewage of various kinds. . . . I found that the most effective precipitant was a specially constructed basic ferric-salt. This salt is so delicately constituted, and so unstable in the presence of organic matter in solution as to instantly combine with it, and, in the case of sewage, a dense precipitate immediately forms, leaving in a very short time a perfectly clear effluent. On some sewages this action is accelerated, and the organic matter more completely precipitated by the addition of a small quantity of milk of lime, or lime-water." Mr. Wardle states that his precipitant has been very successfully tried at Salford. Being in the liquid form, it does not produce much sludge, like insoluble precipitants. The dose is 4 to 8 grains per gallon of sewage.

The Treatment of Manufacturers' Liquid Refuse.—Nearly all this class of pollutions may be best dealt with by means of chemicals—at least as a first step towards final purification. The following notes on the subject by Dr. Sergeant, Medical Officer of Health, Lancashire County Council, are most valuable:—"The principal sources of river pollution by manufacturing refuse within the Mersey and Ribble basins are derived from dye, print, and bleach works, chemical works, tanneries, paper-making works, woollen works, and silk works. The pollutions from the various manufactories are amenable to chemical and mechanical remedies, which may be applied without interfering with the processes of trade. The expense of treatment is not great, and in some cases the operations have resulted in a profit. If the restrictions with regard to pollution were more stringent, no doubt "necessity" would prove the "mother of invention," to the further advantage of the manufacturer as well as the public.

The **dyer, printer, and bleacher** often cause the pollution of large volumes of water partly by mineral, and chiefly by organic matter. The darkened colour of many of the tributaries of the Irwell is due to the presence of waste dye-liquor, consisting of indigo, logwood, &c., with the addition of chemicals, such as "chrome" (bi-chromate of potash), "argol" (bi-tartrate of potash), or copperas, used as "mordants." The effect of the latter is to render insoluble, or "fast," the colouring matter remaining in the dye-liquor. In order to render colourless waste dye-water, lime, sulphate of iron (or green vitriol), sulphate of alumina, or the mineral phosphate of alumina, and acid are usually added to precipitate the suspended impurities. Subsequent filtration may be resorted to if found necessary, and the precipitated solid matters can be used again for various purposes. In calico printing, sodium arsenite is employed as a mordant, and it is fortunate that the quantity used is small as compared with the volume of water with which it is mixed in the process of calico printing. Oxide of iron or magnesia converts this soluble poison into an insoluble arsenite, which may be removed by filtration.

The pollution from **bleaching operations** is of a comparatively slight character, consisting of lime, soda, and dilute acid. The lime liquor can be made to neutralise the acid, and form insoluble sulphate of lime, which would be precipitated. Mr. W. Henry Watson suggests that the refuse "stew" or lime liquor, the refuse soda-ash liquor, and the refuse chloride of lime solution should be run together and mixed, by which much of the lime remaining in solution will be deposited as carbonate, and this, even if subsequently dissolved, is harmless; the supernatant liquor, containing a little alkali (chiefly soda), should then be passed into a separate outfall tank and mixed with the refuse "sours" (dilute sulphuric acid), by which both may be considerably, if not entirely, neutralised.

Pollution by **chemical works** is of a grievous character, and seriously affects the Mersey, and to a less extent the Ribble. In the "alkali" manufacture chloride of sodium (common salt) is decomposed by sulphuric acid, the result being "salt cake." In the course of this process, acids are produced which formerly escaped in the atmosphere in a gaseous state, but the Alkali Act of 1881 requiring these gases to be condensed, manufacturers transferred to the rivers in a liquid form the acids thus recovered. Recently, however, by the adoption of certain methods, it has been found that the acids can be profitably utilised. The "salt cake" fused with lime and coal forms "black ash," from which carbonate of soda is obtained; and the residue, known as "alkali waste," composed chiefly of calcium sulphide, is stacked outside the works in enormous heaps, whence there exudes a foul-smelling liquid, containing sulphuret of calcium in solution. This finds its way to the river, and there meets with chloride of manganese and other waste chemical products, and the resulting fortuitous combinations, besides being extremely wasteful, contribute largely to the pollution of the air and water. A process is now adopted for profitably utilising the waste chloride of manganese and the sulphuret of calcium formed by the waste alkali heaps.

The pollution by **tanneries** consists of the spent lime and tan liquors, with a large amount of highly offensive organic matter in solution. The addition of sulphate of alumina will precipitate the lime, and the gelatinous matter can be coagulated by the addition of tannic acid, and removed by simple settlement, or more rapidly by the use of a filter-press, the remaining effluent being quite clear. By simply mixing the waste lime and tan liquors, with very little additional treatment, the above process may be imitated, and a good effluent produced. The cost incurred is slight, and to some extent recouped by the manurial value of the solids recovered.

In the **manufacture of paper** the waste liquors, strong with lime and soda, and containing grease from filthy rags, and vegetable matter when esparto grass has been employed, are allowed to pass into the nearest stream, to the injury of the fish. A further nuisance is caused by the suspended vegetable matter being deposited on the bed of the river, and undergoing putrefaction. Rivers, such as the Darwen, polluted by this refuse carry a froth or scum which is very persistent and objectionable. By the use of a filter-press the suspended matter can be profitably recovered, and the soda can be regained by the evaporation of the waste liquor. The cost of the plant used in this operation is soon defrayed by the value of the soda-ash recovered.

In **woollen and silk works**, the operation of dyeing and washing gives rise to pollutions of a serious character. The use of large quantities of soap is incidental to the various manufacturing processes, and results in the formation of waste liquor or suds. When poured into a river it kills the fish and covers the water with froth and slime. The value of the waste is now recognised, and a process, known as the "Magma" method, is employed, by which crude oil, useful for commercial purposes or for reconversion into soap, may be recovered from the soap-suds.

By sec. 5 of the Rivers' Pollution Prevention Act solid refuse from mines may not be deposited in a stream so as to interfere with its due flow, nor is it allowable to discharge any poisonous, noxious, or polluting solid or liquid matter proceeding from any mine, unless it can be shown that the "best practicable and reasonably available means" have been taken to render harmless such noxious or polluting matter. "Water in the same condition as that in which it has been drained or raised" from a mine may be admitted without treatment into a stream. Therefore, iron mine-water can be turned into streams in the state in which it is raised from the pits, although the ochreous matter it deposits is very harmful to fish, and might be easily recovered by settlement in suitable tanks."

The Massachusetts Experiments.—During the years 1888-1892, an elaborate series of experiments was carried on by the Massachusetts State Board of Health, and the results are given in great detail in three important volumes; indeed, it is not too much to say that these volumes contain more reliable information relating to the chemistry of sewage treatment, and the filtration of the effluent, than any others hitherto published.

In nearly every instance coming under the author's notice, where reference to these experiments has been made, the important fact that the U.S. gallon contains only 231 cubic inches, weighing 8·33 lbs. at 64° F., whereas the imperial gallon contains 277·274 cubic inches, has been lost sight of. The former is, in fact, the old British wine measure. This is of great importance, because 1000 U.S. gallons are only equal in volume to 833 British. The U.S. ton again is only 2000 lbs., and as in this country we frequently

TABLE IX.—RESULTS OF TREATMENT WITH EQUAL VALUES OF DIFFERENT CHEMICALS, NOV. 22 AND NOV. 26, 1889.

(Parts per 100,000.)

Treatment, per 1,000,000 gallons. (833,000 British.)	Cost of Chemicals per Head per annum.	Turbidity.	Total Solids.	Loss on Ignition.	Fixed Residue.	Ammonia, Free.	Ammonia, Albuminoid.	Chlorine.	Bacteria per Cubic Centimetre.
Original sewage, . . .	Nil.	·40	43·0	18·0	25·0	1·25	·40	4·86	25,840
Filtered through paper,	...	...	34·8	11·2	23·6	1·25	·26	...	...
After settling one hour,	...	·30	38·8	13·6	25·2	1·25	·28	4·82	10,920
1,800 lbs. of lime, . .	$ ·30	·08	45·6	10·2	35·4	1·25	·19	4·83	1,911
1,000 lbs. copperas and 700 lbs. lime, . . .	,, ·30	·12	46·4	9·2	37·2	1·25	·17	4·80	16,044
270 lbs. ferric oxide, .	,, ·30	·08	38·0	8·0	30·0	1·25	·18	4·92	2,047
650 lbs. alum, . . .	,, ·30	·10	34·4	8·0	26·4	1·50	·19	4·88	2,475
360 lbs. ferric oxide, .	,, ·40	·07	37·6	5·8	31·8	1·25	·15	4·96	1,980
870 lbs. alum, . . .	,, ·40	·09	38·2	9·6	28·6	1·25	·19	4·81	1,800
Original sewage, . .	...	·50	53·8	20·4	33·4	1·65	·50	8·40	Not given.
Filtered through paper,	...	...	43·2	13·6	29·6	1·75	·29	...	
After settling one hour,	...	·35	49·2	18·0	31·2	1·75	·44	8·44	
1,800 lbs. lime, . . .	$ ·30	·13	54·8	14·8	40·0	1·60	·24	7·47	
1,000 lbs. copperas and 700 lbs. lime, . . .	,, ·30	·15	54·8	10·4	44·4	1·65	·22	8·01	
270 lbs. ferric oxide, .	,, ·30	·09	46·0	10·0	36·0	1·65	·19	8·42	
650 lbs. alum, . . .	,, ·30	·11	43·2	9·6	33·6	1·65	·25	8·36	
360 lbs. ferric oxide, .	,, ·40	·09	45·6	8·0	37·6	1·60	·17	8·43	
870 lbs. alum, . . .	,, ·40	·12	47·2	10·0	37·2	1·65	·20	8·32	

refer to chemical treatment in terms of tons of precipitant to each million gallons of sewage—1 ton per million being equal to 15·68 grains per gallon, in the United States, 1 ton per million is equal to 16·8 grains per gallon.

With regard to the Massachusetts experiments on sewage treatment with chemicals, the details in the report extend over 54 pages, and cannot therefore be reproduced in this work, but the general results may be summarised with a fair approximation to the facts.

According to the report by the Chemist to the State Board, Mr. Allen Hazen, the chemicals used were:—

Lime, containing 70 per cent. of available calcium oxide, and costing $9 per ton.

Ferrous sulphate (copperas), containing 26 per cent. of ferrous oxide, and costing $10 per ton.

Aluminium sulphate (crude alum) containing 14 per cent. of alumina, and costing $25 per ton.

The sewage experimented upon was that from Lawrence, and is not as strong as average English sewage, chlorine, for instance, generally ranging from 3·5 to 8 parts per 100,000, whilst free ammonia and albuminoid ammonia averaged 1·83 parts and ·66 part respectively.

The general results given in Table IX. were obtained when using the "best amount" of lime, with other chemicals, of equal money value.

"If we take the percentage of albuminoid ammonia removed to represent organic matter, we find that in addition to the suspended matter, the following amounts of soluble organic matters have been removed":—

	Per cent.
With lime, costing 30 cents per head per annum, . . .	22
With copperas and lime, costing same as before, . . .	29
With ferric sulphate, ,, ,, . . .	32
With aluminum sulphate, ,, ,, . . .	20
With ferric sulphate, costing 40 cents per head per annum, .	41
With aluminum sulphate, ,, ,, ,, .	29

The general results and conclusions are as follow:—

"The lime process has little to recommend it. Owing to the large amount of lime water required, and the difficulty of accurately adjusting the lime to the sewage, very close supervision would be required to obtain a good result, and even then, the result is inferior to that obtained in other ways.

"Precipitation by copperas is also somewhat complicated, owing to the necessity of getting the right amount of lime mixed with the sewage before adding the copperas. When this is done a good result is obtained. The amount of iron left in the effluent is much greater than with ferric sulphate, owing to the greater solubility of ferrous hydroxide.

"Ferric sulphate and alum have the advantage over both lime and copperas, that their addition in concentrated solution can be accurately controlled, and the success of the operation does not depend upon the accurate adjustment of lime or any chemical to the sewage.

"The results with ferric sulphate have been, on the whole, more satisfactory than those with alum. This seems to be due in part to the greater rapidity with which precipitation takes place, and in part to the greater weight of the precipitate. It is probable, from the greater ease with which ferric sulphate is precipitated, that it would give a good result with a sewage that was not sufficiently alkaline to precipitate alum at once.

"It is quite possible that the same process would not give equally good results upon all kinds of sewage. Special sewages may require special treatment. For this reason, and also on account of changes in the prices of the several chemicals, it is impossible to say that one precipitant is universally better than another."

The report then gives the average composition of the sewage experimented upon, from which, as before mentioned, it appears that the sewage was weaker than average English sewage. "*41 per cent. of the organic matter, as shown by the albuminoid ammonia, was in suspension, while in the year's sewage the* *proportion was 50 per cent.* Let us take 45 per cent. as the average. If we can remove 30 per cent. of the soluble organic matter and all of the suspended, we shall leave only 70 per cent. of the 55 per cent. soluble organic matter, or 38 per cent. of the whole." In other words, the effect of a good chemical process would be to remove 62 per cent. of the polluting matters; *whilst without chemical treatment, but with an efficient method of filtering out the suspended matter, a purification of 45 to 50 per cent. might be effected.*

We may next briefly examine the experiments by Mr. Dibdin on London sewage. Full details of these may be found in Mr. Dibdin's paper, read at the Institution of Civil Engineers in 1886. The author has constructed Table X. and the diagram subjoined from the figures given in the paper, but in calculating the cost of the different processes he has taken the current values of chemicals. There is one important fact to be remembered in drawing deductions from the figures and diagram, namely, that in many cases the manufacture of lime water may involve an expenditure of money for tanks and other works; the diagram, therefore, must not be regarded as conclusive as to the ultimate cost of any particular process.

In this country, in the lime treatment of sewage, a dose of 1 ton per million gallons is often regarded as a kind of standard. This means that something like 15s. 6d. per million is the unit of cost for chemicals alone when lime costs 15s. 6d. per ton. If we examine the diagram and table we shall see that treatments 4 and 13 are about equally effective in removing impurities, while as regards cost they would in practice probably be nearly equal. Not the least striking feature of the diagram is the failure of any treatment, that could be reasonably adopted, to remove more than 30 per cent. of the dissolved impurities, and the futility of employing large doses of chemicals.

TABLE X.—EXPERIMENTS ON FILTERED LONDON SEWAGE, SHOWING EFFECT OF DIFFERENT CHEMICALS ON THE OXIDISABLE ORGANIC MATTER IN SOLUTION. DIBDIN, 1886.

No.	Treatment in Grains per Gallon.		Cost of the Chemicals per Million Gallons of Sewage.	Percentage Reduction of Oxidisable Organic Matter in Solution.	Percentage Reduction per Shilling of Cost.
			Shillings.		
1	Lime in sol., . .	3·7	3·70	14	2·979
2	Do. do., . .	5·0	5·00	15	3·000
3	Do. do., . .	10·0	10·00	19	1·900
4	Do. do., . .	15·0	15·00	25	1·666
5	Do. as milk, .	15·0	15·00	13	0·866
6	Lime in sol., . . Iron sulp., . . .	3·7 0·3	4·18	11	2·631
7	Lime in sol., . . Iron sulp., . . .	3·7 1·0	5·30	13	2·453
8	Lime in sol., . . Iron sulp., . . .	3·7 2·5	7·45	18	2·416
9	Lime in sol., . . Iron sulp., . . .	3·7 5·0	11·20	21	1·874
10	Lime in sol., . . Iron sulp., . . .	5·0 2·0	8·00	18	2·250
11	Lime in sol., . . Iron sulp., . . .	5·0 4·0	11·00	19	1·727
12	Lime in sol., . . Iron sulp., . . .	5·0 5·0	12·50	18	1·440
13	Lime in sol., . . Iron sulp., . . .	5·0 8·0	17·00	25	1·470
14	Lime in sol., . . Iron sulp., . . .	5·0 10·0	20·00	25	1·250
15	Lime in sol., . . Iron sulp., . . .	10·0 10·0	25·00	30	1·200

TABLE X.—*Continued.*

No.	Treatment in Grains per Gallon.		Cost of the Chemicals per Million Gallons of Sewage.	Percentage Reduction of Oxidisable Organic Matter in Solution.	Percentage Reduction per Shilling of Cost.
			Shillings.		
16	Lime in sol., . . Alum sulp., . .	5·0 5·0	20·00	18	0·900
17	Lime in sol., . . Iron sulp., . . . Animal charcoal, .	5·0 5·0 5·0	22·75	22	0·967
18	Lime in sol., . . Iron sulp., . . . Alum sulp., . .	5·0 1·5 5·0	21·50	20	0·930
19	Lime in sol., . . Iron sulp., . . . Alum sulp., . .	7·0 1·0 5·0	24·25	22	0·907
20	Lime in sol., . . Iron sulp., . . . Alum sulp., . .	10·0 2·0 10·0	43·00	24	0·558
21	Lime in sol., . . Iron sulp., . . . Alum sulp., . .	14·0 3·0 10·0	48·50	21	0·433
22	Lime in sol., . . Iron sulp., . . . Alum sulp., . .	15·0 3·0 15·0	64·50	26	0·403
23	Lime, ... Iron sulp., . . . Alum sulp., . .	28·0 6·0 20·0	97·00	24	0·247
24	Lime, ... Iron sulp., . . . Alum sulp., . .	56·0 12·0 40·0	194·00	31	0·160
25	Lime, ... Iron sulp., . . . Alum sulp., . .	700·0 100·0 500·0	2350·00	52	0·022

Note.—In the second column lime in sol., means lime in solution; iron sulp., means sulphate of iron; alum sulp., means sulphate of alumina. In calculating the cost, the author has taken lime at 15·68 shillings per ton, sulphate of iron at 23·52 shillings per ton, and sulphate of alumina 47·04 shillings per ton. These prices are about correct at the present time, and in the form given are equal to 1s., 1s. 6d., and 3s. per unit respectively, the unit being one grain per gallon, or $\frac{1}{15 \cdot 68}$ ton per million.

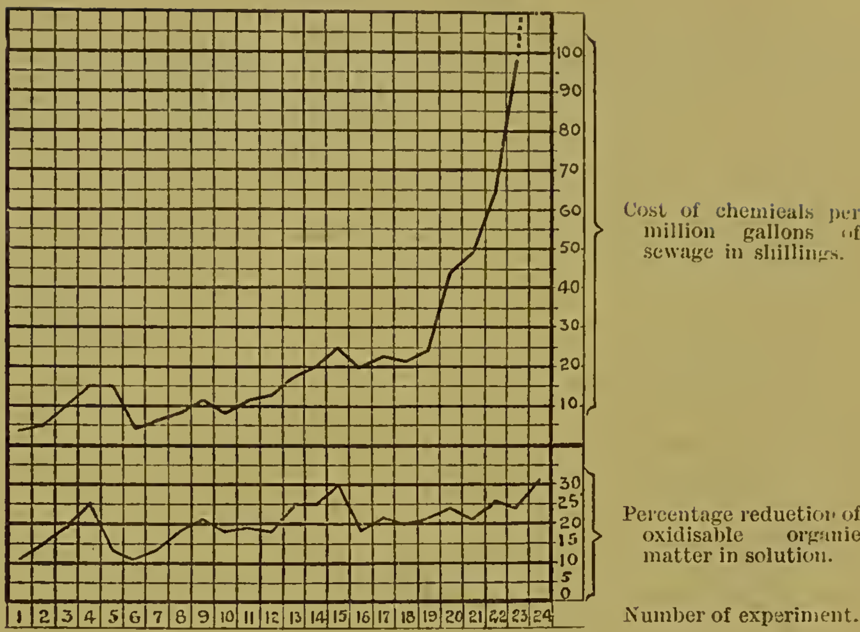


Fig. 7.—Dibdin's experiments on London sewage.

The diagram shows, in a graphic manner, the general results as above tabulated.

The subjoined Table (XI.) gives, in a condensed form, the results of experiments on London sewage made by the author, in conjunction with Mr. Midgley Taylor, F.C.S., and also those of Messrs. Worth and Reed on Tottenham sewage. It should be noted that Tottenham sewage is chiefly of a domestic character, and the amount per head is not more than two-thirds of the volume of London sewage. London sewage, on the other hand, contains vast quantities of manufacturing refuse of all kinds, and is not, therefore, so amenable to treatment as the Tottenham sewage. The results are of an interesting and, it is hoped, instructive nature.

Character of Effluent Water.—In concluding this brief review of the leading chemical processes, it is recognised that it might be thought wanting as regards analyses of effluents. The experiments of Dr. Tidy* on Aylesbury sewage, of Mr. Dibdin† on London sewage, and of other chemists, show that

* *Journal of the Society of Arts*, October 8, 1886.

† *Min. Proc. Inst. of Civ. Eng.*, vol. lxxxviii., 1887.

TABLE XI.—EXPERIMENTS ON LONDON SEWAGE, AND ON TOTTENHAM SEWAGE.

QUANTITIES ARE IN GRAINS PER GALLON.

LONDON SEWAGE, 1893.
SANTO CRIMP AND MIDGLEY TAYLOR, F.C.S.

Settled Sewage.	3·7 Lime.	Filtered, through paper.	5 Lime.	5 Lime. 2 Iron.	5 Lime. 4 Iron.	10 Lime.	10 Lime. 5 Iron.	10 Lime. 10 Iron.
Percentage Reduction of Oxidisable Organic Matters in the Crude Sewage.								
30·5	49·7	50·6	53·6	53·75	54·6	58·2	60	60
Efficiency of Treatment, assuming 60 per cent. to be the Maximum Reduction Attainable, at a reasonable cost.								
50·8	82·83	84·83	89·33	89·58	91	97	100	100
Cost of Chemicals per Million Gallons.								
	s. d.		*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
Nil.	3 8	...	5 0	8 0	11 0	10 0	17 6	25 0

Note.—The cost per million gallons has been calculated in accordance with the method employed in constructing Table x. (pp. 94-95).

In each case, the lime was employed in the form of lime water, and a period of two hours was allowed for precipitation.

TOTTENHAM SEWAGE, 1890.
J. E. WORTH AND LESTER REED, F.C.S.

8 Lime. 8 Black Ash.	11 Lime. 3 Iron.	5 Lime. 10 Iron.	10 Lime. 6 Alum. 1 Iron.	5 Lime. 10 Ferozone.	5 Lime. 10 Alum.	10 Lime. 7 Alum.
Percentage Reduction of Oxidisable Organic Matters in the Crude Sewage.						
57	60	61	68	73	75	78·4
Efficiency of Treatment, assuming 78·4 per cent. to be the Maximum Reduction Attainable, at a reasonable cost.						
72·7	76·5	77·8	86·7	93·1	95·6	100
Cost of entire treatment per head per year.						
s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
1 2·81	0 10·98	1 0·44	1 0·51	1 1·47	1 1·17	1 1·37

Note.—The cost is as given in Mr. Worth's Report, and includes the lime used in the filter presses. In order to compare with the table relating to London Sewage, the cost should be calculated upon the same basis. Lime cost 21s. per ton; black ash, 63s.; iron or copperas, 28s. 6d.; alum, 50s.

sewage is exeeedingly variable in quality, not only as regards its daily, but its hourly flow. In many works on sewage treatment, analyses, taken from reports of the various scientists who from time to time make a brief examination of the leading sewage disposal works, are quoted. But, as a rule, it is very doubtful if the effluent water sample bears any relation to its original condition as sewage, and the degree of purification effected in such cases is not indicated by the analyses, whieh may, indeed, be misleading. A visit to a sewage works, for instance, may be paid at about ten o'clock in the morning; at that hour the nearly pure subsoil water whieh has eollected in the works during the early morning hours is very frequently being displaced by the sewage proper. It is obvious that in such eases, analyses of samples of sewage and of effluent, which have been eollected practically simultaneously, do not afford any information whatever as to the general value of a proeess.

The object to be attained in the employment of any proeess is the prevention of river pollution. Whether the proeess is sueeessful or otherwise, an inspection of the river, into which the effluent has been discharged day by day during a considerable period of time, should elearly indicate, provided the examination be carefully made over a sufficient length of river, in dry hot weather, when the springs are low, and when secondary fermentation, if prevalent, is most active.

The Report of the Royal Commission on Metropolitan Sewage Discharge, 1884, contains the following most suggestive sentences:—

"In the first plaee, no one denies that by any chemical precipitation the *suspended* matters may be almost entirely removed, or in other words, the sewage may be praetically elarified. It is proved that with well devised, not too deep, and abundant tanks, so as to allow of complete subsidence (whieh may be well effected in a few hours), a clarified sewage may be produeed by preeipitation, which will contain less than two or three grains of suspended solid matters per gallon.

And as it is also admitted that the suspended matters are the worst causes of pollution and nuisance, it follows that the clarification must effect a great improvement.

"It seems also to be the general opinion that the chemical processes in their best form will also have *some* effect in removing noxious matters in solution. It is difficult to say how much effect will be so produced. The amount has been differently estimated by different persons, and probably it may vary at different times, with different kinds of sewage, and under different modes of treatment, but it cannot be very large. All agree that a considerable amount of polluting matter must be left in the effluent. . . .

"Precipitating processes, though the same in principle as those of 30 years ago, have been greatly improved in detail, and when well worked, are effectual where the quantity of sewage is not very great, where the sewage can be promptly treated, and where there is a running stream into which the effluent can be discharged, in a proportion not exceeding 5 per cent. of the supply of fresh water.

"But the *rationale* of these processes has apparently been but little recognised; and, indeed, it is only within the last few years that scientific knowledge has sufficiently advanced to enable us to understand the matter.

"There are two chief methods by which effete organic materials, such as excreta, are got rid of—namely, by fermentation and by oxidation. Nature, in this climate at all events, utilises both these processes, and in the above order. The organic molecules of effete matters are first split up by fermentation (and putrefaction is one kind of fermentation) into less complex substances, often of an offensive character, and these are subsequently oxidised into inodorous inorganic substances. The agents by which these fermentations are brought about are those microscopic organisms known as *bacteria*, which either themselves set up fermentation or excrete substances which act as ferments. Bacteria, or their spores, are present everywhere, and, gaining access to sewage, set up fermentation.

But they require time for their propagation and the setting up of their resultant fermentation."

"Now, the whole art of treating sewage chemically, as it is termed, is to precipitate and clarify it while fresh (see Dr. Tidy's evidence), *i.e.*, before bacterial invasion has so far advanced as to set up active fermentation. When this is once set up, the results are very 'disappointing' (see evidence of Dr. Tidy and Aldernan Avery). Precipitation consists in producing an artificial precipitate or coagulum in the fluid, and this coagulum mechanically entangles and carries down the organisms into the sludge. The effluent, now freed in great part from these, must then be brought as speedily as possible under an oxidising influence, either by turning it into a stream containing sufficient oxygen to oxidise the organic materials, or by applying it to land, where it is also brought under powerful oxidising influences.

"Should, however, the effluent be kept undiluted, or should it be turned into a stream in too large quantities for the free oxygen to deal with, the organisms or their spores, which have escaped in the effluent, multiply, and set up a renewed putrefaction. Such effluents, though apparently clear, become clouded, and a secondary deposit takes place in them. Bacterial fermentation of the cleanest of fluids is always attended by clouding and turbidity."

Fermentation.—The subject of fermentation is now receiving an increasing amount of attention at the hands of scientists, and it is difficult to forecast the results which may be attained in the future. Much has been done by Pasteur, by Tyndall, and by others, but the subject is even now in its infancy. It is difficult to appreciate the enormous influence of microbes, which are so infinitely small, but which are so prodigiously prolific, when brought into the presence of conditions suitable for their existence. As an example, Dr. Duclaux* relates that in examining beer-wort, "M. Pasteur once saw two globules increase to eight, including the parent

* *Fermentation*, by Dr. Duclaux. Clowes & Sons, 1884.

globules, in two hours. Thus in twenty-four hours, a single one could produce sixteen millions, were it not that, by their very multiplication, they end by impeding one another." Again, Cohn found that it would take two hours "for two living organisms proceeding from segmentation in certain bacteria to attain the dimensions of the parent, and, in their turn, to multiply. Hence in three days the progeny of a single specimen, if unhampered, would number 4,772 billions," the weight of which he estimated at 7,500 tons! (*loc. cit.*, p. 20). Duclaux points out that the action of yeast and other microbes in wort, is to break up organic matters and resolve them into such simple forms as water, carbonic acid, hydrogen, and ammonia; that this fact is not special to wort, but that "whenever and wherever there is a decomposition of organic matter, whether it be the case of an herb or an oak, of a worm or a whale, the work is exclusively done by infinitely small organisms. They are the important, almost the only, agents of universal hygiene; they clear away, more quickly than the dogs of Constantinople or the wild beasts of the desert, the remains of all that has had life."

Oxidation of Organic Matter.—We may now briefly examine the question as to the part played by oxygen. The Sixth Report of the Rivers' Pollution Commission contains analyses of various waters, from which the following table has been constructed:—

TABLE XII.—DISSOLVED OXYGEN IN WATER.

CUBIC INCHES IN 100 CUBIC INCHES.

Rain-Water.	Cumberland Lake.	Katrine.	Thames.	Deep Well.
·637	·725	·704	·588	·028

The average of the first four kinds gives, as nearly as possible, 12 cubic inches in each cubic foot, the Thames containing 10 cubic inches only. With regard to the effect of oxygen in oxidising organic matters present in polluted water, the question was investigated by the Rivers' Pollution Commission, 1868, the results of which investigation may be found in their First Report (Mersey and Ribble Basins), 1870.

After examining the rivers Irwell, Mersey, and Darwen, at different points on their courses, the Commissioners found "that when the temperature does not exceed 64° Fahr., a flow of between 11 and 23 miles produced but little effect upon the organic matter dissolved in the water." . . . "To test this point further, and in such a manner as to exclude the element of uncertainty introduced into the above experiments by the variability of the composition of the river waters at different times of the day, one volume of filtered London sewage was mixed with nine volumes of water. On analysis, the mixture was found to contain in 100,000 parts ·267 part of organic carbon and ·081 part of organic nitrogen. It was then well agitated and freely exposed to the air and light every day by being syphoned in a slender stream from one vessel to another, falling each time through 3 feet of air. After 96 hours it still contained in 100,000 parts ·250 part of organic carbon, and ·058 part of organic nitrogen; and after 192 hours the undecomposed organic matter still contained ·200 part of organic carbon and ·054 part of organic nitrogen. The temperature of the air during this experiment was about 68° Fahr." Futher experiments are described, and the following conclusion is arrived at:—"We are led in each case to the inevitable conclusion that the oxidation of the organic matter in sewage proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water, and that it is impossible to say how far such water must flow before the sewage matter becomes thoroughly oxidised" (*loc. cit.*, p. 21). The question may be asked "why aerate sewage, if the oxygen has so small an effect?" The answer must be, that certain forms of organic matter can be destroyed only by organisms living in the presence of oxygen. In order that these organisms may effect their purpose, oxygen must be provided for them, otherwise their powers will lie dormant, or they may even be supplanted by the germs of putrefaction, with a consequent production of offensive gases, such as sulphuretted and phosphoretted hydrogen, which impart to the mixture the well-known putrid smell.

A most interesting and valuable contribution on the subject appeared in *The British Medical Journal* of June 17, 1893. In a paper entitled "The probable destruction of bacteria in polluted river water by infusoria," Professor Harvey Attfield described experiments on the effect of mixing river Isar water, swarming with infusoria, with disused well water containing large numbers of bacteria, and also in mixing the latter with water containing few, if any, infusoria. It appeared "that in water swarming with infusoria the bacteria had decreased to less than one-fifth of their original number in six days, whereas in the water containing very few, if any, infusoria, the decrease of the bacteria in six days was only one-half their original number." The experiments were continued, and the following passages explain the further results obtained:—

"In this series of experiments very interesting ocular evidence of the purification that was going on was noticed—namely, the water in the A bottles (with infusoria) became quite bright and clear, while the water in the B bottles (without infusoria) became thicker and more turbid. Professor von Pettenkofer, to whom I showed these bottles, was particularly struck by this point. In this series, the presence of infusoria seemed to have a more marked influence than in the first experiments. For in ten days, a water containing 3,000,000 bacteria per cubic centimetre decreased in bacterial contents to a little over 13,000, while the water containing no infusoria not only gave no decrease in numbers, but rose in bacterial contents from 700 per c.c. to 121,500 in the same time."

The article concludes with this most significant passage—

"From these experiments it would seem that infusoria have some powerful influence in getting rid of bacteria, and possibly so aiding in the 'self-purification' of water."

The experiments on the cultivation of Aspergillus, a species of mildew, by M. Raulin,* show the absolute necessity of providing suitable food for these low types of plant life. An artificial medium was prepared, being composed of a variety of substances, among them zinc. The withdrawal of the zinc which formed but $\frac{1}{50,000}$ (*one fifty-thousandth*) part of the mixture, had the effect of reducing the crop to $\frac{1}{10}$ of what it was in the complete medium. By remaining in the mixture, the zinc increased the weight of the plant to 700 times that of itself. So sensitive is this plant to the action of reagents, that the addition to the cultivating medium of $\frac{1}{1,600,000}$ (*one sixteen hundred-thousandth*) part of nitrate of silver, caused the vegetation to stop suddenly.

In the chemical treatment of sewage, the chemist should, and probably will, be able to indicate what reagent is inimical to putrefactive germs, yet not destructive of those ferments which complete the destruction of dead organic matters by resolving them into innocuous gases and minerals. The subject is even now in its infancy, but it is not too much to hope that its solution is within measurable distance.

In the meantime, the choice of a chemical must be decided by the requirements of each case; but the chemical need not be an expensive one, it should not be used in large quantities, except in special cases, and solutions are preferable to solids, since the production of sludge—which is nearly always valueless and troublesome in disposal—should be kept as low as possible.

* *Fermentation*, Dr. Duclaux. Clowes & Sons, 1884.

CHAPTER VIII.

THE DISPOSAL OF SEWAGE-SLUDGE.

THIS subject was very fully discussed at the Institution of Civil Engineers upon the occasion of the reading of papers by Mr. J. W. Dibdin, F.C.S., and the author (see vol. lxxxviii.; Session 1886-7; part ii.)

The papers referred to will be freely quoted in this Chapter.

Settling Tank Sludge.—There are several methods in which sewage-sludge may be disposed of, but it should be made clear that the sludge under consideration is that collected in settling tanks; in those cases where the suspended matters are carried direct to the land—as, for instance, at Beddington and other broad-irrigation farms—the question must be regarded from an entirely different point of view. The sludge under consideration is a black mud composed of the organic and mineral matters precipitated from sewage by means of chemicals. It usually contains 90 per cent. of water, which rapidly becomes exceedingly offensive if not speedily separated and dealt with.

A cubic yard of sludge, according to experiments made by the author, weighs practically 16 cwts., so that to convert cubic yards into tons, deduct one-fifth, and, conversely, to convert tons into cubic yards, add one-fourth. A cubic yard of London sludge weighs about ·783 ton, but as this does not include a large amount of sand, which is often separately dealt with, the weight is practically the same as that of Wimbledon sludge. A cubic yard of broken cake, as taken from a filter-press, weighs 12 cwts. As percentages of moisture will frequently be referred to, the author has prepared a table showing the loss in weight at varying degrees of dryness; also a diagram which shows the same thing graphically. The following simple rule was used in compiling the table:—

Let W^1 = the original weight of the wet sludge.
„ W^2 = the weight of the sludge cake produced.
„ Q = the percentage of moisture after pressing.
„ P = the percentage of moisture in the wet sludge.

Then—

$$W^2 = \left(\frac{100-P}{100-Q}\right)W^1.$$

EXAMPLE.—What will 96 tons of wet sludge with 92 per cent. of moisture weigh when pressed to cake with 56 per cent. of moisture?

Here $100-P=8$; and $100-Q=44$, and $\frac{8}{44}\times W^1=\frac{8}{44}\times 96$ $=17{\cdot}452$ tons. Answer required.

Sludge is frequently referred to by some writers as containing 90 to 95 per cent. of moisture; but there is a most important difference in the bulk due to these percentages. 100 tons of normal sludge—*i.e.*, that containing 90 per cent. of water—will consist of 10 tons of solids and 90 tons of water, but the solids are sufficient in quantity to produce 200 tons of sludge containing 95 per cent. of water.

TABLE XIII.—PERCENTAGES OF MOISTURE REMAINING IN SEWAGE-SLUDGE AND OTHER MUDS, AFTER THE ELIMINATION OF VARYING QUANTITIES OF MOISTURE.

Loss of Moisture per cent.	Percentage of Moisture in Remainder.	Weight of Remainder.	Loss of Moisture per cent.	Percentage of Moisture in Remainder.	Weight of Remainder.	Loss of Moisture per cent.	Percentage of Moisture in Remainder.	Weight of Remainder.
0	90·000	100	31	85·507	69	62	73·684	38
1	89·898	99	32	85·294	68	63	72·972	37
2	89·796	98	33	85·074	67	64	72·222	36
3	89·690	97	34	84·848	66	65	71·428	35
4	89·583	96	35	84·615	65	66	70·588	34
5	89·473	95	36	84·375	64	67	69·696	33
6	89·361	94	37	84·127	63	68	68·750	32
7	89·246	93	38	83·871	62	69	67·742	31
8	89·129	92	39	83·606	61	70	66·666	30
9	89·011	91	40	83·333	60	71	65·517	29
10	88·888	90	41	83·051	59	72	64·285	28
11	88·765	89	42	82·758	58	73	62·962	27
12	88·636	88	43	82·456	57	74	61·538	26
13	88·505	87	44	82·143	56	75	60·000	25
14	88·372	86	45	81·818	55	76	58·333	24
15	88·235	85	46	81·481	54	77	56·521	23
16	88·095	84	47	81·132	53	78	54·545	22
17	87·952	83	48	80·769	52	79	52·381	21
18	87·804	82	49	80·392	51	80	50·000	20
19	87·655	81	50	80·000	50	81	47·368	19
20	87·500	80	51	79·591	49	82	44·444	18
21	87·342	79	52	79·166	48	83	41·176	17
22	87·179	78	53	78·723	47	84	37·500	16
23	87·013	77	54	78·261	46	85	33·333	15
24	86·842	76	55	77·777	45	86	28·571	14
25	86·666	75	56	77·272	44	87	23·077	13
26	86·486	74	57	76·744	43	88	16·666	12
27	86·301	73	58	76·190	42	89	9·090	11
28	86·125	72	59	75·610	41	90	0·000	10
29	85·915	71	60	75·000	40			
30	85·714	70	61	74·359	39			

The following Table is extracted from the paper by the author* already referred to :—

TABLE XIV.—SLUDGE WITH 90 PER CENT. OF MOISTURE PRODUCED DAILY PER 1,000 PERSONS, 1886.

Name of Town.	Population Draining to Works, 1886.	Ordinary Flow of Sewage in Gallons per diem.	Chemicals used in Grains per Gallon.		Sludge per 1,000 Persons Produced Daily.	
			Lime.	Sulphate of Alumina.	Cubic Yards.	Tons.
Birmingham, . . .	490,000	13,000,000	17·4	...	1·19	0·95
Bradford, ...	188,000	7,300,000	16·0	...	1·20	0·96
Burton-on-Trent, . .	34,500	4,500,000	13·2	...	1·16	0·93
Chiswick, ...	20,000	482,000	7·0	5	1·87	1·50
Edmonton, . . .	25,000	900,000	Hillé	...	0·55	0·44
Leeds, ...	320,000	10,000,000	15·68	...	0·39	0·32
Leicester, ...	132,000	{ 7,000,000 to 9,000,000 }	19·16	...	1·04	0·83
Wimbledon, . . .	24,500	700,000	10·0	6	1·79	1·43

The quantities at Leeds and Edmonton appear to be abnormally low, but towns of the same character, such as the first three of the table and Leicester, agree fairly well, whilst Wimbledon and Chiswick, both which are residential suburbs, are in close accordance.

The Table on p. 109 gives some further details, and as presses are used in each of the towns tabulated, the returns are likely to be quite accurate.

The quantity yielded per million gallons at Wimbledon is the average during 1889-90, and is less than in the table accompanying the paper by the author, smaller quantities of lime having been used both in precipitation and in pressing than at the date referred to in the paper.

* "Filter Presses for the Treatment of Sewage-Sludge." *Min. Proc. Inst. C.E.*, vol. lxxxviii., 1887.

The effect of adding large quantities of lime to the sewage for precipitation purposes, is to increase enormously the production of sludge, and a dose of 1½ to 2 tons of lime per million gallons has been found at Wimbledon to result in an addition of about 60 per cent. to the quantity given in the table.

TABLE XV.—DETAILS OF SLUDGE-PRESSING, 1889.

Town.	Population.	Process.	Sludge-cake per Million Gallons.	Per Head per Annum.	Cost of Pressing Exclusive of Charge on Capital Account.		Authority.	Remarks.
			Tons.	Cwt.	s.	d.		
Brentford, .	12,000	Lime and alum,	8·16	1·730	2	1½	Lacey.	Sold £10 per annum.
Chiswick, .	20,000	,, ,,	7·788	2·184	5	0	Hetherington.	Taken by farmers.
Coventry, .	45,000	... ...	8·0	2·77	2	5	Coddington.	Sold at 1s. per ton.
Crossness, .	...	Lime and iron,	7·3	...	...		...	...
Croydon Rural Sanitary Authority,	22,000	... ...	3·5	1·650	3	0½	Chart.	Last six months' produce sold, £25; sewage not chemically treated.
Leyton, . .	43,000	Lime & black ash, . . .	10·99	2·410	1	8	Dawson.	Pay farmers to take it.
Wimbledon,	24,500	Lime and alum,	8·25	2·44	2	5	Crimp.	Part sold, part used on Board's land.

The figures relating to Crossness are taken from the Report, Metropolitan Board of Works, 1887, in which it is stated that 3·7 grains of lime in solution and 1·0 grain of sulphate of iron were used per gallon for nine million gallons of sewage daily. The sludge-cake produced per million gallons is about nine-tenths of the average of Brentford, Chiswick, Coventry, and Wimbledon. The quantity at Leyton is high, probably because of large quantities of insoluble black-ash waste that are used in treating the sewage. As sludge-cake generally contains a little more than 50 per cent. of moisture, it will be a very close approximation to the facts of the case to say that with the lime and alum or iron process, the pressed sludge will amount to 8 tons per million gallons, equal to 40 tons of sludge as swept from the settling tanks.

As one-half of the pressed cake consists of water, the dry solids are equal to 4 tons per million gallons, or 63 grains per gallon very nearly.

Where sewage is diluted by leakage of subsoil-water into the sewers, or, on the other hand is of a concentrated nature, the yield of solids per million gallons will necessarily be modified, and the above-mentioned data will not be applicable.

Modes of Disposal.—The first step towards the disposal of sewage-sludge is the separation from the solids of as much water as possible in the shortest time practicable, in order, first, that the bulk may be reduced, and, secondly, that time should not be given for the production of the foul gases of putrefaction.

As Manure.—The manurial value of sludge is now admitted to be low, and, except in a few isolated instances, sludge is recognised as a material to be got rid of in the cheapest manner.

There can be no question that sludge does possess some manurial value, and the experiments by Dr. Munro, by Col. Jones, and by the author, show that it is of about the same value as farm-yard manure, weight for weight. Indeed, Dr. Munro is inclined to think that when properly dried and pulverised, a manure may be produced from sewage-sludge worth considerably more per ton than farm-yard manure.

At many sewage disposal works, the preliminary step of separation of the liquid from sludge is partially accomplished by depositing the material upon filter beds, composed of town ashes as collected from dust-bins. This method was at one time in operation at Wimbledon, but houses existed within a distance of 150 yards from the sludge-pits, and a main road to London was even nearer. With a rapidly increasing population, and a corresponding augmentation of the volume of sewage and sludge, it became imperative to take steps to remedy what would soon become a formidable nuisance. The sludge was swept from the settling tanks into larger filters, composed of sifted ashes, well under-drained; ashes collected from the ash-bins were also mixed with the sludge, and when the compost was sufficiently solidified, it was carted on to the land and ploughed in. Careful observation of the drains, however, proved that small quantities only of highly polluted moisture passed through the filters, and that, it is needless to point out, was of a most foul description, by far the greater portion of the water passing away by evaporation; consequently, during wet periods, when the atmosphere was fully charged with moisture, the drying process was much retarded. For instance, after exposure of the sludge in these filters, from September, 1883, to March, 1884, a period of upwards of six months, the sludge still contained about 77·5 per cent. of moisture, being in a sloppy and very offensive state. The rainfall during that period was 12 inches. Exposure of sludge, deposited in the filters from April, 1884, to September, 1884, or for five months, resulted in the material drying down to 71·27 per cent., the rainfall having been 7·71 inches.

The cost of carting this sludge an average distance of 450 yards was 2s. 1½d. per ton; this sum included labour, horse-hire, wear-and-tear of plant and of roads; the cost may appear to be high, but it must be remembered that, in its sloppy state, ½ ton only can be conveyed in ordinary carts, and there was a considerable amount of wear-and-tear on the roads. The cost of spreading as a top-dressing was 1½d. per ton.

The system can only be described as an exceedingly offensive one, and only applicable in those cases where the works are remote from dwellings, and from highways.

As Clinkers.—At Ealing the method of disposal is the same as that formerly in operation at Wimbledon up to the point where the removal from the filter-beds takes place, when instead of being carted to the land, the mixture is burnt in one of Fryer's "Destructors." It was stated by Mr. C. Jones,* in the discussion upon the papers by Mr. Dibdin and the author, that he found no difficulty in getting rid of the mixture of refuse and sludge by means of the "destructor," the mass being reduced to clinker one-fourth the bulk of the original. A special "muffled furnace" was found to be necessary in order to destroy the gases generated on their passage from the furnaces to their chimney shaft. The process of drying in the open filter-beds is, however, an exceedingly offensive one, particularly in hot weather.

At Salford, sludge has also been destroyed in furnaces, and further reference will be made to the process in Chapter x., descriptive of the Salford works. It may be mentioned here, however, that the process was not continued for a lengthy period of time, in consequence of the nuisance produced. At Huddersfield arrangements have been made to burn the pressed sludge-cake in destructors, which have been erected at the new sewage works for the double purpose of burning ashpit refuse and pressed sewage-sludge.

As Cement.—Scott's process is also one of calcination, the manufacture of Portland cement being one of the objects sought to be obtained. It is unlikely that the process will be widely adopted in this country, where raw materials suitable for the manufacture of cement exist in such abundance. The process involves the use of very large quantities of lime in treating the sewage, and was, for some time, in operation at Burnley.

By Digging into Land.—The system of digging the sludge into land, as practised at Birmingham, will be discussed in the chapter descriptive of those works.

By Steamship Carriage to Sea.—This method of getting

* *Min. Proc. Inst. C.E.*, vol. lxxxviii., 1887.

rid of sludge has been in operation at Barking and at Crossness for four years, and will be further referred to in the chapter on London.

The author was recently consulted upon the subject by the Salford Corporation, and after considering every possible method of disposing of this most troublesome material, he recommended the adoption of sludge steamers, and the removal of the sludge to the open sea, outside the mouth of the Mersey. The recommendations have been adopted, and Salford sludge, amounting to about 240 tons per day, will soon be disposed of in this manner.

As regards the London sludge, the method now in operation was warmly criticised at the Institution of Civil Engineers in 1887, on the occasion of the reading of Mr. Dibdin's paper on sludge disposal, but the method is one of those recommended by the Royal Commissioners on Metropolitan Sewage Discharge, and experience has abundantly demonstrated the advantages of the system, from both the sanitary and financial points of view.

The following extract from Mr. Dibdin's paper* explains the proposed mode of disposal:—

"The great advantage of this method is that the sludge will never be seen. Precipitated in covered reservoirs, transferred from the precipitating tanks to special settling tanks, from thence pumped into the sludge vessel, and discharged under water far from land, the sludge will disappear in the most speedy, cleanly, and safe manner that can be devised.

"The objections to this system are threefold:—

"(1) Waste of valuable manure.

"(2) Possibility of nuisance on the coast.

"(3) Delay in transit by fogs and stress of weather.

"The first objection is speedily met by the reply, that if the commercial manurial value of the sludge is a fact, commercial men may be safely relied upon to utilise it. They can have the sludge for nothing in any quantity. Let them take it,

* *Min. Proc. Inst. C.E.*, vol. lxxxviii., 1887.

and deal with it as they will. This consideration applies to all propositions for the profitable utilisation of the filthy matter, whatever they may be.

"The second objection as to the possibility of nuisance on the coast is a mistaken one. Examine the point closely. Some 3,000 tons of 'settled' sludge, equal to about 150 tons of organic matter, will be discharged per diem under water several miles from the coast. This will not be discharged at one spot, but be spread over some 30 miles. Assuming that the discharge from one vessel holding 1,000 tons, equal to 50 tons of organic matter, formed a track when diffused in the water 4 yards deep by 4 yards wide, and 10 miles in length, what would be the quantity of organic matter in that polluted line of water? Only 16 grains in each gallon. Given a gallon of water, containing 16 grains of organic matter, situated say 10 miles from the shore, and in a strong tidal way, how much offence will be given after diffusion, oxidation, the feeding of fish, &c., have acted their part, by the time it has reached the coast, if ever it does reach it? Considering that in a comparatively trifling quantity of water, as in the river, it has rarely been traced more than a few miles from the outfalls, even when mixed with all the multitudinous sources of pollution other than sewage, is it likely that the infinitesimal particles will ever be seen again when once they are fairly deposited in the great bulk of the Channel water? Furthermore, the strongest antagonist to the system cannot but admit that it is absolutely, and in every detail, fully in accordance with both the letter and the spirit of the recommendations of the Royal Commission.

"The third objection, delay by fogs and stress of weather, is a trivial one. An increase in the capacity of the sludge settling tanks, with reserve steam-power, which must be provided in any case to guard against breakdowns, will effectually overcome this difficulty. If the whole of the enormous naval traffic of England can be carried on, as it is with almost mathematical precision, surely the carriage of a few thousand tons of sewage-sludge to the Channel can be as readily accomplished.

"While it is thus clear that in the case of the Metropolis the conveyance of the sludge to sea is the only available remedy, it by no means follows that under other circumstances, and where local conditions are favourable, other systems are undesirable. Each case must be dealt with on its own merits, and according to local requirements."

A further reference to the method adopted for the disposal of London sludge will be found in the chapter on London, but it may be remarked here that the daily output of sludge now amounts to about 5,500 tons, about 91 per cent. of which is liquid.

Filter Pressing.—Of all methods of treating of sewage-sludge yet introduced, that by the filter-press has, in the majority of cases, most to recommend itself. On being removed from the settling tanks, the sludge may at once be dealt with, storage for one or two days' supply of wet sludge only being necessary. By the operation of the filter-press, 10 tons of sludge are at once reduced to 2 tons of cake, 8 tons of clear but exceedingly strong sewage being separated.

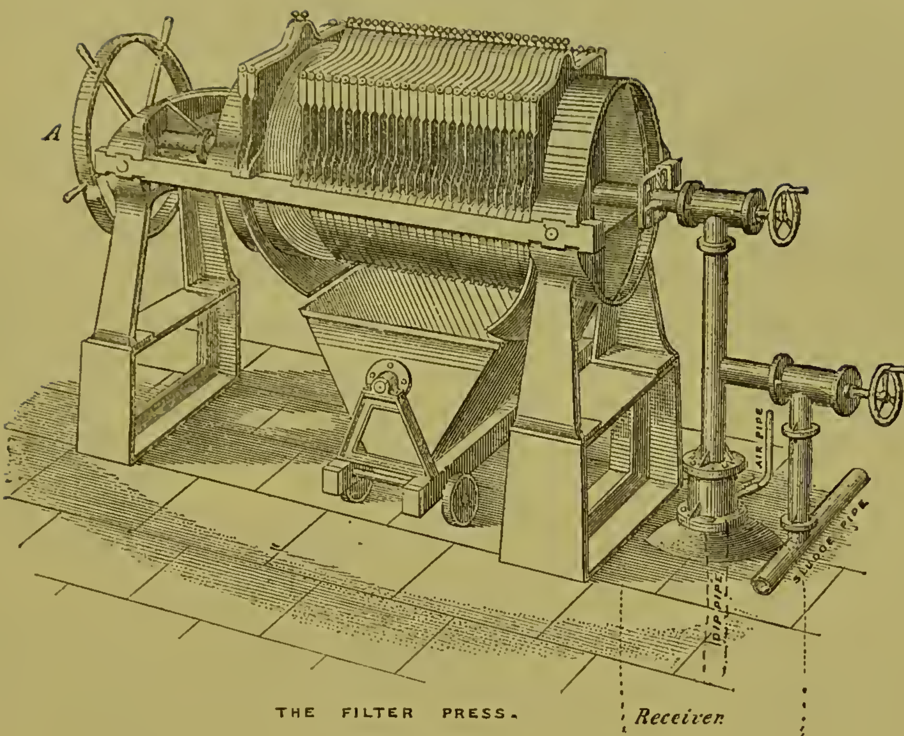
The Filter-press is usually constructed of cast-iron plates, having recesses and drainage surfaces on each face, the projecting rim, forming with its counterpart, when these are placed in a suitable frame, a space or cell. The surface of each plate is covered with a filtering medium of jute- or hemp-canvas, or other like material, and, on filling the cell with the sludge to be treated, and applying pressure, either by pumping more of the material to be filtered into the chamber direct, or by interposing an accumulator between the pump and the press, to accomplish the same purpose with a more uniform pressure, the liquid is forced through the filtering medium, and, passing along the drainage channels, escapes at the bottom of each plate, the solids being retained in the cells. When the liquid ceases to flow from the press, it is opened, and hard cakes are discovered, consisting of the solids separate from the original material treated, together with a varying percentage of moisture.

In the description of the Wimbledon Sewage Disposal Works, some details of the filter-presses employed will be given. The subjoined illustrations show the plate in general use, as patented by S. H. Johnston. In the presses of recent design, however, the plates are square and not round, in order to economise the filter cloth. Fig. 8 is an illustration of the filter-press in perspective, the plates being clearly shown resting upon the side bars. In the filter-press by Manlove, Alliott & Co., the large wheel A is superseded by a small cylinder, the piston in which is worked by compressed air, thus economising time in opening and closing the machine. It may, however, be remarked that all the makers of filter-presses have introduced improvements of some kind in the minor details of them.

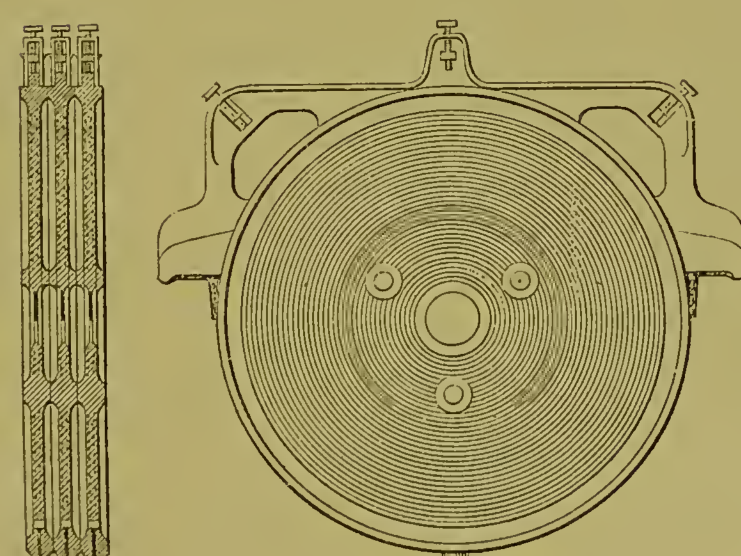
The method usually adopted for forcing sludge into the filter-press is that of compressed air in conjunction with a strong cast-iron receiver. On filling the receiver with sludge, a small quantity of lime is added, varying from 3½ to 5 per cent. of the volume of sludge; and on this being thoroughly mixed with the sludge, compressed air, at a pressure of about 60 lbs. per square inch, is admitted, the mixture being forced up the dip-pipe and into the press. As the water is separated, the solids accumulate in each cell until stiff cakes of sludge are produced. With perfectly fresh, ground, grey chalk lime, the entire operation of filling a press, removing the sludge-cake, and getting ready for a second operation, should not exceed forty-five minutes.

Some makers of presses employ direct-acting pumps instead of compressed air, for the purpose of forcing the sludge into the filter-press, but beyond a small saving in fuel, no advantage is gained by the substitution.

So far, the employment of heat in the evaporation of the water, so largely entering into the composition of sludge, has not been successful. Pressed sludge is in some processes—the



THE FILTER PRESS.
PERSPECTIVE VIEW.
Fig. 8.



SECTION. ELEVATION.
DETAILS OF PLATES
Fig. 9.

A. B. C. for instance—dried in special machines, and then pulverised, but before heat is applied the filter-press should unquestionably be employed.

The cost of producing sludge-cake varies at different works, but it is unlikely that the total working expenses will ever fall much short of 2s. per ton; at the majority of works the cost is about 2s. 6d.; but the treatment of the sewage affects the cost very materially, some precipitants produce a sludge which cannot be pressed in a reasonable time, without the addition of as much as 2 cwts. of lime per ton of cake; on the other hand, a very heavy lime treatment of the sewage—say about 2 tons per million gallons—results in a sludge being produced, which will readily press without the addition of further lime, when pressing may be performed at perhaps 1s. 3d. per ton, but in this case the sludge yielded per million gallons will be so enormously increased, that, as the cake rarely has any marketable value, its pressing and disposal will entail expenses, which would equal the cost of the lighter treatment, when the cost of pressing amounts to 2s. 6d. per ton. Normal lime and iron, or lime and sulphate of alumina, treatment at Wimbledon, for instance, yields about 8 tons of cake per million gallons, costing for pressing at 2s. 6d. per ton, 20s. per million. Heavy lime treatment produces 12·8 tons per million, costing about 1s. 8d. per ton for pressing, or 20s. per million, but there are 4 tons of cake in addition to be disposed of, and as there is practically no demand for it, the lighter treatment is the more economical, although the sludge costs 50 per cent. more to press.

It should be mentioned that the filter-press reduces 5 tons of normal (90 per cent.) sludge to 1 ton of cake, the cost per ton of wet sludge, therefore, is not high.

The subjoined analyses show the principal constituents of sewage-sludge:—

RETURN by the Leicester Corporation showing Salaries and Emoluments of Sewage Farm Managers, Size of Farms, Subsoil, &c.

Town or District.	Population.	Is the management of your Sewage Farm in the hands of a General Manager or Superintendent?	Is he paid by Salary, and, if so, how much; and has he any other emoluments?	Is he provided with a residence free of cost?	Please to give the acreage of Farm, and state whether the Sewage is applied to the whole of it?	What kind of subsoil does the Farm consist of down to a depth say of 6 ft. from the surface?	Can you give the quantity of sewage you have to deal with per day of 24 hours?	Is any part of the Farm specially prepared for intermittent filtration?	Can you give the number of men required to work the Farm?	Do you apply the raw sewage to the land, or is any part treated chemically beforehand?	Persons per acre of land, to which sewage is applied
ALDERSHOT, . . (W. L. Coulson, *Surveyor.*)	12,000 (10,000 drained).	No.	.. .. ..	No.	8 acres.	Loamy sand.	389,000 gallons.	No.	4 men.	Sewage treated with sulphate of alumina and lime previously.	1,250
BEDFORD, . . (John Lund, *Borough Surveyor.*)	25,400	It is in the hands of a Manager.	Paid by salary and commission of 1 per cent. on sale of produce.	Yes.	Total acreage 223 acres. Sewage applied to 130 acres.	Subsoil is from 2 to 3 ft. loam and gravel under.	1,000,000 gallons per day.	No.	17 men and 5 boys.	Sewage is applied in its raw state.	194
BIRMINGHAM, TAME & REA, . . (Wm. Till, *Borough Surveyor.*)	620,000	Yes.	Yes, £350, with use of horse and trap. No other emoluments.	Yes.	1,220 acres. Yes.	Chiefly gravel and sand.	About 16,000,000 gallons dry-weather flow.	No.	About 200.	Treated with lime.	508
BLACKBURN, . . (W. R. M'Callum, Junr., *Borough and Water Engineer.*)	116,000	General Manager over all.	Yes, £2, 15s. per week. No.	Yes, with coal, &c.	179 acres leased by Corporation; 100 acres too high for irrigation by gravitation, remainder hilly. Corporation purchased about 500 acres in Samlesbury, a few miles distant, for irrigation purposes. These farms are let in allotments of 40 to 50 acres.	The farm gravel and sand to a depth of 3 ft. 6 in. The land at Samlesbury is a clay subsoil about 4 ft. in depth.	3,500,000 gallons.	No.	Manager and 6 workmen (excluding farm let).	No; by lime process.	..
BURTON-ON-TRENT, (E. Clavey, *Borough Surveyor.*)	46,500	General Manager.	£150 per annum; no emoluments.	Yes.	566 acres. Sewage applied to 430 acres.	Gravel.	5,000,000 gallons.	Yes; 130 acres.	Average 65 to 70.	Raw sewage applied to land.	108
CREWE, . . . (Geo. E. Shore, *Borough Surveyor.*)	31,000	Yes.	By salary £160 per annum. He has no other emoluments.	Yes.	208½ acres. Sewage is applied to about 255 acres.	Strong clay.	About 1,000,000 gallons.	No; but the whole is under-drained 6 ft. and 4 ft. deep.	From 29 in winter to 34 in harvest time.	Yes; no part is chemically treated beforehand.	121
CROYDON, . . (Thos. Walker, *Borough Surveyor.*)	96,000 (Only 90,000 drain to the two irrigation farms).	Yes, in both cases.	Beddington Manager has a salary of £220, house and gas provided. Norwood manager has a salary of £156. There are no emoluments attached to either position.	.. .. ..	Beddington, total area 525 acres, 420 acres irrigated. South Norwood, total area 105 acres, all irrigated.	Beddington, subsoil, gravel and sand. South Norwood, clay (brick earth class).	Beddington averages 4,500,000 gallons; South Norwood averages 700,000 gallons.	No. ..	Beddington averages 30 men; South Norwood averages 10 men.	The sewage passes through screens to remove the solids; there is no chemical treatment whatever.	B 174 N 162
DONCASTER, . . (W. H. R. Crabtree, *Borough Surveyor.*)	23,625	The Farm is let to a Farmer.	He rents the Farm at about £2 per acre. Prior to application of sewage, rent was only 25s. per acre: for a few years after it was £3 per acre.	Farm buildings and cottages are included in the rent.	278a. 0r. 3p. Yes.	A large proportion is light gravelly subsoil.	From 500,000 to 600,000 gallons per day.	A small proportion; but it is practically all broad irrigation.	Two men distribute the sewage.	Raw. We do not treat it chemically; it is unnecessary in our case.	85
EDINBURGH, . (John Cooper, *Burgh Engineer.*)	270,000	Edinburgh has 4 Sewage Farms, all in the hands of private persons, each employing a Manager for the Sewage and an attached Arable Farm combined.	The Sewage and Arable Farms being combined under one management, the expense or share of salary chargeable to the Sewage Farm is not known.	In every case.	1 Craigentinny, 200 acs. 2 Lochend, 42 ,, 3 Craigmillar, 48 ,, 4 Roseburn, 43 ,, Total, 333 ,,	1 and 2, Craigentinny and Lochend, vary from a boulder clay to a red loam and drift sand; 3, Craigmillar, a gravelly clay; 4 Roseburn clay.	1 and 2, Craigentinny and Lochend, gallons per 24 hours, 7,000,000 3 Craigmillar, 1,000,000 4 Roseburn, 3,000,000 Total gallons, 11,000,000	No.	The aggregate number of men additional to Managers and permanently employed on these 4 farms may be stated at 6.	In every case the sewage is applied to the land in its crude state, without any preparation.	*
KIDDERMINSTER, (Arthur Comber, *Borough Surveyor.*)	30,000	Farm Manager under the Sewage Farm Committee.	£150 per annum. No emoluments.	Yes.	172 acres, 20 not available for sewage, level too high. 40 acres additional land taken on lease for 21 years.	Loamy sand of open and gravelly nature for about 6 ft. to 8 ft., below that gravel, then soft red sandstone.	From 1,500,000 to 1,700,000 gallons per 24 hours.	No part specially prepared for intermittent filtration; the whole of the farm is under-drained with 9 in. and 6 in. pipes, varying in depth from 7 to 13 ft.	Average 15; more at hay harvest. We make our rye-grass into hay.	Sewage is pumped direct from town to farm; no chemical treatment.	156
ORTHAMPTON, . (W. Ibbs Brown, *Borough Surveyor.*)	60,000	General Manager.	Salary £250; house and garden, horse and trap provided by corporation.	Yes.	327 acres, about 20 acres at too high a level for irrigation, and 20 acres used in Farm Yards and Roads.	Loamy gravel.	About 725,000 gallons.	No.	Average 60.	None chemically treated.	209
ORWICH, . . (P. P. Marshall, *City Engineer.*)	95,000	Farm let to E. Taylor, Esq., of Trouse. (We lose £1 per acre).	We do not work the farm ourselves. It is let out as above and worked principally as a Dairy Farm.	No.	500 acres. Yes.	Loamy, overlying marl, sand, chalk gravel.	We pump in 24 hours about 4,000,000 gallons.	No, not required. The plant does the work of purification:	No.	No chemical treatment, not at all required.	190
OTTINGHAM, . (Arthur Brown, *Borough Engineer.*)	240,000	In the hands of a Farm Bailiff.	By salary £300 per annum..	Yes.	650 acres. Yes.	Light soil, sandy substratum, reaching to fine gravel at the depth named (6 feet).	From 8,000,000 to 10,000,000 gallons.	Yes; about 130 acres.	About £30 per week, but it must be borne in mind that our farm is worked as a Dairy Farm, which makes the weekly wages apparently high.	Yes, no part is chemically treated.	370
XFORD, . . . (W. H. White, *Borough Engineer.*)	50,000	Resident Bailiff, who superintends all the farming operations. He reports weekly to the Farm Committee, but the Committee does not interfere to any great extent with the management.	He has a salary of 35s. per week = £91 per annum, with extra pay at harvest time. Taking one thing with another, his place is worth about £110, and in addition he has the farmhouse and garden.	.. .. ..	Total acreage, about 370 acres. Sewage is applied to 335 acres. This area must shortly be considerably increased or some other step taken. The farm is much over-sewaged.	About two-thirds of the land has a sandy subsoil, the remaining third being marly, a portion of it being stiff clay and practically useless.	Dry-weather flow is 1,300,000 gallons per diem. The average quantity pumped (including dry and wet days) is something over 1,500,000 gallons per diem.	Yes; about 32 acres.	About 30 men, women, and boys in summer, and about 20 men and boys in winter.	The raw sewage is applied to the land.	149
UGBY, . . . (Wm. Stewart, *Surveyor.*)	11,000	We let one Farm at £4, 10s. per acre; the other small Farm we have in our own hands, 13 acres.	.. .. ..	.. .. ..	70 acres. Sewage applied to the whole if we require it.	Loamy soil to about 4 ft. then gravel and limestone.	250,000 gallons.	No.	We have one man, who lives on the farm for the purpose of distributing the sewage and keeping trenches, settling beds, &c., in order.	The raw sewage is applied.	157
NBRIDGE WELLS, (. Brentnall, *Surveyor.*)	27,000	Farm Bailiffs, one to each of our two Farms.	(1) £120 (2) £120 } With house and garden and the produce of a cow.	Yes.	(1) 120 acres, (2) 165 acres, excepting 20 acres which is too high for sewage to reach by gravitation.	(1) Clay, N. Farm. (2) Gravel, S. Farm.	750,000 gallons average.	No.	(1) 8 men and boys. (2) 13 ,, ,,	The raw sewage is applied after passing through settling tanks. None is treated chemically.	..
ARWICK, . . (. Melville Richards, *Borough Engineer.*)	12,000	The Sewage Farm is managed by a Superintendent under the direction of a Committee.	He is paid £120 per annum and has no other emoluments.	Yes.	134 acres, all under irrigation.	Clay.	500,000 gallons.	No; but it is all drained from 4 ft. to 5 ft. deep.	12 at 2s. 4d. per day.	The crude sewage is pumped upon the land; chemical treatment is not resorted to.	90
EST DERBY, . (Fredk. C. Everett, *Surveyor.*)	36,400	Management in hands of a Farm Bailiff.	£150 per annum salary, with certain privileges such as keeping cows, pigs, &c. No other emoluments.	The Bailiff has a residence on the farm, free of cost.	The acreage of the farm is 207 acres, and sewage is applied to practically the whole of it.	The subsoil is a sandy clay.	Estimated at 600,000 gallons, dry-weather flow.	No.	The average number of men employed is 20.	The raw sewage is applied, no chemical treatment.	176
MBLEDON, . (. Santo Crimp, *Surveyor.*)	25,000	Yes.	He is as well Road Foreman, being provided with a horse and trap. He has a waterman at the farm to superintend in his absence.	He lives in a house on the farm.	73 acres all irrigated.	Clay, except 16 acres, which is of gravel, &c.	750,000 gallons in dry weather.	No.	The men vary with the seasons.	About one-sixth is applied raw after being filtered roughly. The remainder is chemically treated first.	342
OLVERHAMPTON, (. E. N. Berrington, *Borough Surveyor.*)	80,000	A Superintendent.	£120 a year, and is allowed to keep a cow for his own use. The late Superintendent received £150.	Yes, an excellent house, and in it is a large Committee room.	330 acres. Can't get the sewage on to all the land, but we hope to do so soon.	Every conceivable subsoil, stiff clay, gravel, sand and peat.	Dry weather flow, 2,000,000 gallons.	Yes; but it is a complete failure. The brook into which our effluent goes is very small: in fact a small trout stream (it was!). Then we have a large quantity of salts of iron, acid, &c.	6 men and 4 boys.	We have applied the raw sewage direct for years, and have got into trouble. We are going to precipitate and irrigate with effluent.	..
EXHAM, . . (W. M. Smith, *Surveyor.*)	12,000	Leased to Col. Jones, who is paid salary of £150 per annum.	.. .. ..	No.	84 acres, of which about half is arable, and this receives most of the sewage.	Drift gravel with small beds of clay here and there.	About 400,000 gallons in dry weather.	About 2 acres under-drained.	This varies. Moreover Col. Jones sub-lets the dairy part.	Applied to the land direct after the sludge is allowed to settle in tanks.	143

* The Burgh Surveyor writes in connection with these answers as follows:—I enclose your list of queries with such replies as I can give. I wish to explain to you the position of matters in this respect in Edinburgh, as our experience is not at all on your lines. The great volume of Edinburgh Sewage is discharged into the Sea (Firth of Forth) direct. On each of the three Sewer Outlets there is a Sewage Farm, or as we call them—Irrigated Meadows. These Meadows are owned by private individuals, who have always claimed a right to the use of the water in the burns passing through their respective lands; which burns have gradually been converted into open Sewers.

They have thus fallen heirs to an almost unlimited amount of Sewage; they have no interest in purifying this Sewage in your sense of the word; they use it without stint, and allow the effluent to leave their lands without any regard to its quality or condition. They pay nothing for it, and the crops, chiefly Italian Rye Grass, yield good returns.

The Corporation has not interfered hitherto with the use or misuse of the Sewage. It is regrettable that Craigentinny Farm is not the property of the Corporation, as it is remarkably well suited for a Sewage Farm, and adjoins the Sea, a large part of it consisting of ground reclaimed from the Beach, and mostly drift sand. You will thus understand that my answers to your queries are not of any value for the purposes of comparison, as our position is an exceptional one on the matter in question.

Leicester, *19th January, 1889.*

J. GORDON, C.E.

TABLE XVI.—COMPOSITION OF AIR-DRIED SEWAGE-SLUDGE, BY DR. WALLACE.*

Name of Town.	Aylesbury	Birmingham.		Bolton.	Bradford.		Coventry.		Leeds.		Leicester.	Windsor.
Process of Precipitation.	A. B. C.	Lime.		Lime and Charcoal.	Lime.		Sulphate of Alumina.		Modified A. B. C.	Hanson's Process.	Lime.	Hillé.
		1.	2.		1.	2.	1.	2.				
Date.	1879.	1879.	1879.	1879.	1876.	1879.	1877.	1879.	1876.	1876.	1879.	1877.
Water,	12·60	12·70	13·16	14·34	8·90	6·92	14·04	10·04	9·56	16·40	11·93	11·76
Organic matter, carbon, &c.,	35·60	19·19	20·04	26·18	33·75	34·53	20·58	23·09	20·82	27·92	22·18	12·06
Phosphoric acid,	2·11	0·40	0·72	0·62	0·80	0·73	1·56	2·07	0·64	0·75	1·21	0·87
Sulphuric acid,	2·70	1·45	0·35	0·61	0·64	1·74	1·32	0·56	2·15	1·02	0·51	0·49
Carbonic acid,	...	7·62	8·53	8·30	10·53	13·77	6·64	5·71	8·42	13·11	15·25	22·71
Lime,	2·13	11·19	12·74	14·50	16·90	20·27	9·16	6·65	9·68	17·51	20·16	31·09
Magnesia,	0·18	0·90	1·37	1·06	1·66	5·07	0·86	0·61	5·64	7·67	1·48	1·58
Oxide of iron,	6·20	2·70	3·20	1·98	2·11	2·01	4·14	2·66	4·61	2·32	2·66	1·68
Alumina,	6·75	2·68	2·58	2·97	3·49	3·89	4·13	5·80	7·04	6·30	1·63	2·31
Sand, &c.,	33·50	41·13	37·93	29·50	21·80	10·23	37·83	42·00	31·60	7·36	22·30	14·16
	101·77	99·96	100·62	100·06	100·58	99·16	100·26	99·19	100·16	100·36	99·31	98·71
Phosphate of lime,	4·61	0·87	1·57	1·35	1·74	1·59	3·40	4·52	1·29	1·64	2·64	1·90
Nitrogen,	1·60	0·52	0·49	0·61	0·62	0·66	0·92	1·27	0·66	0·70	1·08	0·52
Equal to ammonia,	1·94	0·63	0·60	0·74	0·76	0·80	1·11	1·55	0·80	0·84	1·31	0·63
Calculated value per ton,	*s.* 33	*s. d.* 10 9	*s. d.* 11 5	*s. d.* 13 4	*s. d.* 15 1	*s. d.* 15 4	*s.* 20	*s. d.* 27 2	*s. d.* 14 2	*s. d.* 17 2	*s. d.* 21 7	*s. d.* 11 5

* *Report to the Magistrates and Council of Glasgow*, 1879.

TABLE XVII.—COMPOSITION OF SEWAGE-SLUDGE, BY DR. MUNRO.*

	Coventry (Dried).		Leyton (Dried).		West Ham (Dried).	
Organic matter,	...	26·14	...	26·08	...	40·32
Containing nitrogen,	1·36	...	1·35	...	1·82	...
Ash,	...	...	...	...	...	...
Soluble in acetic acid.						
Carbonate of lime,	39·07	...	26·36	...	23·72	...
Ammonia, Phosphoric acid,	0·05	...	0·29	...	0·38	...
Ammonia, Oxide of iron, alumina and soluble silica,	1·44	...	7·42	...	1·93	...
Ammonia, Potash,	trace	...	...	...	...	...
Soluble in hydrochloric acid.						
Ammonia, Phosphoric acid,	2·38	...	1·75	...	2·19	...
Ammonia, Oxide of iron, alumina,	7·26	...	7·79	...	8·09	...
Ammonia, Potash,	0·30	...	0·34	...	0·22	...
Insoluble.						
Sand and silicates,	22·84	...	26·21	...	18·30	...
	73·34	...	70·16	...	54·83	...
Magnesia, sulphuric acid, sodium, chlorine, and loss,	0·52	...	3·76	...	4·85	...
		73·86		73·92		59·68
		100·00		100·00		100·00
Total, P_2O_5,	2·43	...	2·04	...	2·57	...
Citrate soluble, P_2O_5,	1·37	...	1·69	...	1·24	...
Air dried as used in expl. plots.						
Water,	36·23	...	21·16	...	15·43	...
Organic and volatile matters,	16·67 (containing nitrogen)	0·87	20·56 (containing nitrogen)	1·06	34·10 (containing nitrogen)	1·54
Ash,	47·10 (containing P_2O_5)	1·55	58·28 (containing P_2O_5)	1·61	50·47 ,,	2·17
	100·00		100·00		100·00	

Wimbledon, as from Press (Lime Process).	
Water,	56·15
*Organic matter,	11·36
Insoluble silicate matters,	7·10
Phosphoric acid, P_2O_5,	1·96
Equivalent to tri-basic phosphate of lime, $Ca_3P_2O_5$, 4·28.	
Carbonate of lime, oxide of iron, alumina, magnesia, sulphuric acid, chloride of sodium, potash, &c.,	23·43
	100·00

* Containing nitrogen, 0·41, equivalent ammonia = 0·50.[1]

[1] At the time the analysis was made the sewage was treated with lime only.

* *Min. Proc. Inst. C.E.*, vol. lxxxviii., 1887.

TABLE XVIII.—AVERAGE COMPOSITION OF PRESSED SEWAGE-SLUDGE FROM CROSSNESS (*J. W. DIBDIN*, 1887).

	Per cent.
Moisture,	58·06
Organic matter,	16·69
Mineral ,,	25·25
	100 00

The organic matter contains—

	Per cent. on pressed Sludge.	Per cent. Nitrogen.
Saline ammonia,	0·035	0·87
Organic nitrogen, calculated as ammonia,	1·025	

The mineral matter contains—

	Per cent.
Carbonate of lime,	7·94
Free lime,	2·45
Silica,	8·08
Oxide of iron,	0·97
Alumina,	3·39
Phosphoric acid (= Phosphate of lime 1·44),	0·658
Magnesia,	traces.

The analyses disclose low manurial values, and if sewage-sludge is to take and retain its place as a manure, in order to save carriage and render it more suitable for application to land, it is necessary to go further than treat it in a filter-press. The sludge-cake should be dried and pulverised, and as its quality must vary with the occurrence of storms, which bring quantities of mineral detritis into the settling tanks, every endeavour should be made to turn out a manure of uniform quality, either by fortifying weak samples or by thorough admixture of the mass.

The conclusions arrived at by the author, after careful observation of the filter-press during several years, are:—Firstly, that the machine offers a ready solution to the question of the disposal of the huge masses of putrescent mud produced daily in sewage-precipitation works; secondly, that these offensive and useless masses may be quickly converted into a practically inodorous manure; and, lastly, that the resulting manure is superior to ordinary farmyard manure.

The disposal of the liquid separated from sludge by means of the filter-press is not difficult. The subjoined analysis shows the composition of this liquid, which is generally free from suspended matter:—

TABLE XIX.—COMPOSITION OF LIQUID FROM FILTER-PRESSES USED FOR SEWAGE-SLUDGE AT WIMBLEDON.

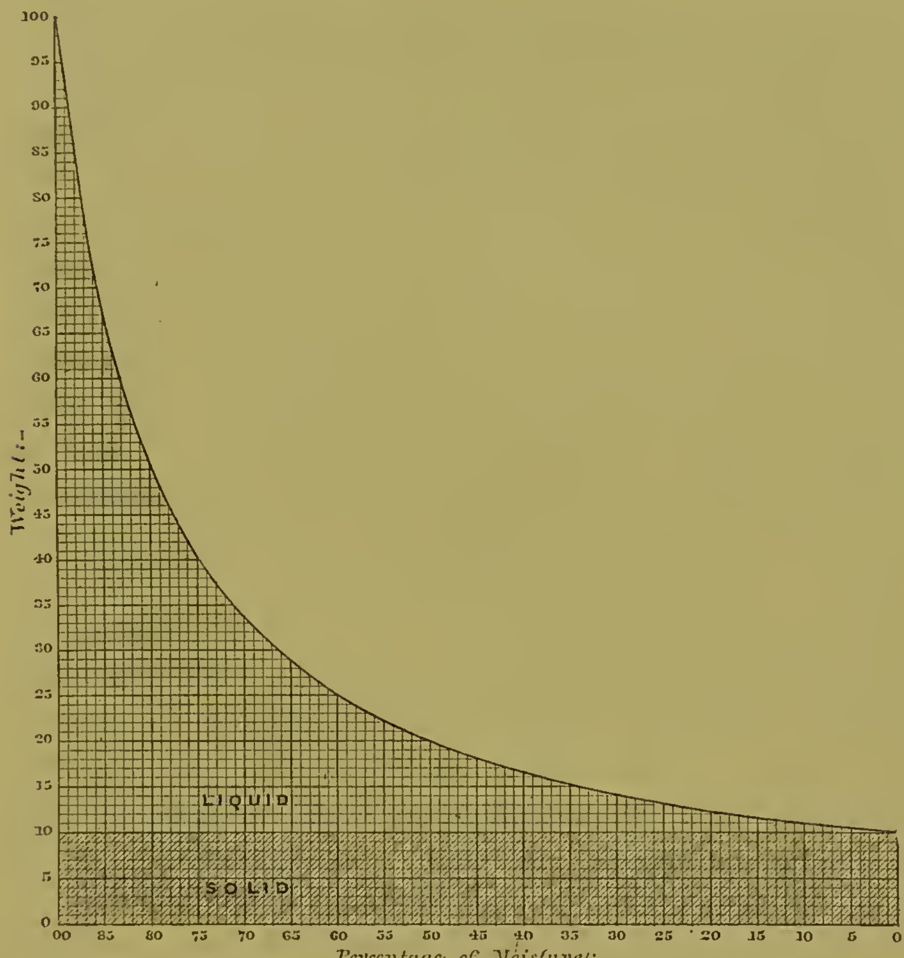
Components.	Dr. Stevenson, 1889.		Midgley Taylor, F.C.S., 1893.	
	Grains per Gallon.	Parts per 100,000.	Grains per Gallon.	Parts per 100,000.
Total solid matter (dried at 120°), .	260·40	372·00	267·82	382·60
Loss on ignition, ...	28·20	40·40	44·10	63·00
Combined chlorine, ...	4·69	6·70	5·36	7·66
Lime (CaO), total, as free lime, carbonate, and soluble salts, . .	131·30	187·57	129·9	185·57
Alkalinity, calculated as hydrate of calcium (slaked lime), . . .	151·70	216·71	176·12	251·60
Free ammonia, ...	6·90	9·86	8·07	11·53
Albuminoid ammonia, . . .	1·80	2·57	2·53	3·62
Oxygen used in oxidising the organic matter in two minutes, . . .	2·00	2·86	6·21	8·87
Ditto in four hours, ...	3·05	4·36	11·80	16·86

It will be observed that the analysis by Mr. Midgley Taylor indicates more polluting matters than that by Dr. Stevenson, and this is explainable by the fact that at the time of the earlier analysis, a light lime treatment of the sewage was employed, whereas in the case of the more recent one, as much as 25 to 30 grains of lime per gallon were being used, and its solvent action upon the solid organic matters in the sludge is very marked. Here is evidence in favour of the employment of light doses of lime, since a very large dose results in much of the solid organic matter in the sludge being dissolved out, and again added to the sewage.

Dr. Tidy* suggested separate treatment of filter-press liquid,

* *Journ. Soc. of Arts*, Oct. 8, 1886.

using as agents either chloride of lime or perchloride of iron in comparatively large quantities.



PROPORTIONS OF LIQUID AND SOLID IN SLUDGE,
AT VARIOUS DEGREES OF DRYNESS.

W. SANTO CRIMP, DELT

Fig. 10.

As, however, at Wimbledon the press-liquor is but about 1 per cent. of the normal sewage flow, and as this liquid is practically a saturated solution of lime with a quantity of organic matter, the author allowed it to flow into the outfall sewer, where it is mixed with the untreated sewage, and it assists to precipitate the suspended matters on the sewage being pumped into the settling tanks. If 5 per cent. of press-liquor is added to ordinary sewage, curdling and rapid precipitation of the solids follow.

Dr. Stevenson informed the author that, "so far as he could see, the only useful purpose that was served by returning the press-liquor to the unpurified sewage was a saving of lime; there being the equivalent of rather more than 1 cwt. of quicklime in 33 tons of press-liquor, your daily yield. . . . It may with care, as *e.g.*, neutralisation with sulphuric acid, be converted into a comparatively rich fertilising liquid; but the 33 tons would require 2 cwts. of oil of vitriol for neutralisation, and this would cost much more than the value of the fertilisers in the liquid." Dr. Stevenson further said that, in his opinion, the best way of treating the press-liquor, was to add to it ten to twelve times its volume of chalky water, and pass it over or through land. He pointed out that by adding this liquor to the sewage the albuminoid ammonia in the latter was increased by $\frac{1 \cdot 8}{100} = 0 \cdot 018$ grain per gallon.

Before definitely deciding upon the mode of disposal, the method of dealing with the sewage must be considered; when the sewage effluent from settling tanks is applied to land, the plan adopted by the author at Wimbledon will be found satisfactory, but if the effluent passes from the tanks directly into a river or stream, small in volume relatively to the effluent, separate treatment may be found to be desirable.

The foregoing diagram (Fig. 10) will be found useful in estimating quantities of water eliminated by filter-presses.

CHAPTER IX.

THE PREPARATION OF LAND FOR SEWAGE DISPOSAL.

Land is generally prepared for the purification of sewage in one of two ways; when the surface is relied upon as being sufficient for the purpose and **broad irrigation** is the mode in which the sewage is applied, the surface should present a gentle slope, in order that the sewage may travel slowly forwards in a lateral direction and also admit of the drainage and drying of the surface subsequently to the application of the sewage.

When **intermittent filtration** is the method by which the purification is to be effected, the land is laid out in level beds, and the sewage applied to each bed passes vertically downwards through a pervious stratum from which, in a more or less purified condition, it escapes by means of drains, or otherwise.

Levelling and Under-drainage.—The laying out of land for irrigation requires an amount of attention and care, generally not fully appreciated. When the subsoil is of sand, or gravel, or other porous material, the preparation is not a difficult matter, since the subsoil water is readily disposed of; either it passes into the streams or water-courses without artificial aid, or a few deep drains are laid for the purpose of relieving the subsoil. But in dealing with the drainage of clay soils, the utmost care is necessary. The reckless draining of these soils, when intended for sewage purification, has not infrequently brought about a state of affairs the reverse of that desired. Clay soils possess the property of cracking in dry weather, consequent upon the contraction of the material when free from water. In undrained clay land, cracks may often be found 1 or 2 inches in width, and 5 feet and upwards in depth; when the land is drained the cracking is intensified, and sewage applied to the surface may pass directly to the drains without undergoing any appreciable degree of purification, and in consequence of the generation in the drains of the material known as "sewage fungus," sometimes issues from the drains actually in a worse condition than when applied to the surface.

At the Wimbledon sewage farm, a large number of drains have been taken up with very beneficial results. In some cases the trenches had been filled nearly to the surface with burnt clay and ashes, or other porous material, and when this had been done the land may be said to have been rendered as unfit for the reception of sewage as it was possible to make it. It has been said that the large quantities of sewage applied tend to prevent cracking, but experience teaches that in practice the cracking cannot be prevented. There are not many sewage farms where a larger volume per acre per annum—16,000 tons—is applied than at Wimbledon; but in hot, dry weather, when evaporation and absorption are most active, cracking is always observable. The subjoined diagram shows the effects of clay soils cracking.

The careful sewage-farmer does not irrigate ryegrass for a period from three to seven or more days before each cutting; this is necessary in order to admit of the crop "hardening," or parting with some of its moisture, thus rendering it more suitable for the market; the ground also drains and hardens, thus admitting of the passage of vehicles over its surface without destroying the roots of the grass, or injuriously

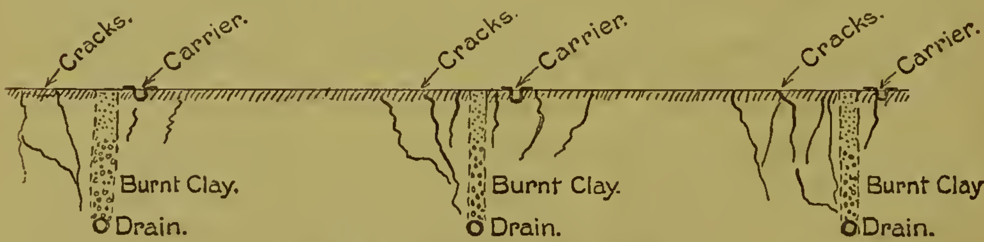


Fig. 11.—Cracking of clay soils.

affecting the surface by making deep wheel-tracks, along which the sewage would readily pass, to the possible pollution of the effluent. During the period when the crop is being "hardened" and removed, the cracking of clay soils is not to be prevented, and the author has seen cases where badly drained fields have compulsorily remained idle in dry weather, being rendered quite unfit for sewage purification.

On the other hand, the application of sewage to undrained soils might lead to an unsatisfactory result. The drainage question was investigated by a Committee appointed by the British Association for the Advancement of Science, and in the Report for 1873, page 446, the following passage occurs:—

"It may seem almost superfluous for the Committee, after so many years of general experience throughout the country, to argue in favour of the subsoil drainage of naturally heavy or naturally wet land with impervious subsoil for purposes of ordinary agriculture; but some persons have strongly and repeatedly called in question the necessity of draining land when irrigated with sewage; and the two farms at Tunbridge Wells, to a great extent, and more especially the Reigate Farm at Earlswood, have been actually laid out for sewage-irrigation on what may be called the "saturation principle;" so that it appears to the Committee desirable to call attention to the fact that if drainage is necessary where no water is artificially applied to the soil, it cannot be less necessary after an addition to the rainfall of 100 or 200 per cent. But a comparison of the analyses of different samples of effluent waters which have been taken by the Committee from open ditches, into which effluent water was flowing off saturated land, and from subsoil drains into which effluent water was intermittently percolating through several feet of soil, suggests grave doubts whether effluent water ought ever to be permitted to escape before it has percolated through soil."

The solution of this most difficult problem may possibly be found in the treatment adopted by the author for the more recent portions of the Wimbledon Farm. The surfaces were very carefully levelled, so as to prevent any ponding of the sewage; the land was divided into plots of about 4 acres by means of roads 12 feet in width; under the centre of each road a drain was laid at a depth of about 6 feet; the surface of the land, prior to being cropped, was ploughed to a depth of 9 inches, and whilst in a rough condition, a thick coating of screened town ashes was placed upon it; the ordinary agricultural operations followed, and as a result, a porous surface upwards of a foot in thickness has been obtained, through which the sewage passes in a lateral direction. As the ground is ploughed every other year, the porosity of the surface is maintained, and the results have hitherto been most satisfactory; certainly the troubles experienced on the older parts of the farm have been altogether wanting on the newer portions. The farm manager, Mr. Snook, recommends occasional subsoiling, in addition to deep ploughing for clay soils. These disturbed surfaces will absorb large quantities of sewage, and if the liquid be carefully and intermittently applied, "lateral filtration" will occur with satisfactory results; the quantity applied per acre per day should not, perhaps, exceed 20,000 gallons, and with that quantity properly applied it is doubtful if any water will escape that has not been in actual contact with the soil. The volume might appear to be large, seeing that with 40 gallons of sewage per head per day, 500 persons per acre would be the unit, but it is rarely the case that more than one-fifth of a sewage farm is under irrigation at any one period.

The unit of 100 persons per acre has been adopted in this country where broad irrigation is employed for the purification of sewage, but where utilisation as well is aimed at, the number per acre should, according to various authorities, vary from 30 to 50.

The birth-place of **intermittent downward filtration,** as applicable to sewage purification, was the laboratory of the Rivers' Pollution Commissioners (see First Report, 1870); although waters used for domestic purposes have long been subjected to this treatment. The experiments were made in the following manner:—

"A number of glass cylinders were blown, each 6 feet in length and 10¼ inches in diameter; they were open at each end, and were placed vertically upon a shallow earthenware tray. A glass tube, open at both ends, is passed down the axis of the cylinder to within about 3 inches of the lower extremity. The object of this tube was to allow air or gas to escape freely from the lower part of the cylinder, so that the passage of the sewage through the filtering material might not be retarded. A layer of small pebbles about 3 inches deep was placed at the bottom of the cylinder; upon this rested a stratum about 5 feet thick (about 3 cwts.) of the soil to be experimented upon; and finally, in some cases, a layer of fine sand 1 inch deep was put upon the top of the soil, to prevent the coarse suspended matters in the sewage from passing into the soil. This left ample space at the top for the sewage which was poured into the cylinder in equal quantities night and morning. The effluent water, collecting in the earthenware tray, flowed off into a vessel conveniently placed for its reception."

In experimenting with Beddington soil, the sewage was found to be effectively purified when the rate of filtration was 7·6 gallons per cubic yard of soil per day.

Experiments with Barking soil gave entirely different results. The soil was found to possess the property of absorbing from sewage a large amount of fertilising ingredients. "It is scarcely possible to overrate the agricultural value of this property in a soil which is destined for irrigation. This quality, however, greatly detracts from its efficiency as a continuous purifier of sewage filtered through it. The application of 3·8 gallons per diem to each cubic yard, for about twelve weeks, showed a continuous increase of organic impurity in the effluent water, which at the end of that time was rapidly approaching in quality to unchanged and unpurified sewage."

Dursley soil gave the best results. "Whilst 1 cubic yard of sand or of Hambrook soil cannot continuously and satisfactorily purify more than 4·4 gallons of London sewage per twenty-four hours, 1 cubic yard of Beddington soil can cleanse 7·6 gallons, and 1 cubic yard of Dursley soil no less than 9·9 gallons in twenty-four hours, which is equivalent to the cleansing of nearly 100,000 gallons of sewage per day by an acre of this soil, provided the drains for the effluent water are 6 feet deep. . . . At the conclusion of the long series of experiments, there were no symptoms of clogging up or diminution of activity, and the effluent water was always bright, inodorous, and nearly colourless. The cleansing power of a soil seems to be more closely connected with physical condition as regards porosity and fineness of division than with its chemical composition. Thus the Beddington and Barking soils, whilst similar in chemical composition, are most widely dissimilar in their action upon sewage. Again, sand and Hambrook soil act very similarly upon sewage, whilst they differ considerably in chemical composition; and lastly, the Hambrook and Dursley soils do not differ very widely in their chemical composition—nevertheless, the latter has more than twice the purifying power of the former."

The Commissioners estimated that an acre of properly drained and suitable soil would be sufficient for the purification of the sewage of 2000 persons, but experience proves that the estimate is too high.

A plot of land is never of the same texture throughout; moreover, when the soil is disturbed by cutting deep trenches for the drains, the excavated material on refilling the trench is rarely consolidated to the same degree as the original soil, and the sewage will pass through the more porous portions more readily than through those of a closer texture; a large filtration area is in short generally unlike the small artificial filters of the Commissioners, and, as a consequence, the unit of persons per acre has now been reduced to 1000.

In experimenting with Lancashire peat, the effluent showed a steady improvement from the first, and it is worthy of remark that the existence of organisms in soil and their effect as scavengers do not appear to have been suspected by the Commissioners. After comparing a sewage farm with the lungs of breathing animals, and the sewage with blood, in both which the air acts as an oxidising agent, the Commissioners say:—

"To this item in the character of both irrigation and filtration as chemical processes, there must be added another cleansing agency, also of a chemical kind, in which the former has greatly the advantage. We refer to the actual appetite for certain dissolved impurities in filthy water, which soil, whether in a tank or covering a field, owes both to general surface attraction and to chemical affinities which some of its ingredients possess."

In 1877 the **purifying action of soil** was investigated by MM. Schlœsing and Müntz, and the results of their experiments were embodied in a Report in 1878.* The general theory advanced may be thus summarised :—

When a liquid, such as sewage, is applied to a porous soil, the suspended matters are arrested at the surface; this is the first action. The water, freed of its insoluble matters, descends into the soil, and each particle of earth being surrounded with an extremely thin coating of liquid, an enormous surface of water is presented to the air contained in the soil. The second action of the soil now comes into operation, which is similar to slow combustion, the organic impurities are reduced to carbonic acid, water, and nitrogen, as in active combustion, but the organic nitrogen itself, which is more difficult to oxidise than either carbon or hydrogen, is changed into inorganic compounds. The means by which these changes are effected are now understood, and are doubtless due to organisms.

Mr. R. Warington examined the question in this country, and in 1884 presented a paper to the British Association for the Advancement of Science, from which the following is extracted :—

"**The Theory of Nitrification.**—Till the commencement of 1877 it was generally supposed that the formation of nitrates from ammonia or nitrogenous organic matters in soils and waters was the result of simple oxidation by the atmosphere. In the case of soil, it was imagined that the action of the atmosphere was intensified by the condensation of oxygen in the pores of the soil; in the case of waters, no such assumption was possible. This theory was most unsatisfactory, as neither the solutions of pure ammonia nor any of its salts could be nitrified in the laboratory by simple exposure to air. The assumed condensation of oxygen in the pores of the soil

* Schlœsing et A. Durand-Claye, *Rapport au Congrès International d'Hygiène de Paris*, 1878.

also proved to be a fiction as soon as it was put by Schlœsing to the test of experiment.

"Early in 1877, two French chemists, MM. Schlœsing and Müntz, published preliminary experiments showing that nitrification in sewage and in soils is the result of the action of an organised ferment, which occurs abundantly in soils and in most impure waters. The evidence for the ferment-theory of nitrification is now very complete. Nitrification in soils and waters is found to be strictly limited to the range of temperature within which the vital activity of living ferments is confined. Thus nitrification proceeds with extreme slowness near the freezing point, and increases in activity with a rise of temperature till 37° C. (99° Fahr.) is reached; the action then diminishes, and ceases altogether at 55° C. (131° Fahr.) Nitrification is also dependent upon the presence of plant-food suitable for organisms of low character. Recent experiments at Rothampstead show that in the absence of phosphates no nitrification will occur. Further proof of the ferment-theory is afforded by the fact that antiseptics are fatal to nitrification. In the presence of a small quantity of chloroform, carbon bisulphide, salicylic acid, and apparently also phenol, nitrification entirely ceases. The action of heat is also equally confirmatory. Raising sewage to the boiling-point entirely prevents its undergoing nitrification. The heating of soil to the same temperature effectually destroys its nitrifying power. Finally, nitrification can be started in boiled sewage, or in other sterilised liquid of suitable composition, by the addition of a few particles of fresh surface soil, or a few drops of a solution which has already nitrified; though without such addition these liquids may be freely exposed to filtered air without nitrification taking place.

"The nitrifying organism has been submitted as yet to but little microscopical study: it is apparently a micrococcus. . . .

"**The Distribution of the Nitrifying Organism in the Soil.**—Small quantities of soil were taken at depths varying from 2 inches to 8 feet, from freshly-cut surfaces on the sides of pits sunk in the clay soil at Rothampstead. The soil removed was at once transferred to a sterilised solution of diluted urine, which was afterwards examined from time to time to ascertain if nitrification took place. From the results it would appear that in a clay soil the nitrifying organism is confined to about 18 inches of the top soil ; it is most abundant in the first 6 inches. It is quite possible, however, that in the channels caused by worms or by the roots of plants, the organism may occur at greater depths. In a sandy soil we should expect to find the organism at a lower level than in clay, but of this we have as yet no direct evidence."

Later researches show that in porous soils the nitrifying organism exists at depths of from 3 to 4 feet.

As in the case of the chemical treatment of sewage, a vast amount of light has been thrown upon this subject by the Massachusetts State Board of Health, and the researches of that Board, as published in 1889 and 1892, form a most important contribution to the literature of the subject. The precise conditions under which the organisms perform their functions are most fully detailed, whilst the effect of the different kinds of sand used in the experimental filters is admirably given. The general results can only be detailed here, since the reports extend over several hundred pages. It has been conclusively proved by these experiments that sand, when properly employed, is capable of removing nearly all the dissolved impurities in sewage. The main points to be observed in its use are—(1) The sand should be nearly uniform in size; (2) the sand should be fairly coarse in grain; (3) the sewage should be applied carefully and systematically—first, in order to ensure all the particles of sewage being brought in contact with the nitrifying organisms, and second, in order to aerate the filter so that the organisms can obtain the oxygen necessary for their existence. As much as 200,000 U.S. gallons per acre were purified daily, when applied in about seventy distinct doses, in the case of the best filter, consisting of coarse sand 5 feet in depth.

The subject of nitrification is now receiving an increasing amount of attention in this country, and the following extract from *Engineering*, of 7th October, 1892, is full of interest :—

"The latest contribution to our knowledge of the best methods of utilising the efforts of the microbe organisms have come from Mr. W. E. Adeney,* Curator in the Royal University of Ireland, and Mr. W. Kaye Parry,† of Dublin, in the form of two papers read before the British Institute of Public Health at the late meeting in Dublin. The two authors have worked to a certain extent in conjunction, Mr. Adeney devoting himself more to laboratory experiment, and Mr. Parry proceeding on a larger scale. Hence these two papers deal with different aspects of the same subject. Some years ago Mr. Adeney set himself to discover how much oxygen it required to support the microbes while they decomposed a given sample of sewage from which the solids had been removed. A given volume of freshly-filtered sewage was mixed with different proportions of Vartry water, and the mixtures, as they were made, were poured into bottles which were filled, and closed with glass stoppers. The bottles were kept at a temperature of about 60° Fahr., for from seven to thirty days. By determining the quantities of ammonia, nitrous and nitric acids, organic carbon and the dissolved gases—carbon dioxide, oxygen, and nitrogen—in each mixture before and after keeping it, the nature and extent of the changes set up in the organic matters contained in it could be examined and estimated. It was found that the variation in results was entirely due to the quantity of oxygen originally present in the different mixtures, the oxygen being introduced in the water. One volume of sewage was mixed with Vartry water in the following proportions: 1 : 9, 1 : 19, 1 : 29, 1 : 39, 1 : 49, 1 : 59, 1 : 69, 1 : 79, 1 : 89, 1 : 99. In mixtures $\frac{1}{70}$, $\frac{1}{80}$, and $\frac{1}{90}$, a decided quantity of oxygen remained unabsorbed, while the organic matters were entirely decomposed. Each mixture remained

* *The Chemical Bacteriology of Sewage ; Its Hygienic Aspect.*

† *A New Method of Sewage Purification.*

sweet and clear, and gave no indication of putrefactive fermentation. In mixtures of $\frac{1}{69}$ and $\frac{1}{59}$, small quantities of dissolved oxygen were found unabsorbed; part of the ammonia only had been oxidised to nitric acid, and some was found remaining. In the $\frac{1}{49}$ mixture a trace of oxygen was detected, and none of the ammonia had apparently been oxidised, although the organic matters originally present had been entirely decomposed, the organic carbon and nitrogen having been converted into carbon dioxide and nitric acid respectively, as in all the previous instances. In the $\frac{1}{39}$ mixture no free oxygen was found; practically the whole of the organic carbon had been converted into carbon dioxide, but the organic nitrogen had only been partially oxidised to nitric acid, some being reduced to ammonia. The ammonia originally present had remained apparently unaffected. In the remaining three mixtures no oxygen was detected. The organic matters had not been completely decomposed, and none of the organic nitrogen had been oxidised, but some had been converted to ammonia. Putrefactive fermentation had been set up with very offensive odours. In mixtures $\frac{1}{19}$ and $\frac{1}{9}$ decided quantities of sulphuretted hydrogen were found.

The lesson of these experiments is very easily learned. The complete decomposition of the organic matters of sewage can only be effected without putrefaction and odour in the presence of an ample supply of oxygen. As the supply is lessened, the ammonia first escapes alteration, then the nitrogen fails to be oxidised to nitric acid, and finally the organic carbon is only partially decomposed. This accords with the contention of some sanitarians that sewage, from which the solids have been precipitated, may be safely turned into a running stream, provided that its oxygen has not already been used up by a similar process in its higher parts, and also that its volume is great relatively to the sewage. Unfortunately, these two conditions are seldom attainable in the case of towns of moderate size, and other means have to be adopted to provide a supply of oxygen to the saprophytic organisms.

Blowing air directly into the liquid does not seem a practicable method; exposure in thin films in filter beds and in very porous soil is already adopted with success, and was the method followed in the Massachusetts experiments already referred to. It has always been understood that the operation is not one of filtration, but of oxidation. When smooth clean pebbles, the size of horse-beans, were employed for months in a sewage filter, it was found that they were perfectly clean at the end of the time. The pebbles had merely acted as operating tables on which the organic matters had been converted into gas and soluble nitrates, to be washed off by the next flow of liquid. Land is often unavailable for irrigation, and even filter-beds take up a considerable space, and are expensive to build (not necessarily, *Author*), so Mr. Adeney set himself to devise other means for supplying oxygen. Nitre is a substance which readily decomposes into nitrogen, oxygen, nitric oxide, and potash, when added to sewage containing aërobic organisms, and it then furnishes the oxygen necessary to their growth. Mr. Adeney, therefore, selected this material, and in conjunction with Mr. Parry, experimented with it on a considerable scale for four years, dealing with 1000 gallons a day. More recently the process has been adopted at the Lunatic Asylum, Dundrum, Dublin. As the action of organisms is necessarily slow, additional means have been adopted to secure the direct oxidation of the sewage in the first instance, and it is only in the last stage that their help is relied upon. If purification by microbes is set up, and the effluent discharged well furnished with an oxygen-supplying material, it may reasonably be expected that the work of purification will be harmlessly completed in the stream. The process will be best understood by describing it as it is carried out at Dundrum.

After passing a preliminary straining chamber, the liquid flows into the first of a series of tanks, 7 feet square and 16 feet deep, being conveyed to the bottom and spread uniformly over the floor. In rising to the surface the fine particles are caught in the gelatinous matter, and a large proportion of the suspended matter is thus removed by a purely mechanical process, and without the addition of any chemicals whatever. (The process so far is the same as the "Wimbledon"—*Author*). The partially purified effluent from this tank is carried through a mixing race to a second and similar tank, receiving in its course a dose of manganate of soda, 2 to 5 grains per gallon. The manganese affects the oxidation of a considerable part of the organic matter, and becomes converted into the brown oxide of manganese, which falls to the bottom, carrying with it the lighter particles that had escaped from the first tank. The liquid is then conducted to a third tank, where nitre (2 or 3 grains to the gallon) is added, in order that such of the constituents as were not amenable to the manganate of soda, or which escaped its action, may be broken up by the saprophytic organisms. As to the time required for this action, the tank capacity at Dundrum is completely filled and emptied every twenty-four hours, but it is believed that less time would be sufficient. The effluent is clear and bright and absolutely non-putrefactive."

During the summer of 1892, experiments with filters were carried out at The Northern Outfall Works at Barking, under the superintendence of Mr. Dibdin and the author. Four materials were used in the filters—namely, coke breeze, burnt clay, pea gravel, and polarite. All these filters gave excellent results, Mr. Dibdin's analyses showing a high degree of purification when the clarified sewage was applied carefully and systematically, and at a rate of about 250 gallons per square yard per day; when filtered, or rather subjected to the action of the nitrifying organisms, at the rate mentioned, the sewage was purified to such a degree as to be of a non-putrescible character. The results were so encouraging that a filter of coke breeze, one acre in extent, was next constructed, but the results are not yet available. It is not suggested that 250 gallons per square yard per day is the limit of each filter, but it is certain that amount might be relied upon.

In a paper read before the Society of Arts in 1882, Mr. Warington pointed out that "a porous soil of open texture will present an immense surface covered with oxidising organisms, and generally well supplied with the air requisite for the discharge of their functions. It is doubtless owing to this fact that nitrification takes place with so much greater rapidity in a soil than in a liquid. The sewage will itself supply the substance required for the nourishment of the oxidising organisms. One material essential to nitrification may, however, sometimes be deficient, namely, the base with which the nitric acid is to combine; without the presence of this salifiable base, nitrification will speedily come to a standstill. In the case of towns supplied with hard water, the sewage may contain as much carbonate of calcium in solution as will suffice for its subsequent nitrification in the soil; but in the case of towns supplied with very soft water this can hardly be the case, and the presence of a considerable amount of lime in the soil itself will become essential for efficient nitrification. . . . Sewage contains the organisms necessary for its own destruction, and under favourable conditions these may be so cultivated as to effect the purpose. A filtering medium of pure sand and limestone, treated intermittently with sewage, will, after a time, display considerable purifying powers, the surfaces becoming covered with oxidising organisms derived from the sewage. No such medium will, however, equal in effect a porous soil, rich in organic life. It will be gathered from the observations now made that it would be possible to construct a filter-bed having a greater oxidising power than would be possessed by an ordinary soil and subsoil. Such a bed would be made by laying over a system of drain pipes a few feet of soil, obtained from the surface (first 6 inches) of a good field, the soil selected being porous, and containing a considerable amount both of carbonate of calcium and organic matter. A filter-bed thus prepared would be far more porous than a natural soil and subsoil, and would possess active oxidising functions throughout its whole depth. . . .

One more point may be worthy of notice. We have already referred to the fact that nitrification, like all other kinds of fermentation, ceases in the presence of antiseptics; the refuse of chemical works may thus sometimes prove a great hindrance to the purification of sewage by soil."

Levelling.—In the preparation of land—other than by draining, which has already been discussed—great attention should be paid to the surface. Whether the system be that of irrigation, or of downward filtration, the surface when levelled should be entirely free from depressions and from mounds. The subjoined diagram will illustrate both a well- and badly-prepared surface, and some of the effects resulting therefrom.

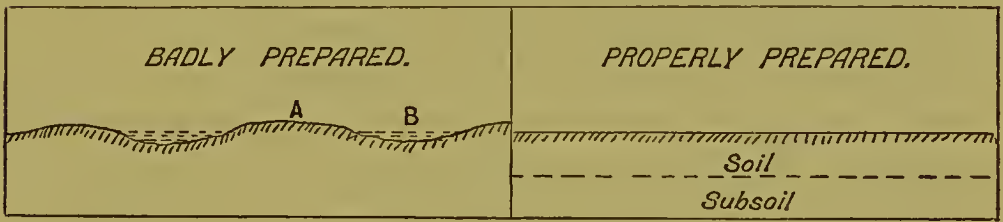


Fig. 12.—Preparation of soils.

In the first case, the sewage will not reach A and the crops on the summit will be poor, as will also be those subjected to deluging at B; the full purifying power of the soil will not be utilised, and a nuisance might arise from the stagnation at B. In the second case, the top soil will be set aside, and when the subsoil has been levelled, will be replaced with an even thickness throughout.

If broad irrigation is adopted on very flat and heavy soil, the land should be laid out on the ridge and furrow system, the ridges being about half a chain (33 feet) apart. A fall is given to the furrows longitudinally, just as in a level road an artificial fall is obtained for the channels by deepening them near the gullies; indeed a field laid out on this system, resembles a series of roads side by side, the sewage carrier, merely a grip, being cut along the top of the ridge, which corresponds with the crown of a road. The surface of wet soils may be readily relieved of its super-abundant moisture if treated in this manner.

Carriers.—When the surface has a sufficient slope, or the subsoil is of an open nature, the fields may be laid out with an evenly graded surface. The carriers, or grips, will then be cut in the direction of the greatest fall, or nearly so, and the sewage will be diverted from the grips to the surface of the land by means of stop-boards, or small sheet-iron stoppers; these latter are preferable and should be provided at the top with a piece of angle iron, which not only stiffens them, but admits of the water-man pressing them into the soil with his foot, when diverting the sewage.

The grips should be of simple construction, and stoneware or other artificial channels are not only unnecessary, but a great hindrance to agricultural operations.

The main permanent carriers—those bringing the sewage to the highest part of each plot—may be of any durable material, and the level at which they are laid should be such as to admit of them discharging their whole contents into some one or other of the secondary carriers, otherwise the sewage will become very offensive if allowed to stagnate. The secondary carriers might be conveniently constructed of stoneware channels, formed by splitting ordinary socket-pipes longitudinally, a process readily performed by manufacturers. The sluices or valves, on the main carriers, for regulating the flow to the secondary carriers, should be constructed in a substantial manner, and preferably of iron. These general details are applicable to both irrigation and downward filtration areas; but when these latter are very porous, and the sewage is applied in small volumes, as from gravitation outfall sewers serving small towns, and not provided with storage tanks, the ridge and furrow, as adopted by Mr. Bailey Denton, is advisable, because the sewage can be diverted down each furrow successively, thus ensuring uniformity of application.

The subjoined sketch shows the usual form of ridge and furrow adopted in these cases:—

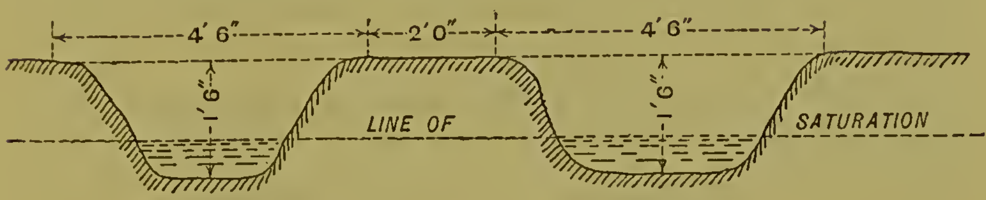


Fig. 13.—Ridge and furrow filtration areas.

The sewage passes laterally into the ridges, and is carried by capillary attraction above the line of saturation, its fertilising constituents thus being rendered available for the nourishment of plant life.

Cropping.—With regard to the cropping of sewage farms, when the area is large compared with the number of persons per acre, and utilisation is aimed at, all ordinary crops may be grown, since the sewage may be applied in moderate doses, and at such seasons as may be most advantageous. But when the area is somewhat more restricted as in broad irrigation farms, with a population of about 100 per acre—the unit generally adopted in this country—the volume of sewage to be applied per acre per annum is often too large to admit of cereals being cultivated, and rye-grass, mangold-wurzel, and osiers, must then be the principal crops. Since an inspection of Table vi. (pp. 42, 43) will show that the average discharge of sewage per head per day is, in the towns tabulated, 35 gallons, this volume multiplied by 100—the number of persons per acre—will amount to about 6300 tons, as the yearly volume of sewage per acre; to that quantity must be added the ordinary rainfall descending upon the farm, and the increase in the sewage due to the non-interception of the rain falling on streets, roofs, and other surfaces; hence it will be seen that the volume of liquid applied per acre per annum, is much too large to admit of the cultivation of crops, other than those suited to much moisture.

In the case of downward filtration, where the sewage of five or more times as many persons is often applied per acre, rye-grass or osiers must be the principal crops, unless the narrow ridge and furrow be adopted, when vegetables or mangolds may be grown on the ridges.

With regard to the **commercial aspects** of sewage farming, generalisations are of no practical value. That sewage possesses a certain manurial value is too well established to need comment, but whether that value can be profitably reclaimed by applying sewage to land, must depend upon a variety of circumstances.

Regarded purely as a commercial undertaking, the utilisation of sewage may be dealt with in the same manner as any other attempt to deal with waste products. The elements necessary to success are in both instances practically the same; the capital outlay on the manufactory or the farm is the first element, the price obtainable for the products is the second, the cost of the management is the third, while the cost of the waste product itself may also be an element; if for instance a long outfall sewer or a pumping station were necessary to the utilisation of sewage on a particular area of land, when the sewage might be otherwise dealt with without constructing these works, their annual cost would be fairly chargeable to the manufacturing account.

In one important particular, however, the parallel must cease. In the case of a successful trading concern, the directorate would be composed of persons having special knowledge of their business, who would have as their primary object the profitable employment of their means. Such a directorate is widely different from that of the Corporation Sewage Farm, as, indeed, it must necessarily be. A capable, but practically unfettered farm manager, must take the place of the trading board of directors, if the best pecuniary results are to be realised, and at the same time the rivers are to be freed from pollution.

The **sanitary aspects** of sewage farming have been discussed over and over again; the supposed evils are the pollution of subsoil water, of rivers, of the atmosphere, and of the crops. Briefly, it may be said that, provided the area of land is sufficient for the purpose, and that it has been properly laid out, no nuisance need necessarily arise if the works are properly managed, and the same remarks apply equally to all sewage disposal works whether sewage farms or precipitation works. Bad management will in both cases lead to an insanitary condition of affairs.

The Judges, appointed by the Royal Agricultural Society in 1879 to adjudicate the prizes in the sewage farm competition, state in their report that "the results of the sanitary inquiry show that sewage farming is not detrimental to life or health."

The late **Dr. Alfred Carpenter** has devoted a very considerable amount of attention to the question, and has for years had experience in watching the operation of the Beddington Sewage Farm. At a meeting of the British Medical Association at Glasgow in August, 1888, he submitted a series of propositions as follows:—

"1. That the application of the sewage of a water-closet town to land in close proximity to dwelling-houses is not injurious to the health of the inhabitants of those houses provided the sewage be fresh; that it be applied in an intermittent manner, and the effluent be capable of rapid removal from the irrigated fields.

"2. The judicious application of sewage to soil of almost any kind, if it be mainly inorganic, will satisfactorily cleanse the effluent water, and fit it for discharge into any ordinary stream, provided the area treated is not less than an acre for each 250 persons.

"3. That vegetable products grown upon fields irrigated by sewage are satisfactory, and safe as articles of food for both animals and man.

"4. That sewage farms, if properly managed, do not set up either parasitic or epidemic disease among those working on the farm or among the cattle fed upon its produce.

"5. That this immunity exists because the conditions, necessary for the propagation and continuance of those disease germs which affect man and animals are absent; the microbic life on sewage farms being antagonistic to the life of disease germs, the latter, therefore, soon cease as such to exist.

"6. That sewage farms may be carried on in perfect safety close to populations. It is not, however, argued that the effluent water is safe to use for dietetic purposes.

"7. That there is an aspect in sewage farming which shows that it is a wise policy for the nation to encourage that form of utilisation from a political economy point of view.

"8. That to be financially successful such farms require that the rainfall be separated from the sewage; the area large enough for alternate cropping, and the capital employed sufficient to ensure a continuous and rapid consumption of the crops produced.

"9. That, if practicable, sewage utilisation by surface irrigation should be, for financial reasons, within the area of its own watershed, and close to the populations producing the sewage; but it is not a necessity that it should be so, provided it be applied to the land within a few hours—not more than twelve—of its discharge, and that there is no arrest of movement for more than very short periods before it is so utilised."

The effect upon health of sewage farming was dealt with very fully by Dr. Carpenter, his remarks closing with this sentence—

"I need not follow this head any further, except to remark that in February, 1887, I submitted a report upon the subject to the Society of Arts in London, in which I conclusively proved that in no single instance, out of nearly 100 cases in which sewage has been utilised by broad irrigation, had any fact been proved to establish the allegations of 'insanitariness' which are sometimes raised against them."

At Wimbledon, upwards of seventy persons reside upon the sewage farm, whilst a hospital for infectious diseases is situated within its boundary, in which hundreds of patients have been successfully treated since the farm and hospital were conjointly established, and so far there is no evidence to show that the farm is in any way prejudicial to health. Although it would be rash to assert that under all circumstances sewage farming will not prove inimical to health, the evidence in favour of any general condition of unhealthiness resulting from its proper application, is altogether wanting; a satisfactory result when it is considered that sewage farms have now been sufficiently long established to admit of some definite conclusions being arrived at.

The annexed Return, which is in much the same form as the one in the first edition of this work, but containing further details, will be found of interest, as containing particulars relating to the management of sewage farms not usually met with. It has been brought up to date, so far as practicable, but in towns with rapidly-increasing populations, changes and additions are constantly being made, and the Table must be taken as indicating the general arrangements as in existence at the date of its preparation.

PART II.

SEWAGE DISPOSAL WORKS IN OPERATION.

CHAPTER X.

LONDON.

It has been said that the history of the London main drainage works remains to be written, and, although during the past four years the author has had exceptional facilities for mastering the main principles of the system, and of observing the manner in which its functions are performed, a description of the details would occupy more time than the author has at his disposal, and would, moreover, be of little value to those engaged in the construction of drainage works, unless, indeed, as in the case of very many of the old sewers, the observations were intended to point out what should be avoided rather than imitated.

A long time ago, the drainage of London and its surrounding villages was much in the same condition as may be found in some provincial districts to-day. Watercourses were found in the valleys, and the land water flowed down them into the Thames. These watercourses in due course became convenient receptacles for liquid and solid filth, and when the nuisance resulting assumed sufficient proportions, the brook or stream was arched over, and a sewer of rude construction was the result. The size, shape, and gradient were left to the judgment of the persons performing the work, and as a consequence even to this day, some of the very old sewers present features rarely met with. In many cases, in flat portions of the Metro-


MAP
SHEWING THE LINES OF
MAIN INTERCEPTING SEWERS,
CONSTRUCTED FOR THE IMPROVED
DRAINAGE OF THE METROPOLIS,
and the PURIFICATION of the
RIVER THAMES.
SIR J. W. BAZALGETTE, C.B.
ENGINEER.
Scale of Miles.
NORTHERN HIGH LEVEL SEWER
MIDDLE LEVEL SEWER
NORTHERN LOW LEVEL SEWER
NORTHERN OUTFALL SEWER
SOUTHERN HIGH LEVEL SEWER
SOUTHERN LOW LEVEL
SOUTHERN OUTFALL SEWER
WESTERN SEWER
ACTON BRANCH
PICCADILLY BRANCH
FULHAM BRANCH
EFFRA BRANCH
BERMONDSEY BRANCH
ABBEY MILLS P.S.
CROSSNESS P.S.
BARKING OUTFALL
RESERVOIR

polis, the gradients are sometimes in one direction and then in the reverse, whilst the size and section often vary, in a length of a few hundred feet, in a most extraordinary manner. Imagine, in the course of time, a rapid extension of the Metropolis, an ever-increasing population, a corresponding increase in the pollution of the streams, and, finally, the Thames itself rendered filthy and offensive, with great, evil-smelling mud-banks at the various points where the streams, or rather sewers, discharged their foul contents into it. Such was the state of affairs up to the time when the main intercepting sewers were first brought into operation in 1866 and subsequent years.

The positions of the main intercepting sewers are shown upon the plan, subjoined, and it will be readily understood that these sewers are constructed at a deeper level than the old main sewers, and that the contents of the latter are now discharged into the newer system at the various points of intersection, and are then conveyed to the outfalls at Barking and Crossness. The old sewers are not shown upon the plan, as they would prove extremely confusing on so small a scale, without proving of much service to the reader.

It will be readily imagined that any scheme for the interception of the sewage of so huge a city as London had become in 1858 when the Main Drainage Act was passed, would be severely criticised—as, indeed, is very proper—and the scheme finally adopted was the outcome of the joint efforts of Messrs. Bazalgette, Bidder, and Hawksley. The scheme was adversely reported upon by the Government Referees, mainly as regards the sites of the proposed outfalls, and the discharging capacities of the sewers.

We may briefly consider the data upon which the calculations for the adopted scheme were based, and how the scheme was formulated, and then see how far the expectations of the designers were realised; and in this connection, after he has read the details given in this chapter, the reader is invited to refer to the Conclusions and Recommendations of the Royal

Commissioners on Metropolitan Sewage Discharge, 1884, as given in Chapter ii. According to the report of the Government Referees, at that date the area sewered was 75,251 acres, the population on that area amounted to 2,656,000, the number of persons per acre varied from 7·3 to 253, and the sewage flow from 0·04 cubic foot per minute to 0·83, the maximum average flow per acre being 0·14 cubic foot per minute. The author has had many opportunities of verifying the details relating to London sewage-flow given in Table III. of this work, and it may be taken that they correctly represent the facts as now existing.

The following details are of interest as showing the growth of the Metropolis:—

Area, 122·10 square miles.

Population, North of Thames, 2,687,084. (Census 1891.)

Population, South of Thames, 1,523,972. (Census 1891.)

Details of outside districts draining into the Metropolitan drainage system:—

	Area, square miles.
Tottenham,	7·25
Hornsey,	4·00
So. Hornsey,	0·49
Willesden,	1·33
Ealing, Acton, Chiswick, parts of,	1·10
Beckenham, Croydon, parts of,	1·51
Total,	15·68

Total population draining to the works on the north side 2·90 million, and to those on the south side 1·524 million (census 1891).

It is probable that at least 200,000 persons more contribute to the sewage system now, as the growth of the population is quite 50,000 per annum, and Tottenham sewage is taken into the London sewers. The main object the designers of the main drainage system had in view, was the interception from the river of the dry-weather sewage, together with a moderate proportion of the rainfall. They calculated, in 1857, that in about 40 years time, a population of 3,448,500 would drain to the works, with a discharge of 5 cubic feet per head per day, and that, in addition, allowance should be made for carrying off a rainfall of 0·01 inch per hour in the urban districts, and one half that quantity in the suburban ones. Fortunately for the designers, experience has demonstrated that the sewers will carry far more than they were calculated to. Recently, in carrying out alterations at Barking—to be mentioned later on—the author constructed a permanent gauging-weir for the purpose of ascertaining at all hours the volume of sewage discharged. The weir is provided with a self-recording gauge, and great care is taken in order to obtain accurate results. Discharges of about 45,000 cubic feet per minute have been recorded, or upwards of 30 per cent. more than the sewers were calculated to carry by the designers of the system.

In the joint report on the "Main Drainage of the Metropolis," by Messrs. Bidder, Hawksley, and Bazalgette, of November 23rd, 1857, at page 142, the formula used in calculating the discharging capacities of the proposed sewers is given as follows:—

$$V = \sqrt{1 \cdot 6HF}$$

Where V = Velocity in feet per second.
H = Hydraulic mean depth in feet.
F = Fall in feet per mile.

We may extract the square root of 1·6 and place it outside, when—

$$V = 1 \cdot 265 \sqrt{HF}.$$

$$\text{and also } V = 0 \cdot 894 \sqrt{H,2F}.$$

$$\text{Therefore } v = 53 \cdot 64 \sqrt{H,2F}.$$

v being = velocity in feet per minute.

It will be observed, therefore, that the formula corresponds very nearly with the well-known one—$v = 55 \sqrt{H,2F}$, as given in the text-books, a formula which is fairly accurate for small pipes at ordinary gradients, but is not at all applicable to the enormous outfall sewers under consideration. In more recent years, however, much progress in the science of hydraulics has been made, notably by Darcy, Bazin, and Kutter, whose formulæ give results much superior to those of the older authorities.

In discussing the volume of rainfall to be dealt with, the joint report of November 1857, gives the following details:—

Savoy Street Sewer.

1857.

From 8 p.m., Oct. 21, to 8 a.m., Oct. 23, } Fall of rain 2·90 in. in 36 hours. Area drained = 116 acres.

	Cubic feet.	Cubic feet.
Produce of rainfall in area drained,		1,221,000
Yield of sewer during period named,	931,000	
Allow for sewage (dry weather),	145,000	
		786,000
Rainfall not yielded by sewer, or 35½ per cent. of total.		435,000

The district is entirely urban, and of rather steep inclination.

Ratcliffe Highway Sewer.

1857.

From midnight, Oct. 21, to 1 a.m., October 23, } Fall of rain, 2·895 inches. Area drained, 332 acres.

	Cubic feet.	Cubic feet.
Produce of rainfall on area drained,		3,489,000
Yield of sewer during period named,	2,124,000	
Allow for sewage (dry weather),	318,000	
		1,806,000
Rainfall not yielded by sewer, or 48 per cent. of total.		1,683,000

The district is entirely urban, densely populated, and of moderate inclination.

For the purpose of estimating the number of times per annum the proposed sewers would be inadequate to convey away both rainfall and sewage, the following Table was prepared by Mr. James Glaisher.

Recently, however, the author thought it desirable to obtain a similar series of observations, and he obtained from the Royal Observatory, Greenwich, the results tabulated with those of Mr. Glaisher.

TABLE XX.—RAINY DAYS AT GREENWICH.

Period.	·001 to ·10.	·101 to ·20.	·201 to ·30.	·301 to ·40.	·401 to ·50.	·501 to ·60.	·601 to ·70.	·701 to ·80.	·801 to ·90.	·901 to 1·01.	1·001 & upw'ds.
1847 to 1857 No. of days,	108	24	12	7	4	2	1·5	1·56	·82	·82	1·72
1880 to 1890,	93	32	15	10	5	2·1	1·1	1·00	1·00	·20	1·50
Averages, .	100·5	28	13·5	8·5	4·5	2·05	1·3	1·28	·91	·51	1·61

With the assistance of Mr. Glaisher's Table, the authors of the Report of 1857 estimated that overflows into the Thames would occur on twelve and a-half days per annum, and that 95 per cent. of the total volume of house, surface, and subsoil drainage would be carried to the outfalls, the remaining 5 per cent. escaping into the river by means of the storm-overflows. When the Royal Commission of 1884 inquired into the working of the main drainage system, evidence was given to the effect that although the number of rainy days might be correctly stated, and that "there were only fourteen to twenty-one days in the year in which there was over $\frac{1}{4}$ inch of rain in twenty-four hours, there would be more than that number when the rainfall would exceed $\frac{1}{8}$ in twelve hours, or $\frac{1}{16}$ in six hours, either of which would tend to produce overflow." (Report, 1884, p. xli.) Also on the same page we read:—

"These allegations are denied by the scientific witnesses of the Metropolitan Board, who contend that the system, with the proposed addition (of storm-overflows), affords ample provision, not only for the present, but also for the prospective drainage."

The calculated discharging capacities of the outfalls, as given in the report, are as follows:—

North side, ...	545	cubic feet per second.
South side, ...	233	,, ,,
Total, ...	778	,, ,,

As before stated, however, the outfalls discharge much more than the calculated quantity, and probably it will be not far from the truth to say that they can convey 1,000 cubic feet per second, or about 540 million gallons per day, or about three times the present dry-weather flow of 180 million gallons per day.

When the author had charge of the main drainage works on the north of the Thames (1890-93), he found that storm discharges occurred on about forty-eight days per annum, and that, on an average, rainfalls of ·13 inch and upwards per diem caused an overflow, although sometimes a fall of ·25 inch in twenty-four hours failed to do so.

We are naturally carried to a consideration of the separate system as regards London, when dealing with rainfall as affecting the London sewers, and from details obtained by the author, he found that under existing conditions, on the north side of the Thames, about 96 per cent. of the sewage proper is conveyed to the outfall, and that as regards street washings due to rain, out of a total of 162 "rainy" days, these washings, when there are any, are carried to the outfalls entirely on 114 days, and are partly so disposed of and partly discharged, together with a varying proportion of sewage, into the river on 48 days, for periods of time varying from a few minutes to several hours. As regards the quality of the street water, the analyses given on p. 9, Table I., show that it is often richer in polluting matters than ordinary sewage; but the samples were taken from streets with much vehicular traffic.

Under existing conditions, therefore, not only is about 96 per cent. of the sewage intercepted from the river, but a very large proportion of the street washings, and when it is remembered that the separate system would only save from the river the 4 per cent. of sewage now discharged into it, whilst, on the other hand, a large quantity of street-washings now carried to the outfalls would be discharged into the river, it must be conceded that from both the sanitary and financial points of view, the separate system for London is undesirable.

The facts relating to sewers of deposit, mentioned by the Royal Commissioners, are of great importance, and it is satisfactory to note that both the late Metropolitan Board of Works, and the London County Council, have done a great deal of good in the direction of reconstructing, under-pinning, and otherwise improving the gradients of the main sewers; whilst the Vestries' and District Boards of Works have also performed much useful work in the same direction, as regards the sewers under their respective charges; and, with a view to lessening the offensive character of the storm-discharges, the good work should be continued until every sewer in London is self-cleansing. That is the ideal which those engaged in the government of London should insist upon attaining.

In designing the main intercepting sewers on the north of the Thames, the engineers kept in view the importance of carrying as much of the sewage, as practicable, to the outfall, by gravitation, thus reducing the cost of pumping the remainder to a minimum. The sewage from the north of the middle-level sewer, therefore, flows by gravitation to the northern outfall at Old Ford, where it is joined by the northern high-level sewer—also a gravitation sewer—and the sewage from both sewers is conveyed by the outfall sewer to the sewage works at the mouth of Barking Creek. The area on the south of the middle-level sewer, together with that adjoining the River Lee, and including the Isle of Dogs, is drained by the northern low-level sewer; the Western portion of the area is drained, in the first instance, to the Western pumping station at Pimlico, where the sewage is lifted 18 feet into the northern low-level sewer. The dry-weather sewage flow pumped at this station is about 20 million gallons per day; moderate falls of rain are pumped with the sewage, but when the northern low-level sewer is fully charged, both sewage and rain water are diverted into the Thames. There is a second pumping station at Abbey Mills, where the sewage from the Western district is again pumped, together with that collected from the remainder of the low-level area, the average daily flow amounting to about 68 million gallons.

An important extension of this pumping station has recently been completed, under the superintendence of the author, by the building of a new pumping station, with Worthington engines as illustrated.

These engines are patented triple-expansion high duty Worthington sewage pumping engines, by Messrs. James Simpson & Co., Limited, Pimlico, London, S.W., each capable of lifting 18,000,000 gallons of sewage per 24 hours, with a boiler pressure of 125 lbs. per square inch. The leading dimensions are as follows :—

High pressure cylinder, . .	15 inch	All of 48 inch stroke.
Intermediate pressure cylinder, .	22 ,,	
Low pressure cylinder, . .	33 ,,	
Pump plungers, ...	36 ,,	

All the cylinders are steam-jacketted. The steam distribution valves, which are of the Corliss type, are arranged below the cylinders, by which arrangement a thorough system of drainage is maintained, following the latest Continental practice.

The cut-off valves are variable by hand, and may be adjusted to cut off at any point of the stroke by handwheels worked from the platform.

The engines are finished in the very best style, all links and levers being bright, and the whole presents a very fine appearance.

One of the main features of these engines is the exceptionally large pump ends, which are fitted with specially designed pump valves suitable for passing sewage. The whole of the machinery is above the floor line, so that everything is in view and readily accessible for examination.

Five similar engines have been supplied to Rotterdam, two for their West Station, each having a capacity of 15,000,000 gallons in 24 hours, one for their East Station having a

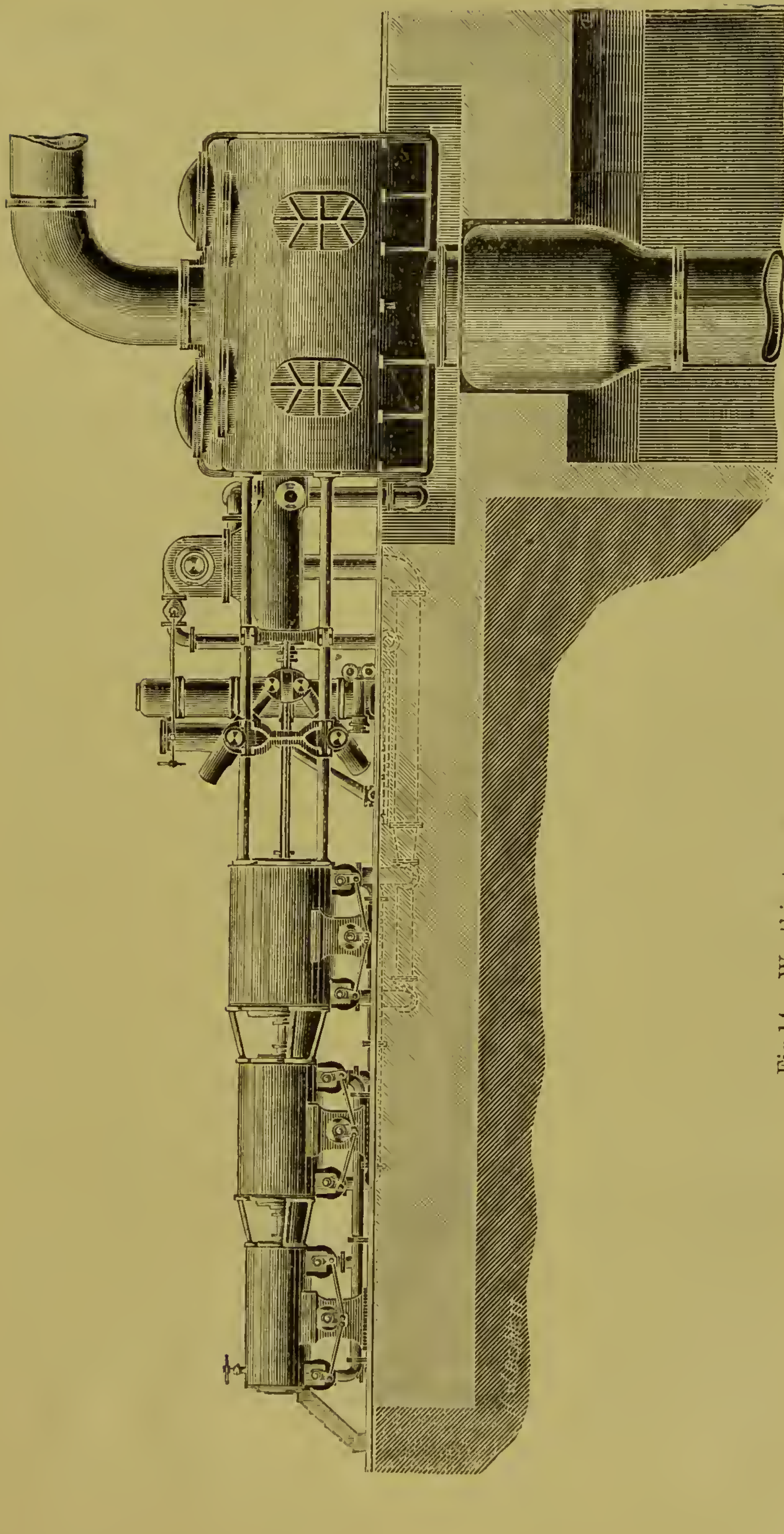


Fig 14.—Worthington sewage pumping engines at Abbey Mills.

capacity of 15,000,000 gallons in 24 hours, and two for their Blommersdyk Station, each having a capacity of 3,000,000 gallons in 24 hours.

Also, four sewage engines, each having a capacity of 15,000,000 gallons in 24 hours, have been supplied to Bombay, India.

All the sewage on the north of the Thames gravitates from Abbey Mills to the outfall works at Barking Creek.

On the south of the Thames all the sewage is pumped, in the first place, as regards the southern low-level area, at Deptford, and, in the second, as regards the whole, at Crossness. At both these pumping stations, the sewage may be diverted into the river during periods of heavy rainfall.

In order to deal with storm waters, the old outlets of the main sewers into the Thames and Lee have been preserved, and are provided with tide valves, penstocks, and other suitable appliances, in order to prevent the river water entering the sewers when the tide is high enough to do so. These old outlets, 34 in number, formed a conspicuous part of the inquiry into the drainage of London by the Royal Commission of 1887. There is an enormous storm-overflow into the Lee at Old Ford, which is not affected by the tide, as well as one or two others, which are carried from the Thames to a point inland, sufficiently remote from the tidal influence as to enable them to act whenever there is a heavy fall of rain. When a storm of rain occurs at or near the time of high water in the Thames, there are large areas, which would be flooded if means were not provided for pumping the storm-water into the river, and there are four auxiliary pumping stations for the purpose—namely, one near Vauxhall Bridge, and one at the Isle of Dogs, on the north of the Thames; one at Battersea and one at Lambeth, on the south. The necessity for these pumping stations will be evident when it is remembered that large areas in the vicinity of them are below the level of high water in the Thames at spring tide. The author has given a brief outline of the existing sewerage works of the Metropolis, in order that the reader may form an idea as to the means by which the sewage is conveyed to the outfalls, and in this connection, although by reason of the extraordinary growth of the Metropolis, further extensions of the outfall sewers are contemplated, he is unable to leave this part of the subject without paying a tribute to the skill and ability of the designers of the system, and in particular to the late Sir Joseph Bazalgette, who in spite of an almost incredible amount of opposition on the one hand, and very great engineering difficulties on the other, carried to a successful issue one of the greatest engineering works of modern times.

We must now pass on to a consideration of the manner in which London sewage is disposed of, a subject which has attracted a vast amount of attention during recent years. The outfall works at Barking and at Crossness are the immediate outcome of the conclusions of the Royal Commissioners on Metropolitan Sewage Discharge, 1884. These conclusions are given *in extenso* at page 26 of this work, but it will be observed that finality was not supposed to be within reach at the present outfalls, because the Commissioners say they do not believe that the effluent, resulting from chemical treatment, can be permanently discharged into the river. They say—"It (the effluent) would require further purification; and this, according to the present state of knowledge, can only be done effectually by its application to land."

Before describing the manner in which the sewage is dealt with, it is desirable to study the composition of London sewage, but there is no connection whatever between the sewers on the north of the Thames with those on the south. The sewage on the south side is probably only four-fifths the strength of that on the north, in consequence of the somewhat dilute condition of the former.

TABLE XXI.—AVERAGE COMPOSITION OF LONDON SEWAGE AT BARKING. (*Dibdin.*)

ALL QUANTITIES IN GRAINS PER GALLON.

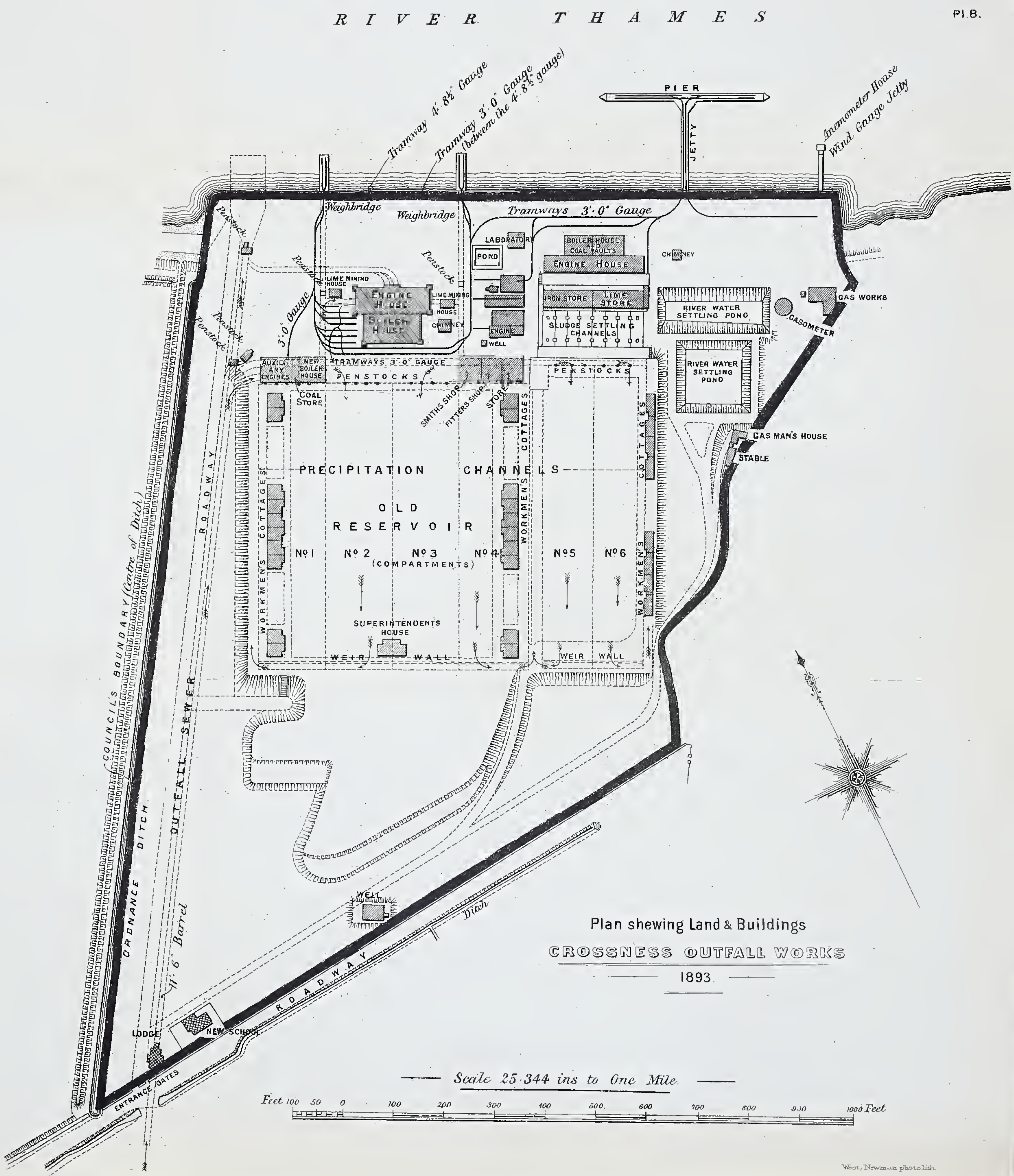
Suspended Matters.	Total Dissolved Solids.	Chlorine.	Ammonia.		Oxygen absorbed from Permanganate.		Remarks.
			Free.	Albuminoid.	In 15 mins.	In 4 hours.	
26·80*	59·80	8·00	3·41	·349	1·90	4·01	The samples were always taken at the Barking Outfall Works.

With regard to the suspended matters, as on the north of the Thames about 44 grains per gallon are sent to sea in the form of sludge, whilst 4 to 6 grains per gallon escape into the river with the effluent, and at the storm-overflows, the quantity given in the Table is doubtless much below the actual quantity, although it must not be forgotten that the chemicals added to the sewage for the purpose of clarification, increase the normal amount of suspended matters. The sewage discharged at the Barking Works is somewhat stronger than that at Crossness, probably in consequence of less infiltration of subsoil water into the sewers on the north of the Thames. Up to the middle of 1893, the sewage flow for the year, to Barking, averaged 38 gallons per head per day, and to Crossness 48 gallons; as the part of the year under consideration was very dry, it is probably very nearly true to say that London sewage on the north of the Thames averages 40 gallons per head, and on the south 50 gallons per head per day.

The operations carried on at both Barking and Crossness are, as regards the treatment of the sewage identical. A general plan of each station is given with this chapter, and the reader need not be troubled with details relating to Crossness, since they would for the most part be only a repetition of those relating to Barking.

With regard to the volume of sewage dealt with at Barking, the average flow for the year ending March 31st, 1893, was

* *Note.*—This quantity is much too low.



Plan shewing Land & Buildings

CROSSNESS OUTFALL WORKS

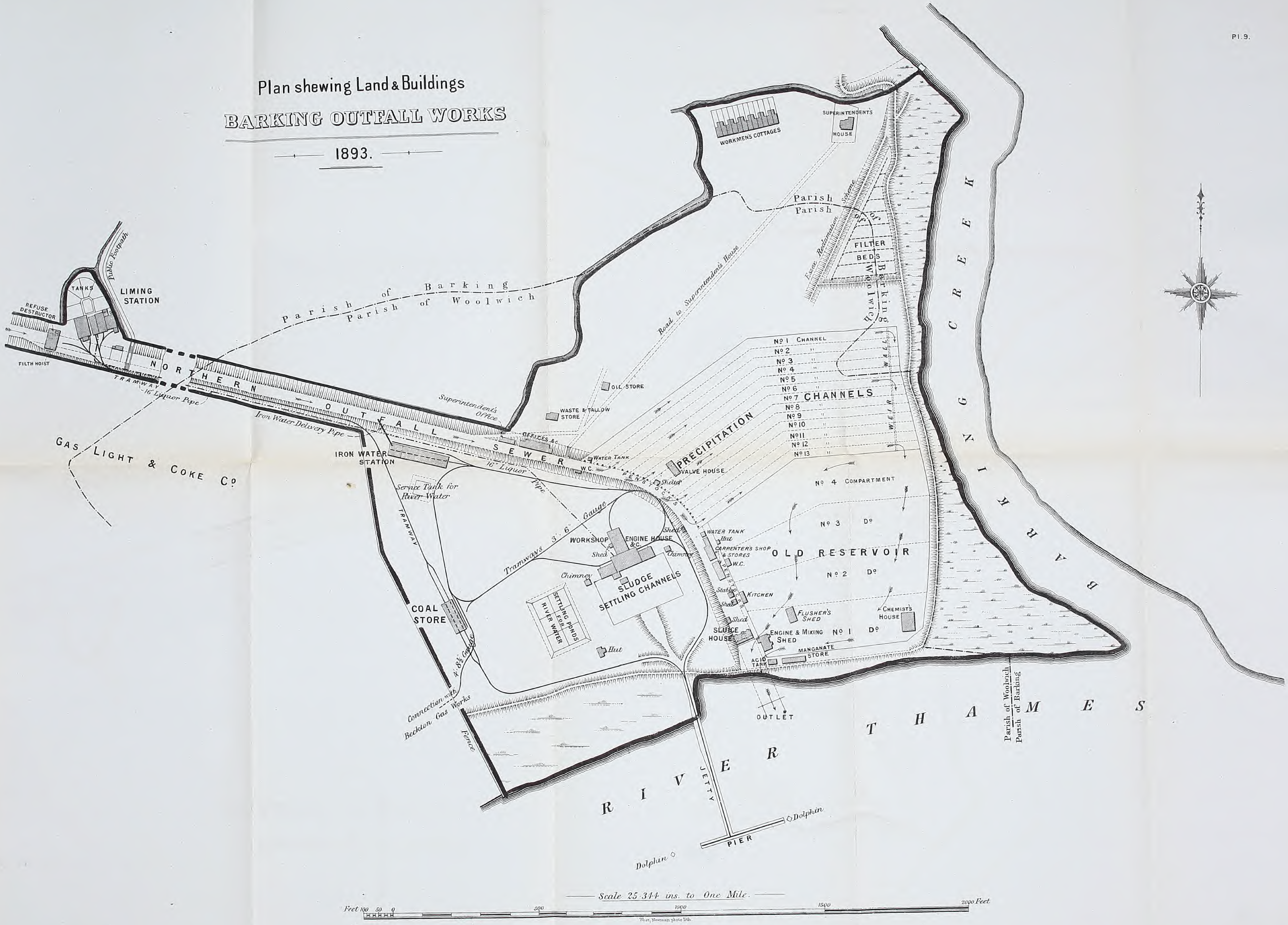
1893.

Scale 25·344 ins to One Mile.

Feet 100 50 0 100 200 300 400 500 600 700 800 900 1000 Feet

West, Newman photo lith.

Plan shewing Land & Buildings
BARKING OUTFALL WORKS
1893.



112·6 million gallons per day; the dry weather flow is about 104 million gallons per day.

On arriving at the liming station shown upon the plan, the sewage is screened by means of large iron cages, the larger suspended matters are removed, and are burnt in a two-cell destructor of the Fryer type, together with the screenings from the sludge—which are taken out in order to prevent clogging of the pump valves. The amount so dealt with is 117 tons per week; dust and clinker are produced, and this part of the process is effectual in actually destroying a very large amount of organic matter, which would otherwise float through the settling tanks and pass into the river.

Immediately on passing the straining cages, the sewage receives its dose of lime-water, amounting to about 4½ grains of lime per gallon. The lime water is prepared by first making milk of lime with a portion of the sewage, this is then discharged into a channel which contains a further supply of sewage, sufficient in quantity to dissolve the lime when allowed sufficient time in the tanks, which, it will be observed, have been provided for the purpose. The lime-water is then pumped into an iron tank, which forms the roof of part of the lime store, and from which it flows into the sewers, and is soon mixed with the sewage. The next operation is that of adding the protosulphate of iron, which is first dissolved at the iron-water station, and then flows into the sewers; the mixing action, due to the rolling motion of the sewage, goes on until the sewage arrives at the precipitation channels, thirteen in number. Each channel is really a long and narrow settling tank, 30 feet in width, and varying in length from 860 feet in the case of No. 13, to 1,210 feet in that of No. 1. These tanks hold collectively about 20 million gallons, or about two and three-quarter hours' sewage flow during the period of maximum discharge (dry weather), after making an allowance for those out of work for cleaning operations. The tanks were designed to work on the intermittent system, but the volume dealt with is so enormous that rapid currents were set up on bringing the arrangements for drawing off the effluent water into operation, and, as a result, two-thirds of the sludge were carried off with the effluent. This matter deserves careful attention; imagine a tank, of the magnitude of one of those under consideration, filled with treated sewage and allowed a period of rest of say two hours' duration; a thin film of sludge will be found on the bottom, and in order to remove this, the clarified water must be drawn off to within an inch or so of the sludge without disturbing the latter, and the tank must be cleaned out. In practice, this was not done, the water could not be drawn off without disturbing the sludge, therefore the tank was charged again and again until there was a large accumulation of sludge, when it was removed. At each re-charging, the sludge already in the tank was again mixed with the sewage, and was carried forward to the end of the tank, from which it was necessary to sweep it into the sludge settling channels by manual labour. On laying these facts before Mr. Binnie, the Council's chief engineer, he at once sanctioned the alteration of the system to the continuous one, and the author built the weir walls, shown upon the plan, over which the effluent water passes, with, of course, the exception of that drawn off by means of part of the old arrangements, for cleansing purposes. The immediate effect of the change was to increase the quantity of sludge from a weekly average of about 8,000 tons to about 23,000 tons for the same period, whilst the cost of cleansing the tanks was materially reduced, as the greater part of the sludge subsides near the inlets of the tanks. In times of heavy rainfall, again, the system as now in operation is much superior to the old system, since there are no valves to open upon a sudden rush of storm-sewage taking place, and all the sewage can be passed through the tanks, even when increased in volume to the extent of four times, thus enabling much of the suspended matters to be removed.

The effluent water, in passing over the weir walls, flows along the channel in the direction indicated on the plan by the arrows into the old reservoir, which was built for storage purposes by the late Metropolitan Board of Works when the main drainage works were first constructed. It now serves as a store for the effluent when the outlets are tide locked, thus the greater part of it is discharged upon the ebb tide.

The effect of the treatment is to clarify the sewage, but the dose of chemicals used is too small to absolutely deodorise it. The author does not suggest, however, that this is necessary in the case under discussion. During the past summer, when the state of the river, as shown by the amount of dissolved oxygen contained in it, demanded further treatment of the effluent, manganate of soda with sulphuric acid were added to it at the rate of about 1 grain per gallon. The sludge, which now amounts to about 25,900 tons per week, is swept from the precipitation channels into a tank under the floor of the engine-house, from which it is pumped into the sludge-settling channels. As swept from the tanks, it contains much more water than when sent to sea, and in order to separate as much as possible, the sludge-settling channels were constructed. The liquor drawn off from the sludge in these channels, is pumped back to the liming station, where it is employed, with sewage, in the manufacture of lime-water.

As before stated, the works at Crossness are the same in principle as those at Barking, but the population draining to them is only about one-half that at Barking; as a consequence, the sewage and sludge are much less in quantity, the sewage, for instance, averages about 74 million gallons per day, and the sludge about 12,050 tons per week. Taking the average flow of the north side at 113 million gallons per day, the total volume dealt with at both outfalls is 187 million gallons per day, producing about 5,430 tons of sludge, containing about 91 per cent. of moisture.

All the sludge is conveyed to the Barrow deep, practically the German Ocean, by means of five twin-screw steamers, each of a carrying capacity of 1,000 tons, but a sixth steamer is about to be added in order to provide for contingencies. During the current year the sludge will probably amount to 2 million tons, and this enormous quantity will be deposited in what is practically the open sea, some 50 miles below the outfalls, to the great advantage of the Thames and of the Metropolis. The quantity is so vast that, in order to properly appreciate its mass, it must be remembered that it would cover no less than 500 acres to a depth of 3 feet.

The new works at Barking cost about £480,000, those at Crossness about £330,000, the five sludge steamers about £125,000, and as further works are now in progress, it is probable that the total final cost will be one million sterling.

The estimated cost of dealing with the sewage, together with that of dealing with the sludge is, for the current financial year, £110,000, or about 32s. per million gallons. The maintenance and working of the five sludge steamers is estimated at £30,850, and this sum is included in the total sum given above. There can be no question that the system of dealing with the sludge is, from every point of view, the best that could be devised as regards the Metropolis.

Whether finality, as regards sewage treatment, has been reached or not, the author would not venture to offer an opinion; there is, however, one fact that cannot be ignored, and that is that the condition of the Thames below bridge is better now than it has been during, probably, the present century. Recently the author has assisted in making some experiments in artificial filtration at the Barking outfall, and it has been demonstrated that, should the necessity arise, a very high degree of purification can be attained by passing the effluent through filters, and that a non-putrescible effluent can be discharged into the river at the present outfalls.

Pl. 10

West, Newman photo-lith.

CHAPTER XI.

DONCASTER IRRIGATION FARM.

The borough of Doncaster has an area of 1,690 acres, a population of 27,000, and a ratable value of £111,656. There are 1,670 water-closets, and 2,372 privies with ash-pits in use. The dry-weather sewage amounts to 650,000 gallons per diem.

The outfall sewers discharge their contents at the pumping station (see key plan), which is situated upon the south bank of the river Don. Here a pair of compound beam-engines are employed in pumping the sewage, which is forced through a 21-inch cast-iron main to the highest point of the sewage farm, the lift being 22 feet. Storm-water overflows are provided near the river in order to relieve the sewers, the pumping machinery, and the sewage farm, from excessive volumes of rain-water, the separate system not being in operation. At night the sewage is not pumped, except in wet weather, the sewers being of sufficient capacity to contain the night sewage. Before entering the pump-well, the sewage is screened through cages constructed of strong iron rods.

Upon the completion of the main-drainage works in 1870, the sewage flowed by means of an existing outlet into the river Don, but the proprietors of that navigation obtained an injunction against the Corporation of Doncaster, restraining them from discharging their sewage into the Don, in consequence of which the sewage disposal works were established in 1873, Mr. B. S. Brundell, M.Inst.C.E., acting as Engineer to the Corporation.

The sewage farm, available for sewage disposal, is of an area of 278 acres, the surface is very undulating over a great part of the farm, whilst the soil varies from that of a light sandy character to a stiff red stratified clay. In addition, there is an area of 20 acres of pasture land now laid out for sewage. Mr. Brundell states, in a communication to the author, that "all the land on the east of the Thorne Road is light and sandy, whilst that on the west side is of clay. At the sandpit there is a sand-hole 20 feet in depth, whilst on the other side of the road there is clay 20 feet in depth. It almost seems that a fault exists under the road itself."

Drainage.—With the exception of the small portion intended for use as a filtration area, drains have been laid only in order to relieve the valleys and low places. As an example of the undulating character of the surface, the drain running from the point E to the point F on the plan, is in places 20 feet in depth. The levels upon the plan indicate clearly the chief irregularities.

Surface Preparation.—With such undulating surfaces, the levelling of the land as in downward filtration areas, was out of the question. The surface - falls in some of the fields vary from 1 in 25 to 1 in 50. "The principle which governed the laying out was to alter the surface as little as possible, but rather to make the sewage fit the surface, so that the carriers were laid along summits, and then, by means of contoured grips, the sewage is led on to the land" (*Brundell*).

Carriers and Distribution.—"The main carriers leading from the sewage tank—which is not much used—are of glazed socket-pipes laid either below the surface or in embankments, as the exigencies of the case demand. These carriers are sometimes worked under a small head of sewage. The subsidiary carriers are grips cut in the land, not always in parallel lines, but rather in such positions as will admit a fall of 1 in 300 being obtained for them. Ordinary stoppers are employed for the purpose of diverting the sewage on to the land."

"**Rotation of Crops.**—Rye-grass or seeds (clover), 1 or 2 years (occasionally rye-grass stands for three years); roots, mangold-wurzel or swede turnips, 1 or 2 years; corn 1 year, and when the year for corn comes round no sewage is applied to the growing crop" (*Brundell*).

In consequence of the large area of the farm great varieties of crops are produced. According to the *Report of the Judges on the Sewage Farm Competition*, appointed by the Royal Agricultural Society, 1879, the following crops were produced in 1879:—Black currants, gooseberries, raspberries, peas, mangolds, wheat, barley, oats, rye, beans, potatoes, turnips and swedes, fallow, clover seeds and rye-grass, meadow grass and osiers. "The volume of sewage applied to various crops differed enormously; as much as 17,505 tons per acre were applied to rye-grass in 1878, which was equivalent to a vertical irrigation depth of 173 inches in the year. Mangolds received 6,455 tons or 64 inches in vertical depth, and permanent grass 4,504 tons per acre or 45 inches in depth; while beans required only 188 tons per acre, or 1¾ inch in depth" (*Report of the Judges*).

Live Stock.—"There are 10 working horses, 20 milch cows, 20 to 30 head of young stock bullocks, and 60 breeding ewes, upon the farm. At first there was a certain amount of prejudice against the milk produced, but it is now accepted without hesitation. The effluent water flowing from the farm is small in quantity, and is discharged into the river Don, which is much polluted by the towns situated above Doncaster. The relative volumes of the effluent and the river are, in dry weather, as 1 is to 2000" (*Brundell*).

Mr. Brundell further states that the process is entirely satisfactory. "The sewage of the town is satisfactorily got rid of at small cost to the ratepayers. No nuisance arises anywhere, and the general feeling is that a sewage farm was the best means of dealing with the sewage at Doncaster."

SANDALL GRANGE

Dr. TRADING ACCOUNT

To Balance from last Account,	£145 14 8
,, Stock, as valued last year,	4,050 10 8
,, Gross Profit carried down,	2,567 19 2
	£6,764 4 6

Dr. PROFIT AND LOSS ACCOUNT,

To Expenses, viz.:—		
Labour,	£567 16 1	
Rent, Rates, and Taxes,	933 6 7	
Oilcake, &c.,	105 11 2	
Seeds,	39 3 9	
Salt, Manure, &c.,	22 17 0	
Renewal of Live Stock,	244 0 0	
Management,	100 0 0	
Tradesmen's Bills, &c.,	155 15 4	
		£2,168 9 11
,, Rent owing, February 2, 1886,		433 16 2
		£2,602 6 1

Dr. BALANCE SHEET,

CAPITAL AND LIABILITIES.

To Subscribed Capital,	£4,000 0 0
,, Rent owing, February 2, 1886,	433 16 2
	£4,433 16 2

SEWAGE FARM.

For the Year ending February 2, 1886. **Cr.**

By Rent owing, February 2, 1885,		£346 9 9
,, Sales, viz. :—		
Corn,	£701 1 4	
Live Stock,	636 9 2	
Roots and Green Crops,	764 16 1	
Sundry Sales,	163 5 6	
		2,265 12 1
,, Stock outstanding, viz. :—		
Implements,	£689 0 0	
Buildings,	98 5 0	
Live Stock,	1,269 0 0	
Corn, Hay, Roots, &c.,	937 0 0	
Tenant Right,	1,158 17 8	
		4,152 2 8
		£6,764 4 6

February 2, 1886. **Cr.**

By Gross Profit as per Trading Account,	£2,567 19 2
,, Net Loss,*	34 6 11
	£2,602 6 1

February 2, 1886. **Cr.**

PROPERTY AND ASSETS.

By Implements, valued at £725, 5s., less 5 per cent.,	£689 0 0
,, Buildings, ,, £103, 8s., ,, ,,	98 5 0
,, Live Stock, valued at	1,269 0 0
,, Corn, Hay, and Roots, valued at	937 0 0
,, Tenant Right, valued at	1,158 17 8
,, Balance in Bank,	247 6 7
,, Net Loss,	34 6 11
	£4,433 16 2

* No interest paid on capital invested, viz., £4,000, so that the loss would be £34, 6s. 11d. + £160, interest at 4 per cent. say.

Financial Summary.—The Corporation are the owners of an estate of 700 acres in extent at Sandall. A portion of this estate forms the sewage farm, viz., 278 acres. The capital expended upon the farm in preparing it for sewage disposal has been as follows:—

Materials, and laying out the land, . .	£3,500
Tenant for labour (laying out part of farm),	300
Buildings, ...	1,000
Extra buildings, cost to tenant, . . .	350
Total, ...	£5,150

The pumping station, machinery and rising-main cost £18,000.

The farm was let for the first fourteen years at a yearly rental of £825 (including cottages). It is now let at an inclusive yearly rental of £550.

The subjoined balance sheet is fairly representative (*Brundell*).

This farm was awarded a second prize in Class II. by the Judges appointed by the Royal Agricultural Society in the Sewage Farm Competition, 1879. About 20 persons reside upon the farm, and their health is stated to be good.

CHAPTER XII.

BEDDINGTON IRRIGATION FARM, BOROUGH OF CROYDON, 1889.

Area, Population, &c.—The area of the borough is 9,014 acres. About 6,314 acres in the south, central, and west parts of it drain to this farm, with a population of about 73,000.

The ratable value of property draining to this farm is about £410,000.

The 14,600 houses in this drainage area have, with very few exceptions, only water-closets, of which it is estimated there are about 20,000.

Sewage Outlets.—There are two outlets of sewage on to the farm, one from Croydon, and the other from Thornton Heath and Upper Norwood. The dry-weather flow varies somewhat with the height of the subsoil water in Croydon Valley, but it may be put at 3½ million gallons in twenty-four hours.

The sewage flows on to the farm from both outlets by gravitation.

About half the roads in the drainage area have surface-water drains in them, with whieh the road gullies are connected, and they discharge into the river Wandle and Graveney brook. Still the volume of storm-water entering the sewers is occasionally very great, and several times a year it may be put at 16 million gallons in twenty-four hours. There is no storm-overflow in any shape or form, and the whole of the storm-water entering the sewers is delivered on the farm. There, in order to cleanse it, it is sometimes run over all the grass land, and other plots as well, to the injury of the erops.

Farm.—The whole of the farm is the freehold of the Corporation, and eontains 525 statute acres, with four farm-steads, the manager's house, and fourteen cottages. Four hundred and twenty acres are laid down for broad irrigation.

About 105 acres are oecupied by farm buildings, cottages, strips of land alongside roads and high ground.

The farm overlies the Woolwich and Reading beds, and the subsoil is chiefly of gravel (very open in some places) and sand. The soil varies considerably, from loam to a light free open soil, but all is very suitable for irrigation. The aspect of the farm is a gentle slope from east to west, averaging about 1 in 175. The farm is compact, the upper side of it being about 1,000 yards from the nearest part of the borough of Croydon, and the outlet side about 450 yards from the river Wandle, into whieh there are two outlets for the effluent water.

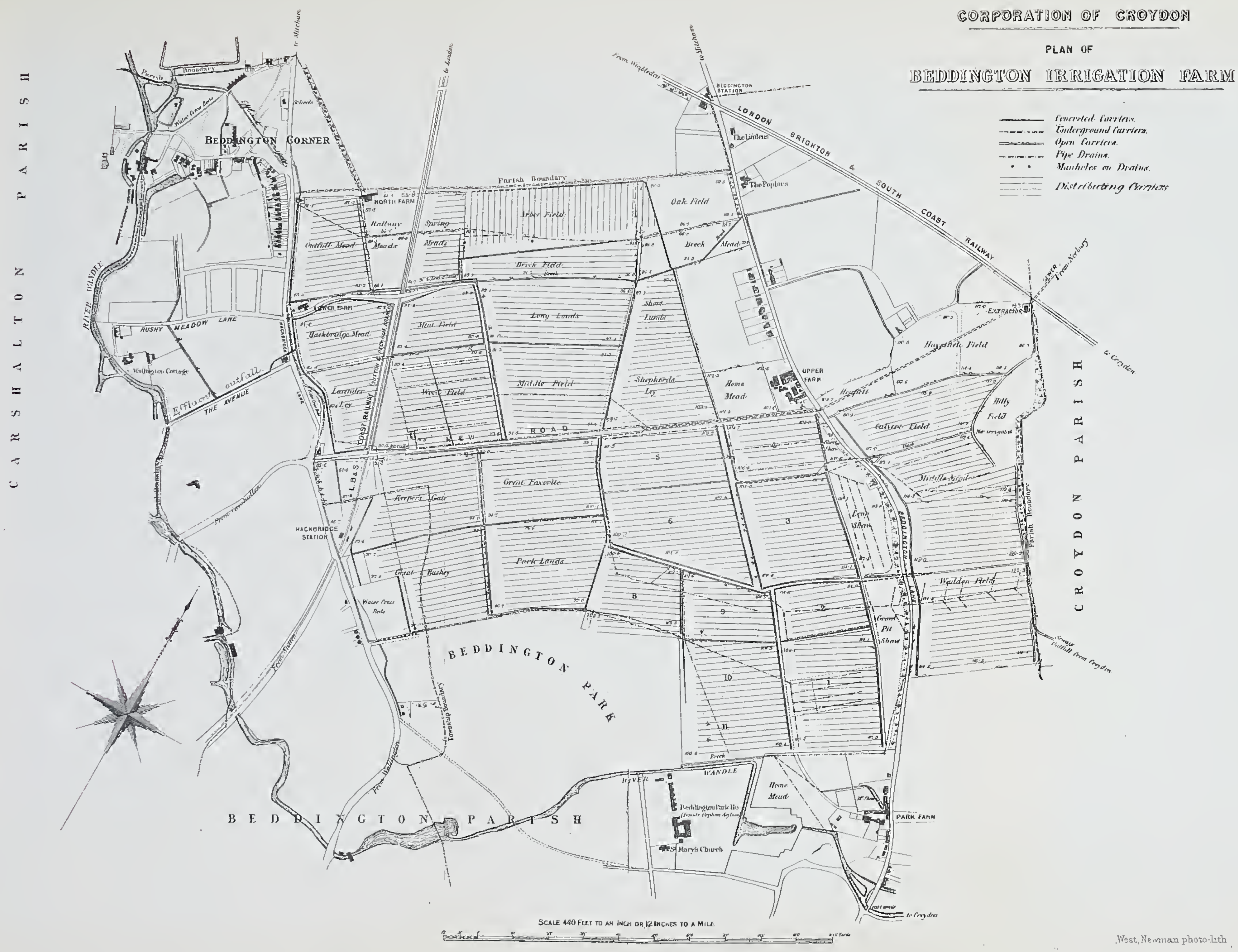
Irrigation.—Irrigation upon part of the farm was begun in

1860, and has since been continuous. There was no under-drainage until ten years ago, and now about 100 acres have drains, generally very wide apart, and from 4 to 9 feet deep, varying in diameter from 4 inches to 2 feet. Although these do not perhaps greatly assist in cleansing the sewage, yet they help to quicken the drainage of the land after the sewage is taken off it.

The ground naturally lying with a very even fall towards the Wandle, the only preparation required was to adjust the surface to suit the carriers, raising some places and lowering others, but so little, that still a proper thickness of soil was left for cultivation.

The bringing-on-carriers at the top of the plots are usually of concrete, from 2 to 4 feet wide, and level as long as the ground permits. If at any place it is necessary to have a drop, this is done by means of a wooden sluice. It will be gathered from this that some of the suspended matters in the sewage subside in the carriers, and this has to be removed from time to time by manual labour.

Small trenches are made with the plough from the bringing-on-carriers down the greatest fall, at a distance from each other of about 50 feet. The ground is a little lower between these trenches, to make the sewage spread over the entire surface. Movable galvanised iron or wooden stoppers, are used to divert the water at varying distances down the trenches. These trenches end about 50 yards from the bottom of the plots, the hollowing ceases, the ground is thus level across, so that the whole breadth of land is irrigated. A pick-up-carrier runs along the bottom of the plot, over the edge of, and into which, the effluent water passes. The system in use is that of surface or broad irrigation, and as a rule, the sewage passes over three separate portions of the farm. It is first passed on to one portion, which is covered with it; from thence the sewage, partially purified, flows to a second portion of the farm, and then to a third, from which it passes in a pure state. The time occupied in passing over



West, Newman photo-lith.

Wages and Manager's salary,	£2,801
Corn and seeds,	220
Horse hire,	30
Implements, ironmongery, and repairs,	133
Repairs to buildings,	36
Rates and tithes,	660
Sundries,	346
	£4,226

During the same time the sales of produce have averaged—

Grass,	£1,682
Mangolds,	914
Cabbage, rhubarb, and potatoes,	882
Stock keep,	544
Hay, straw, wheat, and oats,	387
Sundries,	95
	£4,504

The cost of the 525 acres of freehold land has been £138,771. That of the works, in laying them down, the underdrainage, the outfalls to the river Wandle, farm buildings and cottages, has been £18,000. The annual sinking fund and interest upon the above was last year £7,352, and adding for working expenses and allowing for receipts for produce, the net annual cost has averaged during the past three years £7,074.

Sanitary.—The number of persons living in the fifteen houses on the farm is seventy-two, and their general health is extremely good. The population of the parish of Beddington, in which the farm is situated, is 8,015, and the death-rate in it during the past two years has averaged 7·82 per 1,000. The parish is sewered, the sewage passing into the Croydon Rural Sanitary Authority's system of drainage, and being treated at the Merton Sewage Farm, some three miles distant.

There is no difficulty in cleansing the sewage in the severest frost. The practice is to flow it over ploughed land that will be sown with mangold, and also over the worst rye-grass plots.

Ice is formed on the surface, but the sewage flows underneath it, and the purification still goes on although it requires more area, and the effluent may not be quite so good as at other times.

Effluent Water.—The effluent water passes into the river Wandle, which is usually a clear pellucid stream of chalk water, and rises from springs within 3 miles of the farm outlet. The average relative volume is about one of effluent to eight of river-water. Mr. Walker, M. Inst. C.E., Borough Engineer of Croydon, has assisted the author in the preparation of the foregoing details.

CHAPTER XIII.

BEDFORD SEWAGE FARM—IRRIGATION, 1889.

In 1879 two prizes, each of the value of £100, were offered by the Mansion House Committee in connection with the London International Exhibition of the Royal Agricultural Society of England for the best managed sewage farms in England and Wales. The prizes were accepted by the Council, and one of them was offered in Class I., for sewage farms utilising the sewage of not more than twenty thousand people.

The Bedford and Wrexham sewage farms divided the prize in Class I., and the Bedford farm forms the subject of the present chapter.

By consent of the Council of the Royal Agricultural Society the Report of the Judges—Messrs. Baldwin Latham, Clare Sewell Read, and Thos. H. Thursfield—is given nearly *in extenso*, but is corrected in some particulars so as to fairly represent the present condition of the farm.

"**Farm.**—This farm is held under five separate owners, to whom the following rents are paid by the Corporation of Bedford:—

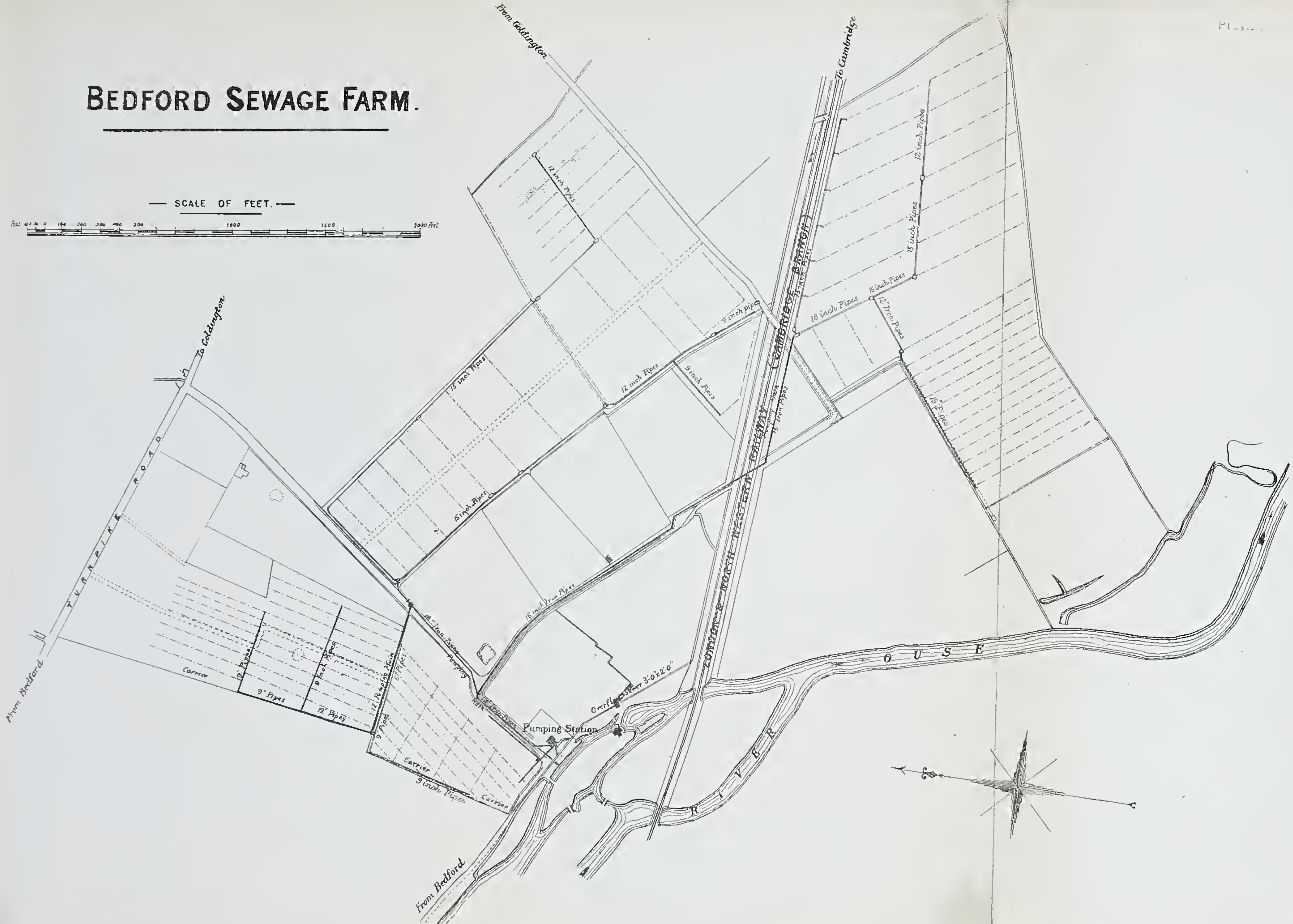
Owners.	Acreages.			Rent Paid.		
	A.	R.	P.	£	s.	d.
Duke of Bedford, ...	43	2	11	196	0	0
Captain Polhill Turner, M.P., . . .	80	0	0	426	0	0
Rev. J. G. C. Campion, ...	20	1	27	130	0	0
Corporation of Bedford, ...	27	2	34	124	0	0
Hospital of St. John, ...	11	1	30	51	10	0
	183	0	52	927	10	0
Add paid to London & North-Western Railway Company for sewer crossing under Railway, ...				1	0	0
				928	10	0

"The farm was established in 1868, and is managed for the Corporation of Bedford by Mr. J. H. Collett, and it receives the sewage of the borough of Bedford, which contains a population of 27,000 persons, and is of the ratable value of £105,000. Of the 183 acres 0 rood 22 poles, 153 acres 1 rood 2 poles are arable, and 29 acres 3 roods 20 poles pasture; and 153 acres of the farm are irrigated with sewage. The soil of the farm is light land, the subsoil being gravel.

"**Experiments on absorption** have been made with two samples of the soil, which show, on an average of three experiments with the most sandy soil, that it is capable of absorbing 33·6 per cent. of its weight in water, and that the more loamy soil would absorb 42·3 per cent. of its weight in water. As a rule, the smaller the percentage in water absorbed, the greater is the percolating power of the water through the soil.

"The sum of £6,950 has been expended upon this farm and upon the works necessary for lifting the sewage upon it, the expenditure being divided as follows:—

BEDFORD SEWAGE FARM.



West, Newman photo-lith.

Cost of land on which pumping works are placed,				£250	0	0
Engine and boiler-house,	£779	15	2			
Pump, engines, &c.,	969	17	3			
Cast-iron delivery main,	748	4	4			
Miscellaneous,	352	18	10			
				2850	15	7
Compensation,				53	1	0
Farm buildings,				603	11	8
Labour, laying out farm, making roads, &c.,	£1213	9	1			
Horse-hire for ditto,	331	3	9			
Pipes, bricks, &c., used on farm,	1647	19	7			
				3192	12	5
				£6950	0	8

"**Pumping and Distribution.**—The sewage from Bedford is brought by gravitation to the site of the pumping station, which is situated upon land contiguous to the farm and adjoining the river Ouse, into which there is a storm-water overflow. When the river is in flood, we were informed that the sewers were liable to be flooded from the leakage into the outfall sewer; and at such times the sewage, with the exception of such portions of the solids as are retained by a grating, is turned directly into the river, as we found on our second visit to this farm, when the whole of it was passing into the river. At the pumping station there are a pair of horizontal high-pressure engines working centrifugal pumps, which are employed to lift the sewage on to the farm. The following figures show the acreage and the height to which the sewage is lifted:—

A.	R.	P.	
30	0	21	Sewage requires to be lifted 21 feet.
123	0	1	,, ,, 13 ,,
30	0	0	Not irrigated.

"At the sewage pumping station there is a tank with an iron screen across it, which intercepts some of the solid matter from the sewage, and a man is engaged to keep this screen free. The matter removed from the sewage, which is a comparatively small quantity, is either used upon the contiguous garden or upon the farm. The pumping is usually only carried on in the daytime. At night the sewage is stored in the sewers, and the average daily quantity pumped is

950,000 gallons. The quantity of coal used daily to raise the sewage, averages 21 cwts. The sewage having been screened, is pumped through an 18-inch iron delivery-main, having a 15-inch iron branch delivery-main to one part of the farm; from thence it is distributed in earthenware pipe-carriers which vary in size, from 18 inches to 9 inches in diameter, and are laid in embankments above the surface of the land. The distribution of the sewage over the land irrigated, is through earth-cut channels, which are ploughed or dug out from time to time as required. A small portion only of the farm, about 5 acres in extent, has been under-drained with 2-inch pipe-drains, 60 feet apart and 3 feet deep. Very little effluent was flowing through these drains at the time of our inspection, but the whole of the fields of the sewage farm are surrounded by deep ditches, which tend very materially to drain the subsoil. We were informed that if the circumstances had admitted of a greater depth being given to the land drains, they would have been placed lower, but the falls in this case would not admit of the drains being laid deeper.

"**Crops.**—A great variety of crops are grown upon this sewage farm, which is treated as a combined sewage farm and market garden. It is somewhat singular that the peculiar crop, whatever it may be, that suits the neighbourhood, seems to flourish under sewage. Lucerne is a plant which we would not select as the most likely to be benefited by sewage, yet in Paris it is almost the only green crop grown on the sewaged land, it being the favourite provender of the district. So onions, that are grown in great profusion around Bedford, seem to flourish upon sewaged land, and appear the most profitable crop to grow. The following Table, which was handed to us by the farm manager, shows the acreage and the value of the produce for the four years, 1875 to 1878, and an examination of the accounts for 1878 showed that the income and expenditure had been as in the Table on p. 178.

"It will be seen from the statement of account on p. 179, that, if the cost of pumping the sewage is deducted, which is fairly not an item of farm expenditure, the farm shows a profit. At least half the farm is very poor land, which is hired at a stiff price, three times what it is worth to an ordinary farmer. The corporation, however, have the advantage of farming a portion of the land under the Duke of Bedford, and therefore came in for an abatement of half a year's rent during the past year (1879); and, moreover, the land subject to this abatement in rent is some of the very best on the whole sewage farm.

"The cropping of the farm for the past year (1879) was as follows:—

	A.	R.	P.		A.	R.	P.
Potatoes,	12	0	0	Brought forward,	129	3	20
Rye-grass,	20	0	0	Winter beans,	3	0	0
Rhubarb,	0	0	20	Kidney beans,	1	1	0
Cauliflowers,	6	0	0	Swedes,	0	3	0
Prickly comfrey,	0	1	0	Cabbage (spring),	4	2	0
Barley,	4	1	0	Lettuce,	0	0	20
Onions,	20	1	0	Asparagus,	0	1	20
Parsnips,	3	1	0	Currant trees, &c.,	2	0	0
Carrots,	6	1	0	Meadow (let),	22	2	0
Wheat,	16	0	0	Pasture in hand,	7	2	0
Mangolds,	26	0	0	Savoys (cabbage),	5	0	0
Oats,	15	2	0	Roads, carriers, &c.,	6	1	2
Carry forward,	129	3	20	Total acreage of farm,	183	0	22

"*Rye-grass.*—The rye-grass on this farm is allowed to stand for two years. It is sown in the autumn or in the spring, as circumstances require. Experience, however, at Bedford shows that this crop has deteriorated in value, so that last year not more than £7, 13s. 4d. per acre was realised for it. This falling off in value is principally due to the fact that there has been such an abundance of grass during the last two years that there has been no great demand for the rye-grass. The green crops yield nothing like the sum they ought to produce. This is due, in a measure, to the fact that the Corporation have to sell the produce in a district which is at all times well provided with green food. The chief drawback to this farm appears to be the absence of live stock, but we

TABLE XXII.—BEDFORD SEWAGE FARM.

Statement of Cropping with Acreage and Average Price per Acre of each Crop for the Years 1875, 1876, 1877, *and* 1878.

Description of Crop.	1875. Acreage.	1875. Average per Acre.	1875. Total Produce.	1876. Acreage.	1876. Average per Acre.	1876. Total Produce.	1877. Acreage.	1877. Average per Acre.	1877. Total Produce.	1878. Acreage.	1878. Average per Acre.	1878. Total Produce.
	A. R. P.	£ s. d.	£ s. d.	A. R. P.	£ s. d.	£ s. d.	A. R. P.	£ s. d.	£ s. d.	A. R. P.	£ s. d.	£ s. d.
Italian rye-grass,	22 0 0	18 2 9	399 0 6	30 0 0	12 8 1	372 2 6	31 0 0	10 6 9¼	320 10 0	24 0 0	7 13 4	184 0 0
Permanent pasture,	30 0 0	6 1 0½	181 10 6	30 0 0	7 8 3¾	222 9 2	7 2 0	8 0 0	60 0 0	7 2 0	6 7 7¼	47 17 0
Mangolds,	40 2 20	14 15 0½	599 6 6	38 0 20	14 0 8¼	535 1 3	37 0 0	12 16 11	475 6 0	35 2 0	13 13 4¾	485 5 5
Swedes,	...	...	...	...	...	...	2 1 30	12 17 9	31 8 1½	2 2 0	13 17 7	34 14 0
Carrots,	7 3 0	15 1 5	116 1 0	16 0 0	10 4 9¼	163 16 4	7 2 0	17 0 0	127 10 0	8 2 0	15 5 7	129 17 5
Parsnips,	...	...	...	...	...	...	1 0 20	17 15 6	20 0 0	1 3 0	20 0 0	35 0 0
Potatoes,	25 1 0	5 11 6½	140 16 6	10 0 0	11 2 2	111 1 6	15 2 0	13 5 2	205 10 0	9 1 0	16 16 9½	155 15 4
Onions,	10 0 20	28 6 10¾	287 0 0	11 0 10	32 8 5½	358 13 9	13 3 0	29 3 7½	401 5 0	16 2 20	33 5 7¼	553 6 3
Wheat,	16 1 10	14 0 4½	228 13 9	10 1 0	6 11 3¾	67 6 1	13 0 0	14 11 9¼	189 13 1½	18 0 0	10 19 1	197 3 6
Oats,	14 0 0	8 3 11	114 15 0	12 0 0	9 14 9	116 17 0	12 2 0	12 5 0	140 17 6	17 0 0	12 9 7¾	212 4 0
Beans,	...	...	...	4 3 0	13 1 0¾	62 0 0	3 2 0	6 0 0	21 0 0	3 3 10	13 2 3	50 0 0
Spring cabbage,	6 1 10	13 17 7	87 12 0	6 0 0	13 8 10	80 13 0	3 0 0	14 0 0	42 0 0	3 0 0	11 8 6	34 5 6
Pickling cabbage,	1 1 0	27 18 11	34 18 8	2 2 0	10 0 11¼	25 2 4	2 0 0	8 12 8¾	17 5 5½	...	...	...
Savoys,	...	...	...	3 0 0	14 13 11	44 1 9	2 1 0	16 0 0	36 0 0	3 2 20	14 0 6½	50 17 0
Cauliflowers,	6 0 0	1 13 4	10 0 0	2 0 0	18 6 6	36 13 0	1 2 0	21 7 4	32 1 0	3 1 20	30 4 5	101 19 11
Kidney beans,	...	...	...	0 3 0	16 0 0	12 0 0	1 0 0	20 0 7½	28 0 7½	0 1 0	24 19 4	6 4 10
Celery,	...	...	...	0 3 0	53 4 4	38 8 3	0 1 0	48 0 0	12 0 0	0 1 20	36 0 0	13 10 0
Cucumbers,	1 0 0	16 1 0	16 1 0	0 3 0	18 13 4	14 0 0	1 0 0	22 15 0	22 15 0	0 2 0	13 7 0	6 13 6
Vegetable marrows,	0 0 10	21 0 0	1 6 3	0 1 0	16 4 0	4 1 0	0 1 0	12 0 0	3 0 0	...	...	...
Rhubarb,	0 0 20	40 0 0	5 0 0	0 0 20	32 0 0	4 0 0	0 0 20	12 0 0	1 10 0	0 0 20	11 10 0	1 8 9
Asparagus,	0 0 20	20 8 0	2 11 0	0 0 20	36 0 0	4 10 0	0 0 20	48 0 0	6 0 0	0 0 20	56 0 0	7 0 0
Prickley comfrey,	...	...	...	...	...	...	...	...	...	0 1 0	10 0 0	2 10 0
Currant trees, &c.,	...	...	...	2 0 0	5 0 0	10 0 0	0 2 0	6 0 0	3 0 0	0 2 0	...	...
Meadow (sub-let),	...	...	...	...	...	...	22 2 0	...	119 0 0	22 2 0	...	119 0 0
New asparagus and seed beds,	...	...	...	...	...	...	1 3 0	...	...	1 1 0	...	...
	180 3 30	...	2224 12 8	180 1 30	...	2282 16 11	180 0 10	...	2307 11 10	180 1 10	...	2428 12 5

TABLE XXIII.—BEDFORD SEWAGE FARM.

Statement of Accounts for the Year ending 31st December, 1878.

Income.	£	s.	d.	Expenditure.	£	s.	d.
Valuation of Stock and Plant, 31st December, 1878,	£1,375	2	0	Valuation of Stock and Plant, 1st January, 1878,	£1,237	1	0
Sales of Crops,	1,884	18	10	Wages,	573	15	7
Horse—Corn, Rye-grass, and Hay consumed,	165	0	0	Manager's Salary,	145	0	0
Permanent Works,	13	7	10	Horse—Corn, Keep, and Straw purchased,	9	14	7
Income Tax repaid,	13	2	9	Horse—Corn, Rye-grass, and Hay consumed,	165	0	0
Land Tax repaid,	4	3	11	Seeds and Plants,	144	11	9
Rent of Meadow Land,	119	17	0	Permanent Works,	13	7	10
Balance—Loss on working,	243	15	11	Auctioneer's Commission and Expenses,	73	18	0
				Rent,	928	10	0
				Rates and Taxes,	84	6	4
				Insurance,	2	0	0
				Miscellaneous Bills,	104	12	4
				Cost of Pumping Sewage,	337	10	10
	£3,819	8	3		£3,819	8	3

understand that the Corporation, since our last inspection, have erected a complete set of farm buildings to accommodate twenty-four milking cows, with open sheds for young stock, and piggeries; also, a residence for the farm manager; and they may reasonably expect that a well-managed dairy-farm, so conveniently situated for the sale of milk, will pay fairly well.

"*Potatoes.*—Potatoes are planted on the flat, 18 inches to 30 inches from row to row, and the distance of the tubers in the rows varying from 15 inches to 18 inches apart, depending upon the variety of potato grown. Early ashleaf and magnum bonum are the kinds most liked. The potatoes are full of top. A dressing of stable-dung is applied to the land. The potato-crop is not irrigated with sewage during the period of growth. The farm manager reported, November 7th, 1879, that the magnum bonum potatoes are entirely free from disease, and that they have just finished digging upwards of 30 tons of splendid stuff, the produce of 7 acres.

"*Mangolds.*—Mangolds are planted on the flat, as are all other crops on this farm, the idea being that in the case of land laid out as at Bedford in short plots on a quick fall, the sewage is more readily applied to the crop on the flat than if the crop were planted on ridges; for if the ridges ran with the fall, the sewage would rapidly flow down the comparatively short length of the fields into the ditches at the bottom; and if the land is ridged across the fall, even if every ridge was an exact contour of the land, very uneven distribution of the sewage would take place. The objection to the flat system adopted at Bedford, on account of the physical features of the land, appears to be that the sewage is liable to pond in places, on account of the unevenness of the ground, and that the growing crop is liable to be soiled by direct contact with the sewage. The mangolds are drilled in rows 26 inches apart, and are hoed out to 12 inches from plant to plant, the quantity of seed sown per acre being 5 lbs. The early sown mangolds, both here and on other farms, have run to seed. The mangolds on this farm are a good plant; one field especially, which was sewaged in the winter was capital; they are irrigated from time to time during the period of growth.

"*Onions.*—The seed is drilled in rows 8 inches apart. The bulbs of the onions should be from 4 inches to 6 inches apart in the rows. The quantity of seed sown is from 8 lbs. to 10 lbs. per acre, depending upon the quality of the land and the time of sowing. The cost of cleaning this crop is about £5, 10s. per acre in ordinary seasons. This year the wet weather has interfered very much with the cleaning, and the weeds have been a great trouble. The onions are thinned out the second time of cleaning. This crop was very fair for the season, but in places where the water lodged, the plant was destroyed. The crop is not irrigated with sewage while growing, but sewage is applied to the land before the seed is sown.

"*Cabbage.*—This was a good crop, considering the severe winter, and sold at 8d. per dozen, delivered on rail for Manchester. Cauliflowers are usually planted in June and cleared in October. It is a crop that answers well on this farm. Both cabbage and cauliflowers are planted in rows, so that the plants are 2 feet distant from each other. The land previous to planting is marked out both ways with a drill. The precision thus gained in planting the crop is found to give greater facility for afterwards using the horse-hoe.

"*Prickly Comfrey.*—A small quantity of this crop is grown for horse-fodder. The roots were planted in March, 1878, and the crop was cut three times in that year. The roots are planted 24 inches apart each way, and the crop is said to take any amount of sewage. The manager states that he believes it to be impossible to damage this plant with sewage, for the crop had been continuously flooded with sewage for three weeks in succession, and this treatment was found more beneficial than otherwise.

"*Carrots.*—Carrots are drilled in rows about 12 inches apart, and the plants are from 4 to 6 inches distant in the rows. Carrots are not sewaged during their period of growth. The crop, which did not appear to be a very good one, has, we learn, been sold, and produced nearly £16, 10s. per acre.

"*Parsnips.*—The parsnips were a very fine crop; they are drilled in rows about 12 inches apart, and the plants are from 8 to 10 inches apart; 7 lbs. of seed per acre are used.

"*Swedes.*—A small quantity of swedes are grown, but they have not been sewaged. They are drilled in rows 24 inches distant, and the roots are hoed out to 12 inches apart; 3 lbs. of seed per acre are drilled.

"*Rhubarb.*—A small quantity of rhubarb is grown, but on that part of the farm which is seldom sewaged. The roots are placed at a distance of 4 feet apart, and they are moved once in every five years.

"*Wheat.*—Red Browick is the variety grown. The crop was level, heavy, and good, and followed potatoes. The land had not been sewaged for two years, and the crop was not sewaged during the period of growth.

"*Oats.*—White Polish are the sort grown; they were a very good and heavy crop. This crop was sown on land in which parsnips and mangolds had been grown the previous year. The parsnips had not been sewaged when growing; the mangolds were sewaged while under cultivation. The oat crop looked much better on the part following the mangolds than on that following the parsnips. This crop, like all other cereal crops, is not sewaged during the period of growth.

"*Barley.*—This was a heavy crop, but lodged. It was sown on land that had grown mangolds the previous year, and the land had been sewaged after the mangolds had been removed at the end of the year 1878.

"*Celery.*—Celery is grown on this farm, and it is found to be one of the best sewage crops grown. The trenches for the reception of the young plants are well sewaged before planting, and the crop is greatly benefited by the frequent dressings of sewage during the period of growth. The sewage is applied between the rows.

"*Lettuces, asparagus,* and other small garden crops, are grown on land that receives an occasional dressing of sewage.

"*Rotation of Cropping.*—A portion of this farm being liable to flooding, it is found impossible to carry out, on this account, any regular system of rotation of cropping. On some of the land the following system is observed :—First, rye-grass for two years; second, mangolds; third, wheat or oats; fourth, onions or potatoes, followed by rye-grass.

"*Horses.*—Six strong Shire-bred horses are employed on this farm solely for working the land and for other farm operations. In the summer, the horses are principally fed on rye-grass, and in the winter on beans, oats, and chaff, with a considerable amount of roots, carrots being generally used until Christmas, and mangolds afterwards. The manager reported that this course of feeding keeps the horses particularly healthy. He also reported, in answer to special inquiry, that he never had a greasy legged horse on the farm, and does not consider the horses on the sewage farm more liable to that, or any other disease, than on farms under ordinary cultivation. He further reported that the veterinary surgeon's bill on this sewage farm, during the last four years, averaged about 3s. 6d. per horse.

"*Sanitary Result.*—Eight persons reside on the farm, six of whom are children, and about twenty men and boys are engaged on the farm who do not reside on it. Mr. J. H. Collett, the farm manager, reported—

"'No man, either living or working on the farm, or any man living near, has ever suffered from any epidemic disease.

"'No man ever employed on this farm for a sufficient length of time to have felt the ill-effect of sewage has died up to the present time, neither has there been a death of any resident, young or old.

"'I can give you no other information on this point, excepting that my men have been particularly healthy, and I have never heard the men employed on this, or the adjoining farms, or any person living near, ever complain of injury or annoyance from our utilisation of sewage.'"

The general account and balance sheet for the year 1888, as given upon pages 184 and 185, are interesting, as showing the position of the farm ten years after the date of the Report given above.

BOROUGH OF BEDFORD.—
IRRIGA

Dr. *GENERAL ACCOUNT AND BALANCE SHEET FOR*

To Live Stock, comprising Working Horses and Colts, Dairy Cows and Young Stock, and Breeding Pigs, in hand 1st January, 1888,	£999 16 0	
,, Cultivations, Seed and Labour, Roots, Potatoes, Onions, Plants, &c., in hand 1st January, 1888,	990 15 0	
,, Corn in Stack and Granary, Hay and Straw at Market value, in hand 1st January, 1888,	593 12 0	
,, Glass Houses and Tenants' Fixtures, Hovels and Fences,	214 12 0	
,, Dead Stock and Dairy Vessels, in hand 1st January, 1888,	501 8 6	
		£3,300 3 6
,, Labour,		801 11 8
,, Manager's Salary,		150 0 0
,, Corn, Keep, and Straw purchased,		298 7 1
,, Corn, Rye-grass and Hay consumed, produce of Farm,		590 0 0
,, Seeds and Plants,		90 19 11
,, Auctioneers' Commission and Expenses,		28 14 0
,, Live Stock purchased,		36 10 0
,, Dead Stock purchased, including Implements and Fences,		26 3 10
Rents—		
To J. G. Coventry-Campion, Esq.,	£130 0 0	
,, Duke of Bedford,	196 0 0	
,, ,,	35 0 0	
,, Hospital of St. John,	34 6 3	
,, F. E. F. Polhill-Turner, Esq.,	426 0 0	
,, ,, ,,	19 10 0	
,, Corporation of Bedford,	124 0 0	
,, Trustees of Bunyan Meeting, Bedford,	85 0 0	
,, L. & N.-W. Railway Co., Sewer under Railway,	1 0 0	
		1,050 16 3
,, Poor Rates,		87 12 5
,, Income Tax,		37 18 11
,, Land Tax,		11 15 8
,, Insurance,		9 0 6
,, Miscellaneous Bills,		133 15 9
,, Veterinary Surgeon's Contract,		10 0 0
		£6,663 9 6
To Balance brought down,		£414 8 7

Name of Landlord.	Acreage. A. R. P.	Rent per Acre. £ s. d.	Annual Rent. £ s. d.
J. G. Coventry-Campion, Esq.,	20 1 27	6 7 4	130 0 0
Urban Sanitary Authority, late Duke of Bedford,	43 2 11	4 10 0	196 0 0
,, ,, ,,	7 3 13	4 9 6	35 0 0
Hospital of St. John,	11 1 30	3 0 0	34 6 3
F. E. F. Polhill-Turner, Esq.,	80 0 0	5 6 6	426 0 0
,, ,,	6 2 0	3 0 0	19 10 0
Corporation of Bedford,	27 2 34	4 9 5	124 0 0
Trustees of Bunyan Meeting, Bedford,	25 1 0	3 7 4	85 0 0
L. and N.-W. R. Co., Sewer under Railway,	...	...	1 0 0
	222 2 35 @	£4 14 4	£1,050 16 3

URBAN SANITARY AUTHORITY.

TION FARM.

THE YEAR ENDING 31st DECEMBER, 1888. Cr.

By Live Stock, comprising Working Horses, Colts, Cows, Bulls, Young Stock and Pigs, in hand 31st December, 1888, ...	£1,106 11 0	
,, Dead Stock, comprising Implements, Dairy Implements, &c., in hand 31st December, 1888, . .	360 10 6	
,, Produce, comprising Roots, Onions, Potatoes, Garden Produce, &c., in hand 31st December, 1888, .	1,119 9 11	
,, Corn in Stack and Granary, with Straw and Hay, at Market Value, in hand 31st December, 1888, .	679 12 1	
,, Glass Houses, Hovels, Plants, &c., at Newnham Walls, in hand 31st December, 1888, . .	178 13 6	
		£3,444 17 0
,, Sales by Auction, ...		370 15 11
,, Sales by Manager, ...		1,806 16 8
,, Corn, Rye-grass, and Hay consumed, as per contra, .		590 0 0
,, Income Tax, repaid, ...		24 15 8
,, Land Tax, repaid, ...		11 15 8
,, Balance carried down, ...		414 8 7
		£6,663 9 6

JOSHUA HAWKINS, *Mayor*,
J. W. D. HARRISON, *Chairman*,
JOHN ELWORTHY CUTCLIFFE,
ROBT. P. JARVIS,
CHARLES ASTELL,
JOHN BARRAND,
THOS. C. MAY,
JAS. POTTER,
W. E. TAYLOR,
} *Members of the Farm Committee.*

T. S. PORTER, *Clerk to the Urban Sanitary Authority.*

JOHN H. COLLETT, *Farm Manager.*

12th February, 1889.

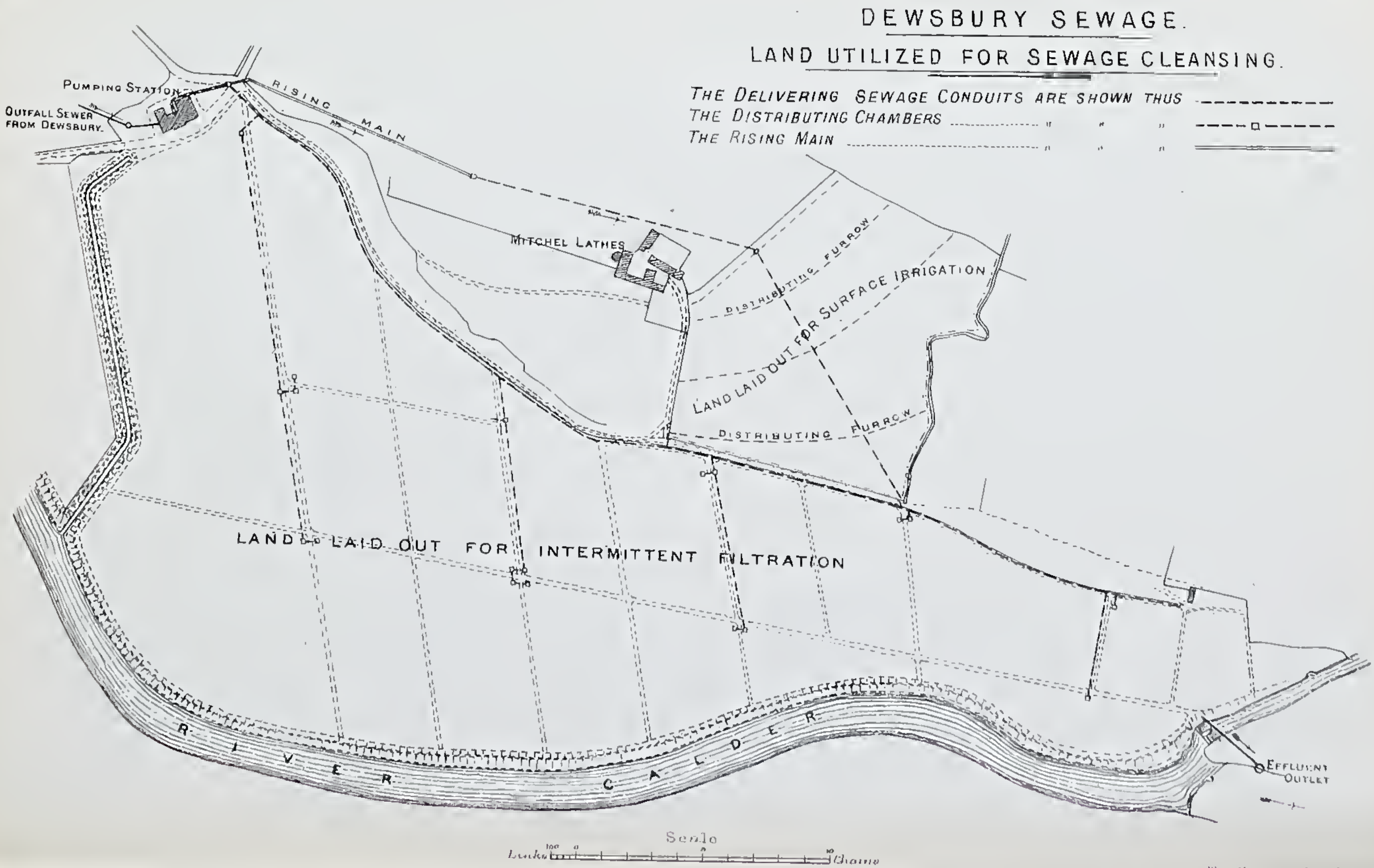
CHAPTER XIV.

DEWSBURY AND HITCHIN—INTERMITTENT FILTRATION, 1889.

The two accompanying plans illustrate methods for the purification of sewage by means of intermittent filtration through natural soil, as carried out at Dewsbury (Yorkshire) and Hitchin (Hertfordshire) by Messrs. Bailey-Denton, Son & North, of Palace Chambers, Westminster. They are given as instances of that method of sewage disposal because they embrace points of considerable interest dissimilar in character one from the other; though each is typical of several towns throughout the country.

1. DEWSBURY.

Dewsbury, which has a population of 30,000 people, with a ratable value of £106,767, is a manufacturing town of importance, situated on the river Calder. It may be classed with towns in which water-closets and middens are mixed, and as being a commercial centre of importance in which the quantity of trade liquid and dye-refuse admitted into the sewers is very considerable. The sewage farm consists of over 70 acres, 50 of which are laid out as filtration areas, while some 10 or 12 acres of higher ground serve for surface irrigation. The sewage has to be lifted to both levels. The soil for the most part is porous and of a sandy character, very suitable for filtration. The crops grown are principally roots and rye-grass, which succeed very well, and have in dry summers particularly proved of great value. The sewage is distributed through the filtration areas by means of furrows. By this means the liquid is not allowed to come into contact with the leaves of the growing vegetation, but spreading laterally through the soil, reaches their roots, and can be applied during



West, Newman photo lith

almost any stage of growth without disadvantage. The position of the sewage furrows is changed every one or two years, so that as much land as possible may derive benefit from mixture with the sludge, which is taken out of the furrows when the sewage is not under distribution. It is spread over the level beds or lands on each side at times when there are no crops growing upon them, and then dug or ploughed in.

The last season (1888) at Dewsbury was not propitious for sewage farming. It was very wet, but general satisfaction was, nevertheless, expressed by the Council, as in better seasons the farm pays its way.

The work of surface preparation at Dewsbury proved expensive, owing to the outlay incurred in forming the surface into larger horizontal areas than usual, but the cost on the whole farm did not exceed £110 an acre.

The principal feature of this scheme is the evident capability of the soil to purify by filtration much more than the sewage proper discharged from Dewsbury, assuming that the surface waters had been carefully excluded from the sewers, the trade liquid properly regulated, and the larger solid organic and mineral matters properly screened and separated from the liquid before it reached the land. At present, however, the Borough Authorities have desired not to spend the money required on separating the solid matter from the liquid, therefore, the whole quantity is run into the sewage furrows.

The farm manager writes that "the crops are doing well, some of the land being cropped four times, whilst the effluent is always good. Indeed, many mill-hands came down to bathe at the outlet, it being the only clear water for miles that they can bathe in." This fact is striking, because it was from this part of the river Calder that the Rivers' Pollution Commissioners took the *water* wherewith to write their "memorandum," in lieu of ink, showing the condition of the river.

2. HITCHIN.

The second example of intermittent filtration at Hitchin (Hertfordshire) presents more than ordinary features of importance, for it shows that, in spite of difficulties, an effluent admissible into a running stream can be obtained with certainty, even when the filtering medium is peat of a boggy nature.

Hitchin is a town with a population of 10,000, and a ratable value in 1888 of £27,803, and it is essentially a water-closet town.

Mr. Bailey-Denton was called in by the Local Board of Hitchin some ten years ago, owing to the failure of the lime process, which was partially adopted there to purify the sewage before its admission into the river "Hiz," the consequence being that the fish in the river were killed, and the cattle on the grazing land below the outlet were unable to drink the water of the river.

Hitchin is situated at the junction of the chalk with the greensand formation, at the base of the northern escarpment of the London basin.

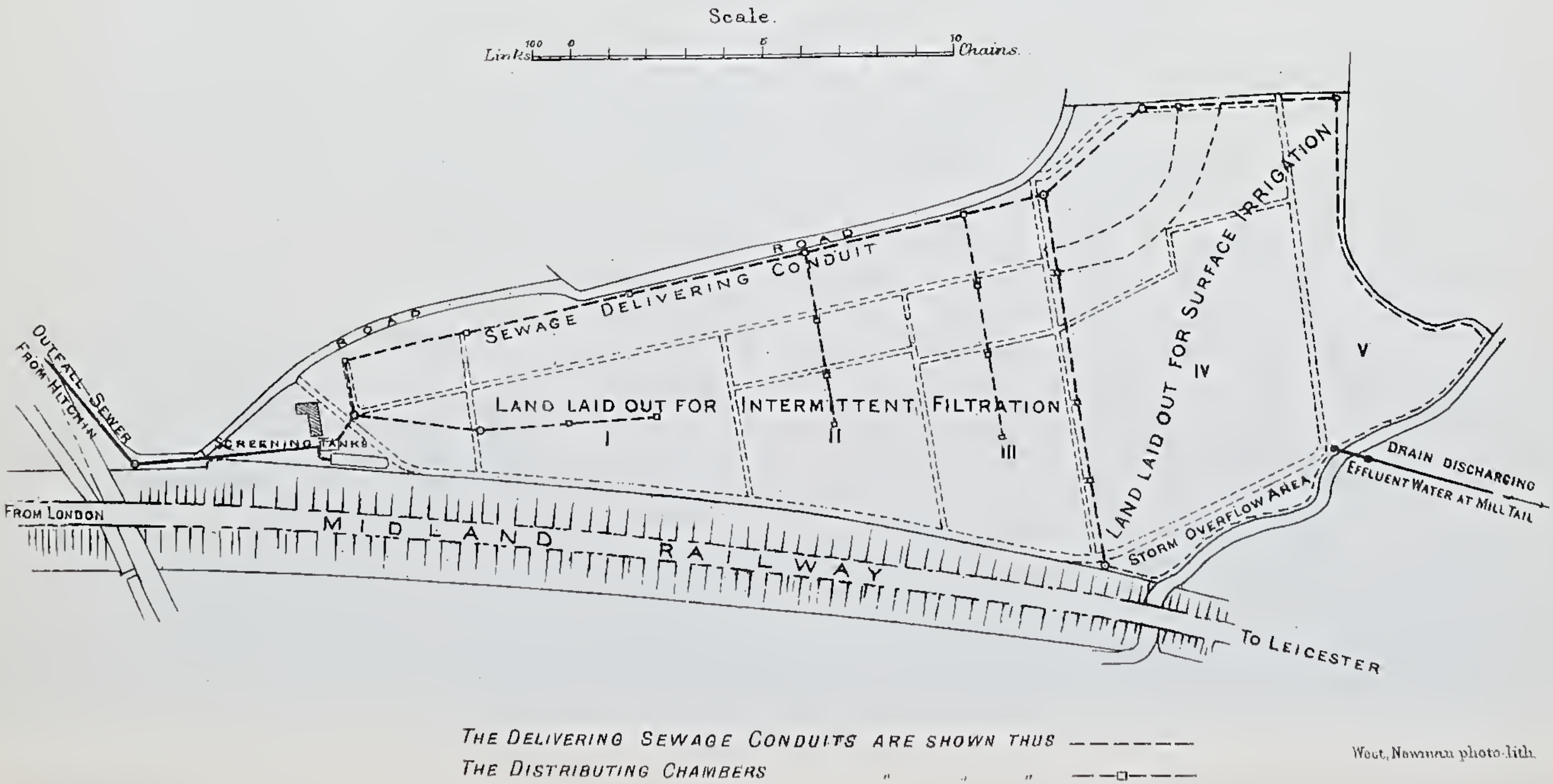
The sewage farm consists, for the most part, of peat mixed with gravelly clunch (lower chalk). £2,300 was spent in laying it out for sewage purposes.

Mr. Bailey-Denton recommended the Hitchin Local Board, in the first instance, to acquire 30 acres and lay out 27 for filtration, but that Authority rejected this advice, and instead, acquired about 22 acres, of which only 19 were actually available for use. Besides the natural unsuitability of the soil, there is another special drawback to filtration and to irrigation at Hitchin, and that is, that the main outfall sewer of the town was originally laid under the bed of the river; and, although some portion of it has since been taken out and relaid at some distance from the river, there still remains a good deal of it which has never been touched, and which, consequently, admits through its leaky joints a copious quantity

Pl. 14.

HITCHIN, HERTS.

LAND UTILIZED FOR SEWAGE CLEANSING.



West, Newman photo-lith.

of river-water. The constant addition of surface-water to the "sewage proper" from this source, and from the "subsoil" in which the internal sewers of the town are laid, swells the total quantity of *dilution* to more than the whole of the water-supply of the town. Moreover, the work of separating the rain-water from the sewage has only been partially affected, with the result that if only a shower of rain falls on the town, the outflow from the sewers is suddenly increased to an amount equal to that of the sewage proper. The consequence of this extra addition of liquid has been that the land has had to be very closely under-drained, whilst to secure a constant discharge, the under-drains have to be frequently flushed to keep them free from sedimentary and obstructive matter.

The land is laid out in a similar manner to that at Dewsbury, excepting that the beds are narrower, the under-drains more frequent, and the sewage furrows far more numerous.

The position of the sewage furrows is changed every winter or early spring, and when doing this, care has to be taken that they are not placed immediately over the under-drains, but at some distance from them; for, if cut immediately over the drains, the sewage passes straight down to the pipes without purification being secured.

The management of the sewaged land is now in the hands of a committee of the Local Board, and it is not, we understand, farmed at a loss. Mangolds and rye-grass are the principal crops, whilst osiers are grown on a certain portion of the land which is not closely under-drained. Roses and strawberries prosper under moderate doses of sewage.

The sludge is treated in a similar manner to that practised at Dewsbury, and the contents of the tanks when emptied are placed on any portion of the land requiring it.

The accompanying analysis of a sample of the effluent, taken by the surveyor of Croydon, may be of interest. It is, however, clear that the sewage is a very weak one, because the chlorine is only about three-eighths of that found in average sewage.

"ANALYTICAL REPORT.

"LABORATORY,
"7 WESTMINSTER CHAMBERS, S.W.

	Grains per Gallon.		Parts per Million.	
	Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.
Sample of 'effluent water from the sewage farm at Hitchin,' sent by the Croydon Local Board, .	36·3	3·3	5·00	1·00

"This is not drinking water; but it may be discharged into a stream.
(Signed) "J. ALFRED WANKLYN."

Students and others interested in the purification of sewage by means of intermittent filtration would do well to visit such places as Abingdon, Malvern, Barnsley, Hitchin, Kendal, Merthyr, and Forfar.

In the case of Forfar, we understand that in the year 1888 there was a surplus of £82, 14s. 10d. after payment of

TABLE XXIV.—FORFAR SEWAGE DISPOSAL.

ANALYSES OF SAMPLES OF WATER FROM FORFAR SEWAGE WORKS, TAKEN JULY, 1888.

		Natural Sewage.	Sewage after passing through Area.
Solids Dissolved, . .	Grains per gallon, .	37·5	36·5
Chlorine, . . .	,, ,, .	5·2	3·7
Free Ammonia, . .	Parts per million, .	69·0	0·12
Albuminoid Ammonia,	,, ,, .	2·5	0·78
Suspended Matter, .	Organic, grs. per gallon,	21·0	None.
	Inorganic, ,,	23·5	None.
Nitrate, . . .	Nitrate of Soda, . . (Grains per Gallon).	None.	9·6

all outgoings (on the farm of 40 acres, of which only 24 acres are laid out for sewage treatment). We append an analysis of the natural sewage and of the purified effluent taken at this place on the 24th July, 1888, and would add that Dr. A. P. Aitken, the chemist to the Highland and Agricultural Society of Scotland, who made the analysis, regards this example as a most remarkable one, showing the excellence of intermittent filtration when carried out under favourable circumstances, and has publicly expressed the opinion that Corporations who have the sewage difficulty to face, should make a careful inspection of the Forfar works.

The author is indebted to Mr. Bailey-Denton, M. Inst. C.E., Engineer for the works, for the foregoing particulars, and for the plans (Plates 10 and 11).

CHAPTER XV.

MERTON, CROYDON RURAL SANITARY AUTHORITY, 1889.

Population, &c.—Population draining to works, 22,500.

Ratable value of drainage district, £134,555.

Water-closets, general.

Dry-weather sewage flow, 1,500,000 gallons per diem.

The sewage flow is large in consequence of the sewers being, for the greatest part, laid in very wet ground, and the mileage being high per 1,000 of the population.

The Sewage Disposal Works were constructed by the Croydon Rural Sanitary Authority, for the prevention of the pollution of the river Wandle by the sewage from the parishes of Beddington, Merton, Mitcham, and Morden, and the hamlet of Wallington. So serious had this pollution become in 1878, that a riparian owner obtained a perpetual injunction against the Rural Sanitary Authority, in consequence of which, important works of main drainage and sewage disposal were at once proceeded with.

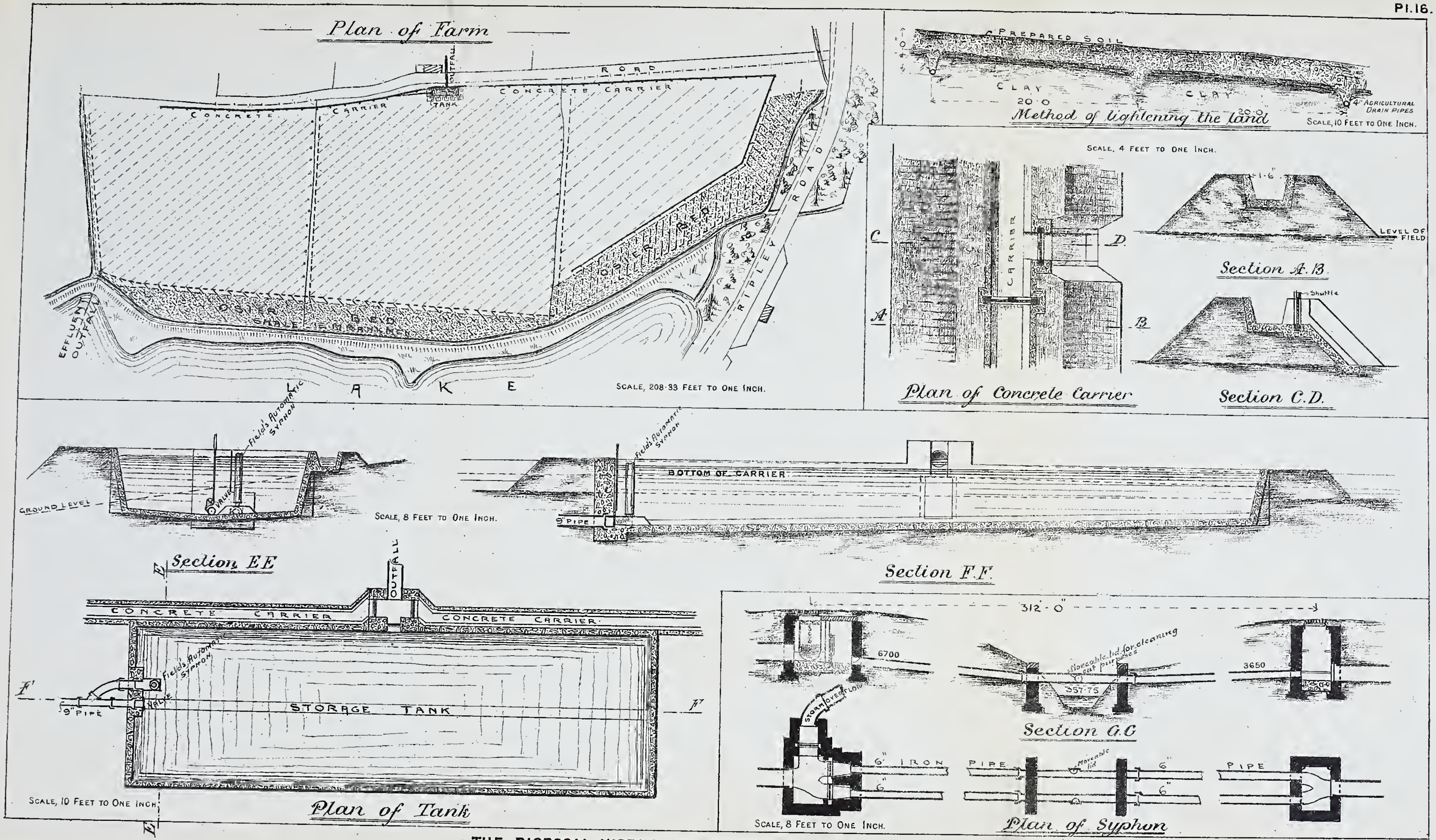
Previous to this, however, in 1873, Sir Joseph Bazalgette, Past President, Inst.C.E., was consulted, and after reviewing the various methods of sewage disposal then in operation, pronounced himself as being in favour of irrigation, and selected a site for a sewage farm in the Beverley-brook valley, on stiff London clay.

Subsequently, a proposal was made for the extension of the West Kent outfall sewer to Merton, and the reception by it of the sewage of the combined district, but as the ultimate disposal of the sewage could not be clearly foreseen, the project fell through.

In 1874 Mr. Baldwin Latham, M.Inst.C.E., prepared a scheme, also selecting a site for an irrigation farm in the Beverley-brook valley. The Rural Sanitary Authority were given the refusal of the land for a limited period of time, and upon the expiry of the limit the offer was withdrawn, although in the meantime the necessary surveys and plans had been prepared.

Mr. Baldwin Latham next selected three sites for filtration works in the Wandle valley, a smaller area of land being advisable in consequence of the much higher prices obtainable for land in that valley, as compared with the more remote Beverley-brook sites. In the Wandle valley, however, the land consists largely of alluvium, and is generally of a porous nature.

Eventually, a site situated partly in each of the parishes of Mitcham and Wimbledon was purchased, and a new survey was made and plans were prepared. After the inevitable Local Government Inquiry had been held, and sanction to the scheme had been obtained, a contract with B. Cooke & Co. was entered into by the Rural Sanitary Authority, and the whole of the works, comprising 55 miles of main sewers, and the sewage disposal works, were executed during the years 1878-9-80. The author was engaged upon the various surveys and in the preparation of the plans, and acted as Resident Engineer during the construction of the works.



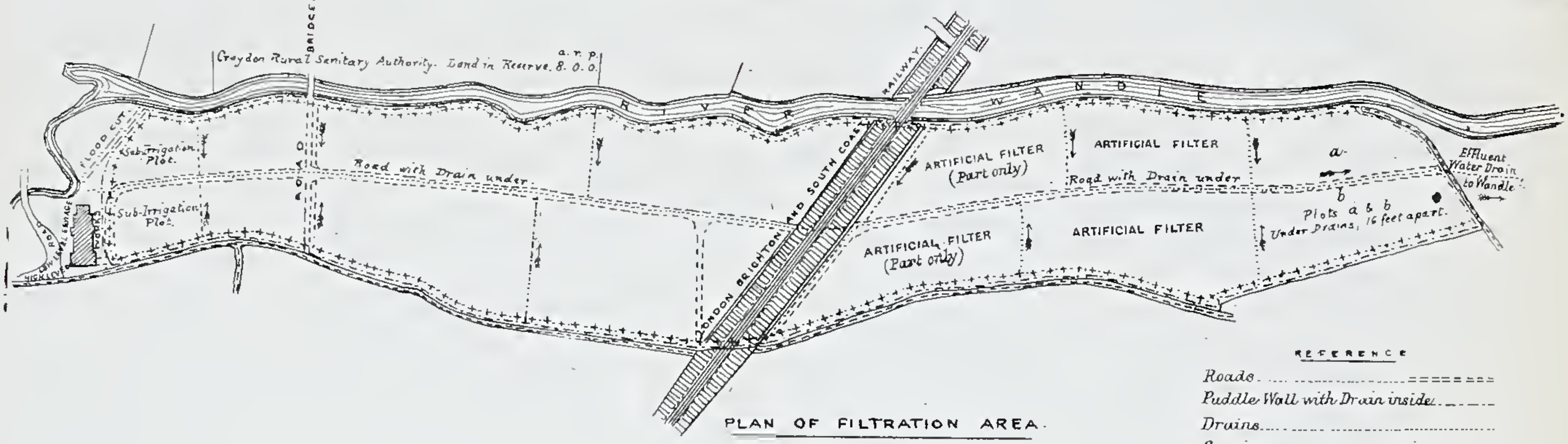
THE DISPOSAL WORKS OF SWANWICK. W. H. Radford, Engineer.

West, Newman photo-lith.

Pl. 15.

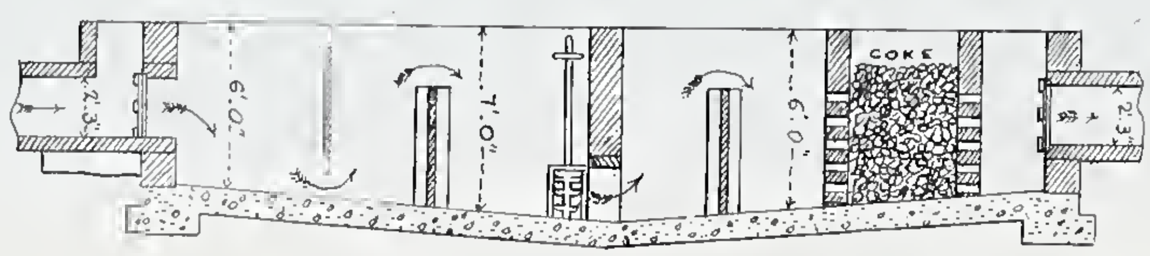
CROYDON RURAL SANITARY AUTHORITY.

MERTON SEWAGE DISPOSAL WORKS.



PLAN OF FILTRATION AREA.

Scale: $\frac{1}{5000}$



SECTION OF STRAINING TANK

Scale, 10 feet = 1 inch.

West, Newman photo-lith.

The sewage is collected and conveyed to the disposal works by means of two outfall sewers, one of which was constructed at a level sufficiently high to admit of its contents gravitating to the filtration area, whilst the low level sewage has to be pumped, its quantity being about one-tenth of the total.

Tanks.—All the sewage is received into two tanks, an arrangement of valves admitting the use of one tank only, whilst the other is being cleansed. The mode of construction of these tanks is shown upon the plan (Plate 15), it will be observed that they are merely straining tanks, being much too small to act as settling tanks. A wall of coke is placed across each tank in order to act as a filter for the retention of the grosser solids. The author would here remark that he much prefers the "Wimbledon" system of straining sewage.

On cleansing a tank, the sludge is admitted into the sludge-pit, whence it is pumped into filter-presses, which are provided for its treatment.

Distribution of Sewage.—The partly clarified sewage is then conveyed to the filtration-area, where it is disposed of upon the intermittent filtration principle.

The land is 28 acres in extent, and its composition varies greatly; in some portions it is of an open, gravelly nature, whilst in others it is sandy and peaty, and in one portion clay was met with.

It was of importance that in a limited area, as much subsoil water as possible should be shut out, and for that purpose a clay puddle wall, 2 feet in thickness, was constructed around the entire area. Throughout the work the trench for the clay puddle was carried down to the London clay—which everywhere exists beneath the subsoil of the filtration-area. A large cemetery is situated upon part of the eastern boundary of the land, and having regard to the nature of the drainage water found in the gravel beds adjoining this cemetery, a puddle-wall was an absolutely necessary condition to the purity of the effluent. In consequence of the land being 1000 yards in length and only

140 yards in breadth, the puddle-wall encloses a small area compared with its length, and its cost per acre is necessarily high.

Drainage.—The land was sparingly under-drained, a main drain being constructed under the central road, and a drain was placed under each cross-road; a drain was also placed inside the puddle-wall, and connections with the main drain were made at intervals of about 400 feet, thus dividing the filtration-area into a series of sections, upon which the sewage is applied upon the intermittent principle.

The average depth of the drains is 6 feet, thus there are 271,000 cubic yards of the filtering material enclosed by the puddle-wall, or 12 cubic yards per head of the present population.

Filtration.—Upon making the excavations for the drains, a bed of clay, 5 acres in extent, was met with, and this was burned into ballast, and an artificial filter was constructed in the manner shown upon the drawing (Plate 15). The ballast was spread in layers with a thickness of 3 inches, interposed between which was porous soil taken from high portions of the land. An excellent, but costly, nitrifying filter was thus constructed in place of the impervious clay, and, so far as the author is aware, the method was here employed for the first time.

The surface of the filtering area was laid out in a series of level beds; great care was taken to restore the surface soil to its original position.

The two plots nearest the pumping station necessitated novel treatment, in consequence of their proximity to the residence of the riparian owner, already referred to, about 100 yards only separating them. After being under-drained, the surface of the ground was lowered to the irrigation level, and then rows of 9-inch perforated pipes were laid upon the surface, and were connected with the sewage carriers, each pipe being provided with a sluice at the point of junction. The rows of pipes were laid at distances apart of 16 feet

6 inches, and the entire area was then covered with a bed of coarse screened gravel, 1 foot in thickness, upon which was placed the surface soil. The sewage is thus applied beneath the surface, and the results have so far been satisfactory. Fine vegetables are grown upon these plots, the moisture being brought to the roots by capillary attraction.

Crops.—The greater part of the land has hitherto been cropped with rye-grass, but having regard to the comparatively large volumes of sewage applied per acre, and to the fact that the suspended matters are only partially removed from the sewage, and also that the grass is frequently submerged to the extent of several inches when sewage is applied, the author is of opinion that osiers alone should be grown, unless the system of ridge and furrow be adopted. A commencement with osiers has been made, and it will probably become the future crop upon this farm.

One of the main carriers is constructed of concrete, the other of 18-inch stoneware pipes, jointed with cement-mortar, and made watertight. An outlet from each carrier is provided at distances apart of 33 feet, the sewage being discharged into ordinary grips cut in the surface of the soil. Each outlet is provided with a stoneware block having a ground face and iron lugs, and fitted with a wooden shutter, for the purposes of regulating the distribution of the sewage.

Sewage Fungus Cases.—A somewhat curious, but very instructive, law-suit arose in connection with this sewage farm. In order to provide an outfall for the effluent, of sufficient depth to admit of deep drainage at the lower end of the farm, a site for its discharge had to be found lower down the valley, below the second mill. In consequence of the position of the Metropolitan boundary restricting the routes available, the Rural Sanitary Authority having no power to construct works within the Metropolitan area, the outfall was made to discharge into a large pond at the head of a bye-wash, whence the effluent flowed to the Wandle. A riparian owner brought an action against the Rural Sanitary Authority to restrain them from discharging their effluent water into this pond, upon the ground that its water was polluted by reason of such discharge. As a matter of fact, although frequent analyses of the effluent were made, and its condition, from the chemist's point of view, was quite satisfactory, yet it contained sewage fungus, in somewhat large quantities. This curious plant grows freely in the under-drains of the farm, and is constantly broken off and brought out in the effluent water. The author examined a great number of samples, and found it to consist not only of the well-known *Beggiatoa alba*, but of enormous quantities of *vorticellæ* as well. These solid matters settled in the pond at the head of the bye-wash, and upon the sluice gates between the river and the pond being periodically opened, the river water rushed in with great velocity, stirred up the deposits, and for a few minutes the pond presented a very filthy appearance.

The following extract from the judgment may be of interest, as this was the first "sewage-fungus" case:—

"The water which flows into the bye-wash (and here I speak partly from personal observation) contains in it a very large quantity of what is called sewage-fungus. The evidence about that substance was interesting and curious; . . . it appears to be a vegetable found in waters which contain sulphur. It was said to be without odour whilst alive, but when dead to be capable of giving off sulphuretted hydrogen, and so becoming foul to the nose. My own observation of what was happening last Tuesday, coupled with the appearances in the pond itself, and the evidences of the witnesses, entirely confirms this account. . . . I have no doubt whatever that that pond, which was proved to have been clear within the last four or five years, and good for perch, has been turned into a very filthy pond mainly by this agency. . . . It is, I think, as plain as anything can be, that a continual discharge, such as I myself saw running into the pond in large quantities, is 'a discharge of sewage or filthy water' not free from all foul or noxious matters, such as would affect or deteriorate the purity and quality of the water in the bye-wash, but that it has seriously affected and deteriorated it, and must inevitably do so" (*Mr. Justice Denman*).

The result of the action was a perpetual injunction to restrain the Rural Sanitary Authority from polluting the pond and bye-wash, with the imposition of a fine of £200. Special fungus filters were eventually constructed, one at the point where the effluent leaves the farm, the other at its entry into the pond, and these intercept large quantities of fungus; the Rural Sanitary Authority also acquired the rights of ownership of the pond, and the upper part of the bye-wash.

Details of Cost.—Artificial filters, complete, £750 per acre; sub-irrigation plots, complete, £622 per acre.

NATURAL FILTRATION AREA.

Proportion of puddle-wall, per acre, ...	£40	8	0
,, roads, ,, ...	13	0	0
,, drains, ,, ...	67	6	0
,, carriers, ,, ...	71	0	0
,, levelling, ,, ...	30	0	0
Total cost, . . .	£221	14	0

	The annual working expenses of the farm, the manager's salary, pumping, sludge-pressing, repairs, &c., amount to	£2,104
Cr.	By sales of farm produce (1888), ...	463
	Net annual cost, . . .	£1,551

CHAPTER XVI.

ROCHESTER, KENT, AND SWANWICK, DERBYSHIRE.

In this chapter, two methods of dealing with the sewage of small populations are given.

In the first case, the drainage works of Borstal, a part of the city of Rochester, will be described.

(*a*) **Rochester.**—The population of this part of the city is about 1,350. As a result of a *mandamus* issued by the High Court of Justice, at the instance of the Local Government

Board, the Corporation advertised for schemes of drainage and sewage disposal, and that submitted by the firm, of which the author is a partner, was adopted.

The drainage system was designed in accordance with the general requirements of the Local Government Board, all the sewers are laid down in straight lines, with a manhole or inspection chamber at each junction of a branch with the main sewer, and at each change in direction and gradient. The system is fully ventilated throughout, and is provided with automatic means of flushing.

With regard to the disposal of the sewage, as land of a highly suitable character for sewage purification could be obtained at a reasonable rate, the author adopted that method of disposal. Before the sewage is applied to the land, however, the suspended matters are removed, and the sewage is partly purified on the "Wimbledon system." This method is fully described in Chapter xxvii., and the straining tanks and nitrifying filters are illustrated on Plate 28. In the present instance, modifications have been introduced, both in order to meet the new conditions, and to take advantage of the author's long experience of this kind of appliance. The straining tank serves a double purpose; in the first place, the heavy suspended mineral and other matters are deposited upon the floor of the tank, thus preventing the choking of the filter, which is constructed upon a second floor at a higher level. The filtering material then acts its part—first, in arresting the lighter suspended matter, and secondly, as a nitrifying medium, since the filter soon becomes charged with the nitrifying organism, fully discussed in Chapter ix. Analyses of the effluent from the Wimbledon filter-tanks, recently made by the author's partner, Mr. Midgley Taylor, F.C.S., show that the suspended matters in the effluent are less than three grains per gallon, whilst nitrates are abundant.

As a general result of this simple and inexpensive method of dealing with sewage, the latter may be applied to land [in comparatively large volumes, being in a partly purified condition, and in a highly satisfactory condition for its final purification; the sludge is reduced to a minimum quantity, and the expense of a chemical treatment is saved.

The author felt no hesitation in recommending the system, having had twelve years' experience with it at Wimbledon.

As before stated, the land is of a highly suitable character, and being mainly of chalk, under-drains are not necessary, and as the land slopes gently towards the river Medway, very little work was necessary in order to render it fit for sewage purification.

The entire scheme is a most economical one, the total capital cost of both drainage and sewage-disposal works amounting to less than 30s. per head of the present population using them.

A brief reference to the "Scott-Moncrieff" process may not be out of place here, since the principle involved is that of the "Wimbledon system." The *Engineer* of 5th January, 1894, contains a reference to this system as follows:—"It has been claimed for the Scott-Moncrieff process that it was unaccompanied by the deposition of sludge. So far as relates to the organic solids essential to sewage, this may be true. But various solid matters, some of a very intractable nature, such as grains of granite and particles of iron, enter into the sewers of our large towns. It is expecting too much of the microbes to imagine that they will ever dispose of these materials. If they can get rid of all else, they will render enormous service."

(*b*) **Swanwick.**—The following details relate to the sewage works of Swanwick, Derbyshire.

Population draining to works, 4,000, 1889.

Water-closets not general, but there is a public water-supply.

The **works**, comprising main sewers and a small sewage farm, were carried out in 1886 for the purposes of draining and disposing of the sewage of the villages of Swanwick, Leabrooks, and upper Somercotes, which are within the Local Board District of Alfreton.

Conveyance of Sewage.—The sewage is conveyed to the sewage farm by means of pipe sewers, the levels admitting of a gravitation scheme being adopted.

On its passage to the farm, the sewage has to be carried across a ravine by means of syphons. Two were employed, each of cast-iron pipes, 6 inches in diameter, having movable iron lids at the lowest points for cleansing purposes. At the head of the syphons there is an arrangement of shuttles, by means of which the sewage passes through one syphon only in dry weather, whilst in wet, both are in operation. A storm-overflow is provided for the disposal of excessive rain-falls, the discharge being into the brook. These arrangements have given general satisfaction.

The sewage farm is 15 acres in extent, and consists of stiff clay, there being no light porous land available. The land has been treated very much in the same manner as described in the chapter on "The Preparation of Land," p. 127.

Treatment of Sewage.—Mr. Radford, Assoc. M. Inst. C.E., of Nottingham, who designed and carried out the works, and to whom the author is indebted for the details and particulars, states—"The land on the farm is a stiff yellow clay, with a foot of loamy soil on the top, and it was lightened and prepared to receive the sewage in the following manner:—The ground was covered with 6 inches in depth of fine engine ashes, obtained from some works in the immediate vicinity; the soil was then ploughed up with subsoilers to a depth of 2 feet, a steam cultivator being used for this purpose. The subsoiler was passed through the land four times, the last time at right angles to the others; the greater portion of the ashes falling behind the tynes into the soil, thus rendering the land far more porous than before. The land was then scuffled twice at a less depth, to thoroughly mix the ashes with the top soil.

"The land was afterwards drained 5 yards apart with

4-inch agricultural drain-pipes placed diagonally with the slope and about 4 feet in depth. The clay was thrown well away from the drains, and a 6-inch layer of rough ashes was placed over them; the trench was then filled in with top soil mixed with fine ashes. The sewage, after soaking through 2 feet of lightened soil, flows down the slope along the top of the clay until it reaches a trench, where the mixture of soil and ashes allows it to descend to the drains.

"After the sewage has been effectually purified by the above means, the effluent is discharged into the Butterley Canal Reservoir.

"A bed of osiers was planted on the level land next the Reservoir, so that any excess of sewage during a storm can accumulate there until it can filter through the land to the drains.

"Small embankments about 1 foot 6 inches in height, were placed to prevent the sewage overflowing into the dykes, which surround the farm on three sides.

"The above method of dealing with the sewage has resulted in an effluent of a thoroughly satisfactory nature; it is eminently adapted for those districts where a clay subsoil is the only one available for sewage irrigation purposes."

In small districts, the night sewage is small in quantity, and if turned upon land which is naturally porous, or has been artificially made so, would soak into the soil quite close to the carriers, thus producing an unsatisfactory result, since a very small area of land would be employed, quite insufficient to produce a good effluent. Mr. Radford has made provision for this contingency by constructing a small storage tank at the head of the farm, into which the night sewage—or, indeed, all if desired—may accumulate; the tank is provided with a Field's automatic syphon, by means of which, when full, its contents are suddenly delivered into the carriers, and conveyed to the portion of the farm desired.

The main carriers are constructed of concrete, and are provided with wooden sluices at intervals of 30 feet, which divert the sewage into the grips, or subsidiary carriers as may be necessary.

Crops.—The osiers were found not to thrive, in consequence of the small volume of sewage available, and the setts were removed.

Wheat, oats, cabbages, and rye-grass are grown upon the farm, the annual sales producing about £80.

Cost.—The rental paid for the land is £2 per acre, the working expenses are not available, but probably amount to as much as the sales of produce.

The cost of preparation of the land, including £400 paid for furnace ashes, was £1,123. The plan has been supplied by Mr. Radford (see Plate 16).

CHAPTER XVII.

THE EALING SEWAGE WORKS.

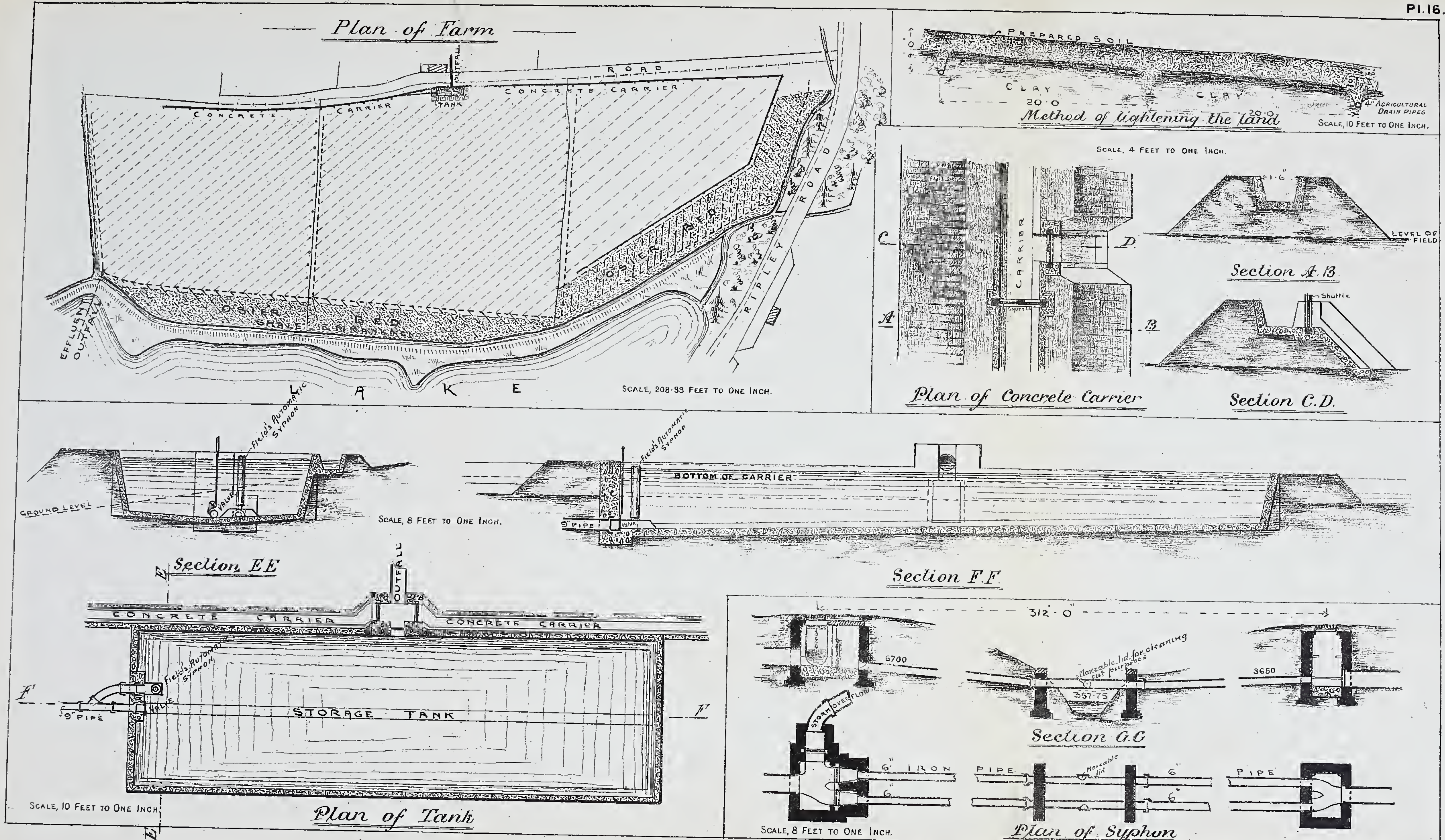
These works possess much interest, as they are among the oldest of their class, and it is here that the sewage problem has been divested of some of its difficulties. The works were established many years ago, and attracted the attention of the Rivers' Pollution Commissioners in 1870.

It was long since recognised that, in many cases, clarification is the first step as regards sewage treatment, and we find filters were employed at Ealing for that purpose.

Filtration.—The Commissioners say—*

"The sewage is received into two deposit tanks, each 64 feet long by 10 feet wide, and 8 feet deep. These deposit tanks are each divided into five chambers by planks having small openings to admit of the passage of sewage water; in the fourth chamber a rough filter of gravel or burnt ballast is formed, through which the sewage passes by ascension. Between the deposit tanks and the first set of filter beds, are two

* Rivers' Pollution Commission, 1868.



THE DISPOSAL WORKS OF SWANWICK. W. H. RADFORD, ENGINEER.

West, Newman photo-lith.

iron baskets containing charcoal closely packed; after passing through these baskets, the sewage is received into the first set of filters, and rises through 18 inches of burnt clay ballast, which is now used in preference to gravel and sand.

"The water then flows over the weir at the end of the first set of filters into chambers containing wire baskets filled with burnt clay ballast, and is led by iron pipes into the second set of filter beds, where all the heavier suspended matter contained in the sewage water is deposited, the liquid then rising through 2 feet of burnt clay ballast.

"The capacity of the deposit tanks and of the spaces under the filter-beds which are employed as deposit chambers, amounts to 27,500 cubic feet. The area of filters in the deposit tanks is 240 superficial feet; that of the first set of filter-beds is 630 superficial feet, and that of the second set of filter-beds is 1,000 superficial feet. There is thus a total area of 1,870 superficial feet; and the sewage in its transit passes, in all, through 7 feet 4 inches of filtering materials.

"The soil collected in the deposit tanks and filters is removed through cast-iron valves placed 13 feet apart, and drops into vaults below, being afterwards mixed with the dust and ashes collected by the scavenger, and sold for manure.

"The process, as thus carried out, entirely fails to transform the *soluble* putrescent organic matters into innocuous mineral compounds. This failure is due partly to the filters being far too small for the volume of sewage dealt with, and partly to the circumstance that the filtration is performed upwards instead of downwards. For efficient purification by filtration, it is essential that atmospheric oxygen should have frequent and free access to the interior of the filter, *a condition which is entirely excluded in upward filtration.* (Not necessarily, *Author.*) Nevertheless the filtered sewage was being run into the *Thames* by permission of the Board of Conservators under the following certificate extracted from a report dated October, 1868, by Mr. Charles Jones, Surveyor to the Local Board of Health, Ealing:—

"'LONDON HOSPITAL, *March* 21*st*, 1868.

"'The sample of liquid contained in the bottle marked A, 16th March, 1868, which was sent here on the 16th of March, is a very weak solution of carbonate and sulphate of ammonia, with a little calcareous and organic matter and common salt.

"'The total amount of these matters is only about 56 grains per imperial gallon, and therefore the liquid is perfectly harmless to animal and vegetable life, and is not offensive.

(Signed) "'HRY. LETHEBY.'"

(NOTE.—This effluent would not now be considered "harmless to animal life."—*Author.*)

"On the occasion of our visit to the sewage works at Ealing, one month later, we were informed that a mean daily volume of 400,000 gallons of sewage, from a population of about 7,500, was being treated. The time of its transit through the series of filter-beds was only 10 minutes. *The suspended matters were, of course, to a great extent arrested, but the effluent liquid retained nearly all the original amount of soluble putrescible organic matter, and was totally unfit to be admitted into running water*, as is evident from an inspection of the following analyses of the samples which we collected at the time of our visit:—

TABLE XXV.—"TREATMENT OF EALING SEWAGE BY FILTRATION.

"RESULTS OF ANALYSES EXPRESSED IN PARTS PER 100,000, AND INCLUDING BOTH SUSPENDED AND DISSOLVED MATTERS.

Description.	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.
Sewage as delivered at works, April 24, 1868, . . .	115·5	27·848	2·930	7·000	·000	8·695
Sewage flowing from last filter, April 24, 1868, . . .	78·5	6·093	2·780	4·250	·076	6·361

"The causes of the failure of sewage filtration at Ealing are sufficiently obvious; they are, first, the inadequacy of the mass of filtering material; and, secondly, the absence of all provision for the frequent aeration of that material. We find, from experiments, that the efficient purification of 400,000 gallons of sewage per day by filtration would require at least 40,000 cubic yards of filtering material, whilst the Ealing filters contain only 60 cubic yards."

We now find (1890) that the works have constantly been added to, that the tank accommodation is of the most ample dimensions, and that clarification is now effected by means of chemicals; the effluent water being conveyed to the Thames as heretofore.

Before leaving this part of the subject, it may be interesting to ask how far the sentence above, printed in italics, is applicable to many of the chemical processes?

Ealing, with a comparatively small effluent, and an enormous river for its reception, is successful in dealing with its sewage. Where the conditions have been the direct opposite, as at Birmingham, Nottingham, Leicester, and elsewhere, the most perfect chemical processes have broken down, simply because there has not been sufficient water in the rivers receiving the effluent, to complete its purification.

The following description of these works has been supplied by Mr. Chas. Jones, C.E.

Works.—"The Ealing Southern Sewage Works were designed by Mr. Charles Jones, A.M.I.C.E., in the year 1863, to meet the requirements of the village of Ealing, and with an eye to a very large development of this western suburb of London. At the time of their construction the population of Ealing was about 5,500, with a ratable value of a little over £18,000; at the present time, 1889, the population is 24,000, and the ratable value £152,000. These figures are given in order that the necessity for gradual growth of the works may be fully recognised, whilst at the same time the fact that in all the increase that has taken place the working out of an original and comprehensive scheme has ever been borne in mind.

"In designing these works, Mr. Jones, after a careful investigation of the various best known sewage works in the country, decided upon a system of subsiding tanks supplemented by chemical precipitants (where and when necessary), believing that an effluent might be produced which would satisfy the requirements of the Conservators of the River Thames, into which the effluent is discharged; and the fact that for twenty-six years these works have, under the supervision of Mr. Jones, met with the approval of not only the Thames Conservators, but of a very large proportion of the men best qualified to judge of their merits, is a very fair evidence of their efficiency and their worth.

"The Ealing Works were the first complete sewage works constructed in the 'valley of the Thames,' and there can be no doubt that the attention they attracted, and the name they gave to Ealing as a well-drained place, has had much to do with the undoubted prosperity of this favourite suburb.

"The land taken by the Board in the first instance consisted of one acre of the main road from Ealing to Brentford, the boundary being the south wall of subsiding tanks, Nos. 1 and 2 (see plan). These tanks were respectively 64′ 0″ × 10′ 0″ and 8′ deep, and 34′ 0″ × 10′ 0″ and 5′ deep, there being a slight fall between Nos. 1 and 2. No. 1 being divided (each tank) into six bays or divisions by 9″ deals, which, being placed about half an inch apart, act as strainers. Some few years later large subsiding tanks were erected, the dimensions being 55′ 0″ × 10′ 0″ and 10′ deep, the outlet being into the Ealing Lane, and thence to the Thames. From the construction of the works in 1863-4, the whole of the treatment of the sewage, and the several works connected with the sanitary work of the district, and the depôt for ashes, &c., were carried out upon this comparatively small space of one acre, of which only about three-fourths was available. The growth of the population, however, was such that in 1882 it was decided to still further enlarge the ground area by the purchase of an additional two acres, and the construction of three more tanks, at a lower level, the surface water level of these when full being 6½′ below the bottom of inlet outfall sewer. These tanks are 178′ × 25′ × 9′ deep, and when working, as shown by arrow marks on the plan, give a run for the effluent water, after chemical treatment, of about one-fourth of a mile before passing over the tumbling bay, and thence to the Thames by the low-level outlet.

"**Chemical Treatment.**—The chemical treatment carried out at these works for many years, has been the milk of lime process, supplemented by clay and sulphate of alumina, the proportions being 10¼ grains of lime, 11½ grains clay, and 2 grains of sulphate of alumina per gallon. One important feature, and upon which Mr. Jones lays great stress, is the amount of oxidation produced by the several falls, and the apparatus arranged for this especial purpose, and which, we believe, is to be very largely increased in the re-arrangement of the works (1889) taking place, owing to the continued increase of the population. Probably that which strikes the visitor to these works most is the very large area devoted to effluent water tanks, and there can be no doubt that to this specialty very much of the success of the work is due. Mr. Jones claims to have a larger amount of tank space at Ealing than at any town in England. At the same time, many towns turn out a first-rate effluent—so far as suspended matters are concerned—with much less tank accommodation.

"The treatment of the sludge has formed an important feature; difficulties having arisen some years since in disposing of the same, Mr. Jones directed his attention to the best mode of dealing with the difficulty, and eventually decided upon burning it, in connection with the house-refuse; and, whatever difference of opinion may exist as to the advisability of such a course, one thing is certain, Mr. Jones, by his method, gets rid of the nuisance, both of the sludge and house-refuse, produces a hard clinker, which is valuable for many purposes—such as concrete, tar-paving, artificial stone, &c., &c.—and provides sufficient steam to work the machinery for pumping,

&c., necessary at the works, without any cost for outside fuel, whilst the destructor, combined with the 'fume cremator,' invented by Mr. Jones, carries on the work without any nuisance."

The arrangements for adding the chemicals are of ingenious, but simple character. The lime is converted into "milk of lime," in one of Scott's mixers, and, with the clay, passes into the "main inlet shoot," where it becomes thoroughly mixed with the sewage in the passage of the latter to the tanks. The sulphate of alumina solution is not added until partial clarification has taken place, which Mr. Jones thinks is right in principle.

In consequence of several operations being carried out at the depôt, it is somewhat difficult to arrive at the annual cost of these works. A general plan of the works is given on Plate 17.

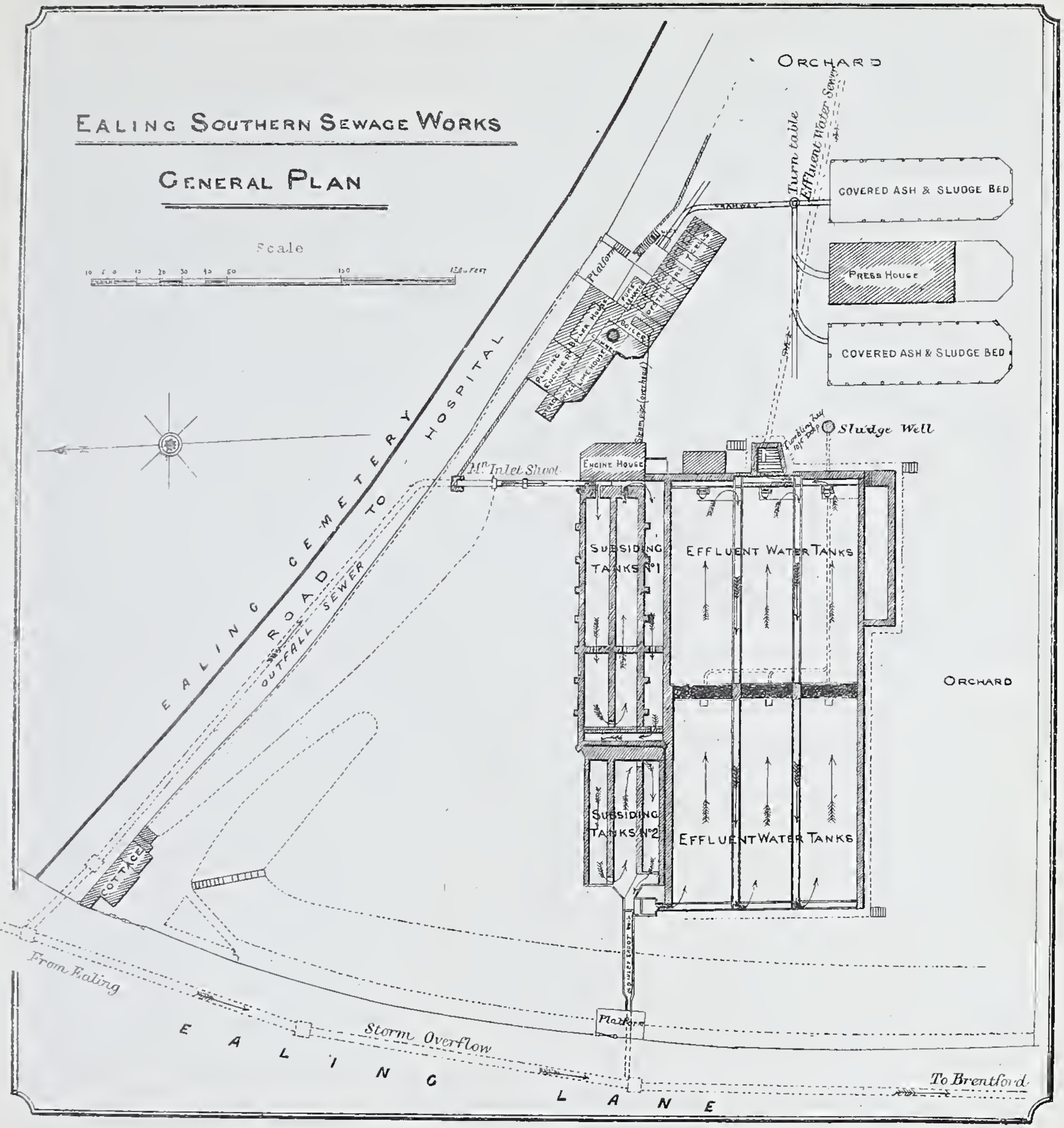
CHAPTER XVIII.

CHISWICK, 1890.

Population, &c.—Population, 21,000. Ratable value, £115,000 (about £90,000 for Local Board purposes). Water-closets, 4,600. Dry-weather sewage flow, 550,000 gallons per day. There is one storm-overflow.

The separate system of drainage is partly in operation, but large numbers of roofs now drain into the sewers, particularly as regards houses built since the year 1883. With few exceptions the roads are not drained into the sewers.

Works. — The works were constructed in response to a demand by the Thames Conservators, whose powers extended to the enforcement of a penalty of £100 per diem in case of non-compliance. Whilst enormous penalties were being incurred with impunity by neighbouring parishes, and large amounts were being expended by the now defunct Lower Thames Valley Main Drainage Board, and by the opponents



West, Newman photo lith.

of its schemes, Chiswick was employed in the useful works of drainage and sewage disposal. The works were designed by Mr. H. O. Smith in 1876, and were constructed under his superintendence during the years 1877, 1878, and 1879.

Outfall.—The sewage is conveyed to the disposal works by means of two main outfall sewers, one is 2 feet in diameter, constructed with stoneware pipes; the other 2 feet 6 inches by 1 foot 8 inches, built with bricks. These sewers discharge into the pump-well as shown upon the plan, their inverts being at ordnance datum level.

The sewage is lifted to 19 feet above O.D. by means of two of Davey's differential pumping engines, each indicating 15 H.P., and together capable of delivering 1,200,000 gallons of sewage in twelve hours. Although one pump can ordinarily lift, in seven hours, the sewage produced daily, the two are insufficient to lift all the sewage and flood-water reaching the pump-well in periods of heavy rainfall. The sewage has therefore to rise against them in the sewers until the storm abates and the engines gain on the flow. A storm-water overflow has been provided for the purpose of conveying the excess direct into the Thames, if the water should rise dangerously high.

Treatment.—As Chiswick is quite near the Thames, parts of the town being, in fact, situated upon its banks, and the volume of the river-water is in dry weather about 800 times greater than that of the sewage of the town, it was decided that a chemical process should be adopted, it being considered that an effluent sufficiently pure to meet the exigencies of the case might be produced by that means, at the least cost to the ratepayers. Eight settling tanks were constructed, and a reference to the plan will show that the mode of construction differs as regards four of the tanks

In the case of the large tanks, a set of coke-filters has been constructed at a low level, the section showing their position, and it was intended to pass all the effluent water from the large tanks through these filters before it escaped into the outlet channel. The small tanks were provided with two sets of filters, one set at a high and the other at a lower level, the intention having been to allow the effluent to overflow from the top water-line through the higher filters into the river when the lower outlet was tide-locked; the effluent thus discharged could also be passed through the lower filters on its way to the outlet channel at low tide. In practice, it has not been found necessary to use these filters, and they now contain no coke. The designs are, however, good, and particular attention may be drawn to the wooden channel above the large coke-filters, by means of which a large amount of aeration of the effluent can be obtained when the tanks are worked on the continuous flow system. Each tank is provided with a floating arm valve for the purpose of drawing off the top water, and although a series of sluices admit of the continuous flow system being worked, the absolute rest method is preferred.

Each tank is provided with floating scum boards, which are placed midway in the length of the tank, and work in channel-iron guides placed upright against the partition walls.

The total tank capacity amounts to 800,000 gallons, and Mr. Hetherington, the manager of the works, states that the tanks may be filled with sewage and emptied, after chemical treatment, six to eight times per diem, according to the state of the tide, the works being situated upon a tidal reach of the Thames.

It may be mentioned that the storm-overflow is rarely used. Its invert is 5 feet above those of the main sewers, and it is tide-locked at half tide.

Clarification.—The mode of treatment finally adopted for the clarification of the sewage is precipitation by means of lime and Spence's alumino-ferric. The Local Authority was advised to adopt the process by Dr. Tidy, and its employment has given entire satisfaction to the Thames Conservators.

The inverts of the tanks are segmental in cross-section, and they slope towards the sewage inlets, underneath which are the sludge outlets. The slope of the inverts of the large tanks is 1 in 90, and that of the small tanks 1 in 50.

Sludge.—Upon cleansing a tank, the sludge is swept through the valve at O into a culvert, whence it gravitates into the "sludge-pit," a screen being placed at the entry to this pit in order to intercept large solids, and thus prevent damage to the filter-presses, of which there are two by Messrs. Johnson & Co., each 36 inches in diameter, with twenty-four plates. Air is employed in forcing the sludge into the presses. An air-pump first exhausts the steel receivers of air, and into these the sludge from the sludge-pit rises. Lime is then mixed with the sludge in the receivers, in the proportion of 14 lbs. of lime to each cwt. of wet sludge, and compressed air is then employed to force the material into the presses. The press-liquor flows back to the pump-well, where it mixes with the crude sewage. The cakes of sludge are given away to market gardeners, and is now all got rid of on these terms.

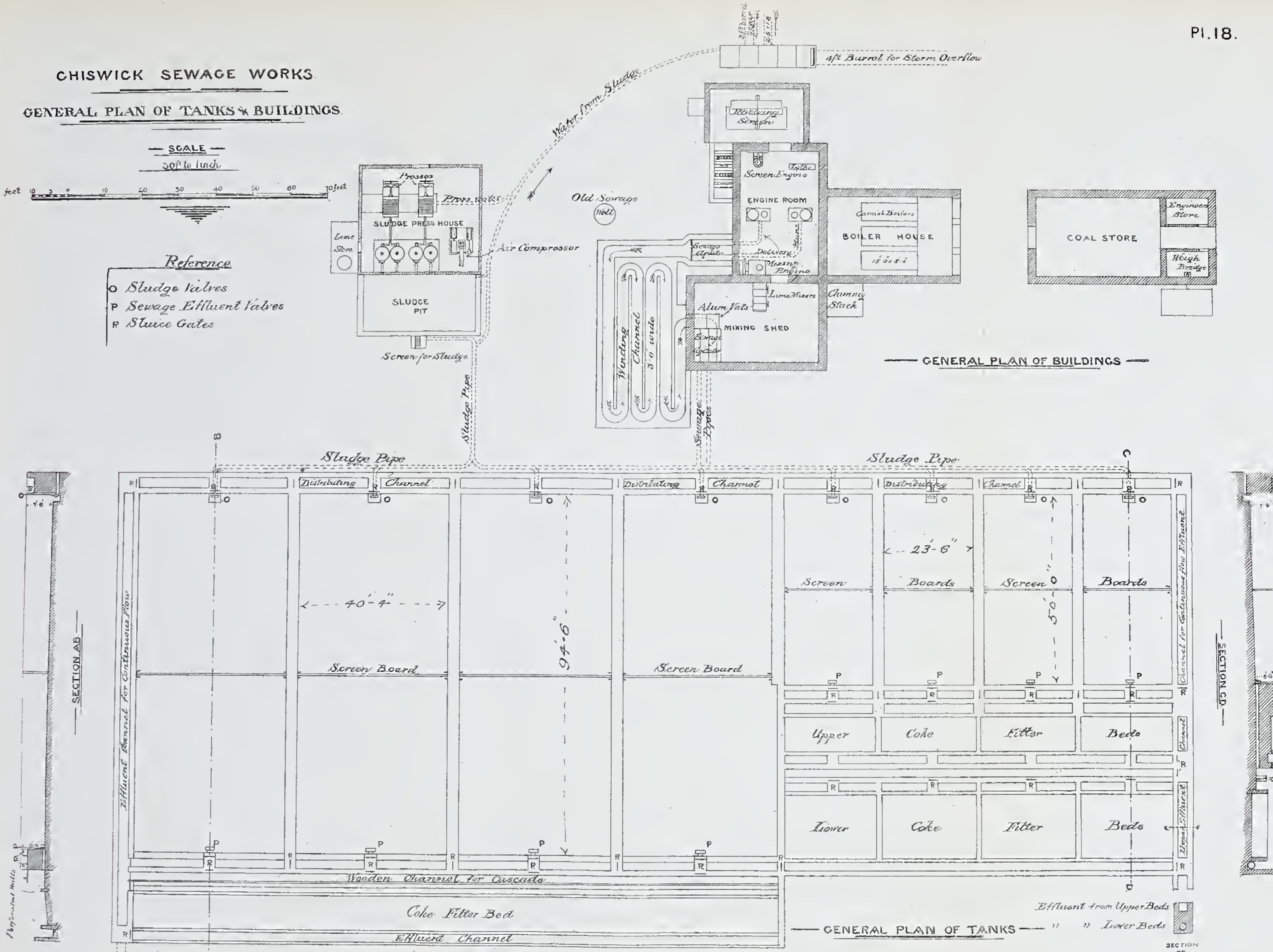
The Local Board of Chiswick experienced trouble with its sludge before the filter-presses were erected; the Thames Conservators were satisfied with the effluent, but the wet sludge became offensive to an owner of land, whose property adjoins the sewage works, and the aid of the Court of Chancery was invoked, with the result that filter-presses were erected in 1884. Under the circumstances, very little time was available to mature plans, or to study other works, and, indeed, filter-presses for sludge were used in but four cases, so far as is known. The plant as originally erected was not at all satisfactory, the arrangements for introducing the sludge into the presses being far from successful, the sludge receivers being placed horizontally instead of vertically, as at Wimbledon (see plan of Wimbledon works); in consequence of this arrangement, large accumulations of detritus took place inside them, reducing their capacity so much that two charges of wet sludge were required to fill a press with cake, thus involving the waste of much time. The cost of pressing amounted to the exceptionally high figure of 5s. per ton, and Mr. Hetherington advised a re-arrangement of the receivers, and the addition of one more; his recommendations have been carried out, the work being performed under his personal supervision, and the cost of pressing the sludge now amounts to 3s. 6d. per ton. This is rather more than sludge ordinarily costs in pressing, but it appears that the sludge contains quantities of size and china-clay from a wall-paper printer's works, which block the filter cloths and add very materially to the cost of pressing. In experimenting with various precipitants at Wimbledon, the author has found that those of a clayey nature invariably produce the results indicated above.

The chemicals used in the treatment of the sewage are lime and Spence's "alumino-ferric," in the proportions of 7 grains and 5 grains per gallon respectively, Dr. Tidy having advised this mode of treatment. After being slaked and thoroughly mixed with water, the lime is applied to the sewage at the points where the pumps deliver into the "sewage agitator;" the limed sewage then flows along the winding channel, by means of which the agitation of the sewage is kept up, and the lime is thoroughly mixed with it. On arriving at the mixing shed, the alum—in solution—is added, further agitation is effected, and the treated sewage flows into the distributing channel, and thence into the settling tanks as desired. The mixing arrangements are well-devised and are very effective.

Cost.—The staff employed consists of:—

		£	s.	d.			
One engineer, .	@	£2	15	0	per week,	with	residence, &c.
,, .	@	2	0	0	,,	,,	,,
One stoker, .	@	1	7	0	,,	without	,,
,, .	@	1	7	0	,,	,,	,,
One press man,	@	1	13	0	,,	,,	,,
,, .	@	1	5	0	,,	,,	,,
One tank man,	@	1	1	0	,,	,,	,,
		£11	8	0			

Pl. 18.



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Wages £11, 8s. per week, or £592, 16s. per annum. Add, for holidays and miscellaneous, £35 per annum, or

Total wages, ...	£627	16	0	
Fuel, ...	350	0	0	
Grey lime, . . .	150	0	0	(for pressing).
Alum, ...	150	0	0	
Clay cross lime, .	120	0	0	(for sewage treatment).
Press cloths, &c., .	75	0	0	
Gas, Rates, &c., &c.,	100	0	0	
	£1,572	16	0	

This represents a rate of 4·6d. in the pound.

In consequence of pumping at night being performed, and the contingent necessity of employing a double shift of engineers and stokers, the cost is somewhat high.

The sludge-cake produced per annum amounts to 2,200 tons, which is removed by market gardeners free of cost to the Board.

The author is indebted to Mr. Hetherington, the manager of the works, for the details given in this chapter, and for the plan (Plate 18).

CHAPTER XIX.

KINGSTON-ON-THAMES—A.B.C. PROCESS.

The sewage disposal works recently completed at Kingston are of excellent design, more particularly as regards the settling tanks. The arrangements for dealing with the sludge are also very complete, and present certain novel features, to be described later.

Twenty-six years ago the drainage of the town was enforced by the Local Sanitary Board; the sewers constructed consisted of stoneware-pipe sewers, and a large brick outfall, which discharged into the river Thames near Kingston bridge. The outfall was 4 feet 6 inches in vertical diameter, and both sewage and rainfall passed into the river by means of this outfall.

When the necessity for purifying the sewage became apparent, the Town Council made several efforts to procure land for irrigation purposes, but neighbouring towns opposed, and, finally, through the efforts of the late City Solicitor, Sir Thos. Nelson, a Joint Main Drainage Board was formed, having as its objects the drainage and sewage disposal of twenty-three contiguous towns and parishes, of which Kingston was one.

One of the schemes put forward by this body was for conveying the collective sewage to Moulsey. Another, proposed by Sir Joseph Bazalgette, was for carrying the sewage of all these places to the main sewer of the West Kent district, involving a culvert for the purpose 27 miles in length. The Corporation of Kingston determinedly opposed these schemes, and finally succeeded in getting the Joint Board abolished, after upwards of eighty thousand pounds had been spent in promoting schemes, litigation, and contingent expenses.

Upon the dissolution of the Joint Board, many of the parishes took immediate, but independent, action, with the result that a number of sewage disposal works have been actually constructed, or are in course of being executed.

At Kingston, a tract of land adjoining the river and close to the old outfall was purchased, and works have been carried out, and are now in operation.

Outfall.—On referring to the block plan, it will be observed that the sewage has been diverted from the old outfall into the new works. At the point of diversion an overflow-weir has been constructed, by means of which storm-water may escape into the old outlet below the point of interception, and thence into the river; the A. B. C. Company are not compelled to treat more than 45 gallons per head per diem (see Plate 19).

The Surbiton Improvement Commissioners joined the Kingston Corporation in their scheme of sewage disposal, and all the sewage from both districts enters the works at the same point.

Engines.—In consequence of the gradients of the sewers, all the sewage has to be pumped.

The engines are of novel construction, and centrifugal pumps are employed in raising the sewage.

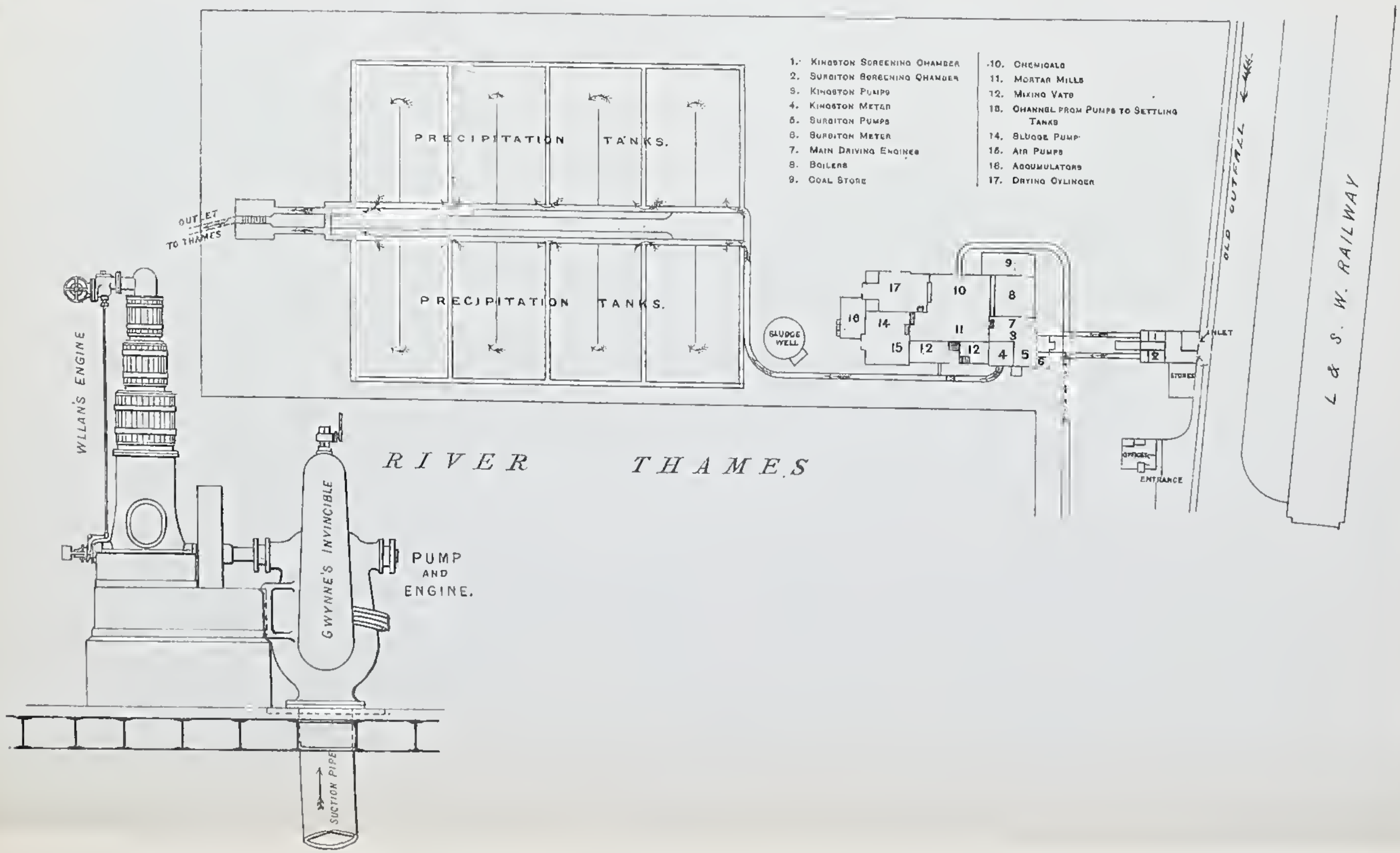
The engines are of the kind known as the Willans Patent Central-Valve Engine, and, together with the boilers and other fittings, have been manufactured by Willans and Robinson, Limited, of Thames Ditton. They include two engines, each of forty indicated horse-power, for driving the mixing mills, drying cylinders, air-compressors, and other machinery at the works; three pumping engines, each capable of raising 100,000 gallons of sewage per hour; and three (for Surbiton) each able to raise 45,000 gallons per hour—eight engines in all. The maximum lift of the pumps is 19 feet (*i.e.*, when clearing the pump-wells), normally, it is about 10 feet for the Kingston, and 13 or 14 feet for the Surbiton pumps. The engines, pumps, and boilers, with their subsidiary fittings, have been erected by the makers in accordance with plans which have been approved by Major Macaulay, Borough Surveyor of Kingston-upon-Thames, and by Charles E. Robinson, Esq., M. Inst. C.E., on behalf of the Native Guano Company. All the engines are non-condensing, and work with steam of 150 lbs. pressure. The two driving engines, and the three larger pumping engines, are on the triple-expansion principle; the three smaller pumping engines (for Surbiton) are compound. The combination of engine and pump is of a simple and very compact nature, as shown on the Plate.

The volume of the Surbiton sewage is ascertained by means of a large undershot-wheel-like meter, invented by Mr. Robinson.

Tanks.—All the sewage is pumped into the channel—No. 13 on the block plan—where it immediately receives its dose of "B.C." mixture, and is quite deodorised; the solution of alum is then added, and the treated sewage is conveyed to the settling tanks, which are eight in number, in two sets of four.

The tanks are each 85 feet long and 49 feet broad, and are partially divided in the middle, longitudinally, by a wall, about three-quarters the distance of the entire length. The tanks are deeper at the near ends and shallower at their rears, so that the tendency of the sludge deposited is to gravitate towards the front wall, whilst the dividing wall tends to cause the fluid portion to circulate round into the second half of the tank, giving it more time to settle before the surplus water runs off by a trumpet-mouthed vertical pipe, sècured to the wall. Attached, also, to the same front wall of each tank, is a jointed pipe, to which a floating valve is attached for draining off the remainder of the water nearly to the surface of the sludge beneath. The water so drawn off is conveyed by an iron pipe to the same place of discharge as the effluent, which constantly flows off from the trumpet-mouthed pipes. Another jointed pipe in the same wall can now be let down into a sump-hole, and the sludge drawn off by a sludge-pump, and ejected into a circular sludge-tank, whence it is drawn off as required, and conveyed by an iron pipe to four large iron vertical cylinders or accumulators. The action of filling these is by suction, the exhaust being accomplished by an air-pump. To prevent these accumulators from becoming too full, a floating ball is raised by the inflowing sludge, until it closes the air-passage, when the exhaust, of course, ceases. The compressed air at three or four atmospheres of pressure is then turned on, and the contents of the accumulators are forced up to the first floor of the building, and there into filter-presses, which express the fluid and mould the solid residue into cakes. The press-liquor runs back to the sump-well, and the cakes are put into a heated revolving cylinder, in which they are thoroughly dried. To prevent the escape into the atmosphere of foul emanations in this operation, the gases from the revolving cylinder are drawn off by a fan, and carried by iron pipes, first to a closed chamber, in which they are subjected to the absorbing action of water spray, amid layers of brushwood. The purified gases are then conducted in stoneware pipes to a cooling tank placed at the top of the building; thence again by pipes to a second

BLOCK PLAN. — KINGSTON SEWAGE DISPOSAL WORKS.



West, Newman photo-lith

chamber, and finally into the external atmosphere by a flue in the boiler stack. The condensed fluid flows from the pipes to the sewer. After the compressed cakes of sludge are dried, they are put into a disintegrator, and broken down into a fine manure, which is put into sacks, and sold at three pounds per ton to farmers and gardeners under the name of "native guano."

Cost.—The works were designed by Major Macaulay and Mr. Robinson, and have cost about £23,000.

The works are entirely operated by the Native Guano Company, who receive a subsidy from the Kingston Corporation and from the Surbiton Improvement Commissioners, amounting to 3d. in the pound upon the ratable value.

The population of Kingston (1889) was .	26,156
and of Surbiton, ...	11,912
Total, . .	38,068

The ratable values were—

Kingston, ...	£105,342
Surbiton, ...	90,018
Total, . .	£195,360

The author is indebted to Major Macaulay and to Mr. Robinson for the details of these works.

CHAPTER XX.

SALFORD SEWAGE WORKS.

Population, &c.—The important Borough of Salford, covering an area of 5,208 acres, and having a population at the date of the last census of 198,717, continued up to the year 1862 without the authorities displaying any interest in the ever-important question of drainage. In fact, the borough being bounded for a considerable part of its circumference by the river Irwell, there did not appear to be any pressing necessity for expenditure on main drainage works whilst there was so convenient a receptacle as the river for the filth of the borough. Twenty years ago, however, Salford, unlike the other districts adjoining, many of which up to the present time have done practically nothing to divert their liquid refuse from the river, recognised the imperative necessity of undertaking a work which was ultimately destined to be one of importance, and began the construction of arterial drainage works of considerable extent. It is true that many of these newly constructed mains gravitated towards and discharged into the river, presumably with a view to their being ultimately connected to an outfall sewer to be hereafter constructed along the valley line, and which would intercept from the river all sewage and manufacturers' liquid refuse carried by the subordinate drains.

Main Sewer.—Several suggestions regarding the interception of the sewage from the river were made by competent professional men, all the schemes possessing certain similarity to each other, and finally Mr. Fowler, M. Inst. C.E., the Engineer to the Corporation, prepared a scheme which received the approval of the Council, and in the year 1873 the first portion of the intercepting sewer for this scheme was commenced. This sewer is a work of considerable magnitude. It has an average diameter at its outlet of 8 ft. 3 ins., and it diminishes in area to the upper end, where the sewer is of egg shape, having an interior section of 4 ft. by 3 ft.

Works.—The total length of the sewer constructed up to the present time is 4 miles 5 furlongs, but as large areas at present unbuilt upon come to be occupied with houses, the arterial sewer will, no doubt, be lengthened at its upper extremity. As the outfall sewer advanced towards completion it became necessary to consider in what manner the sewage of the borough could be most effectually and economically treated at the outfall, and the Corporation, after very careful consideration, determined, in 1876, to establish works at Mode Wheel, a suburb of Salford, for treating the sewage by precipitation, the volume of which was estimated at 12 million gallons daily. Plans were accordingly prepared by Mr. Fowler, who, towards the end of the year 1877, and before the outfall works were commenced, left the service of the Corporation for Newcastle-on-Tyne, and was succeeded by Mr. Arthur Jacob, M.Inst. C.E., at present Engineer to the Corporation. The works as originally designed were, in their main characteristics, similarly to those at Knostrop, which were designed by direction of the Leeds Corporation for treating the sewage of that borough by the A.B.C. process. The arrangement of the works, as originally designed for the Salford Corporation consisted of a series of twelve tanks, arranged in duplicate in two rows. Into these tanks it was intended to lift the sewage direct from the intercepting sewer by means of a pair of centrifugal pumps, the total lift being 14 feet. Adjoining the engine-house was to have been erected a building for the reception of the machinery to be employed in treating the sewage. This machinery was designed to be driven by an engine of forty horse-power. After passing the precipitating material into the sewage, it was arranged that it should flow into the tanks, one series only being used at a time, whilst the reserve series was being cleansed. After being delivered into the tanks, a wide cascade or flight of steps was to be provided for the sewage to flow over, with the object of its being aerated, and from the foot of the cascade the sewage was to flow into the river Irwell.

Before carrying this scheme into effect, it was deemed advisable that the plans should be submitted to the Chief Engineer to the Local Government Board for his opinion. This gentleman, though not speaking in his official capacity, gave a general assent to the arrangement of the works; but, at the same time, pointed out that it might hereafter be necessary to pass the sewage, after undergoing precipitation, through filter-beds, before allowing it to enter the river.

This suggestion, coming as it did from the Engineer to the Central Authority, necessarily led to an alteration in the arrangement of the works, and it was decided in prospect of filtration becoming necessary, to place the tanks at some distance from the river, and on high ground, in order to secure full command of the land bordering on the river. The raising of the tanks to a height of 29 feet above the outfall necessarily led to the selection of a different type of engine and pumps, and it was finally decided to employ a pair of compound vertical engines, driving a pair of double-acting plunger pumps placed vertically under the steam cylinders. These engines have been erected by the firm of Messrs. James Watt & Co. of Soho. They are capable of lifting the whole of the sewage from the area which supplies the intercepting sewer, and rather more than a quarter of an inch of rainfall in the day of twenty-four hours.

Certain other changes were made from the original designs. Instead of making the tanks of earthwork and puddle, with sloping sides lined with stone on the inside, they have been constructed of concrete, and the sides of the tanks are made almost vertical for facility of cleansing.

The engine-house is, as a matter of course, erected in the vicinity of the outfall sewer; but the mixing house is placed close to the end of the tanks, which have been constructed at a distance of 90 yards from the engine-house. The Engineer, finding himself in a position to utilise the fall of the sewage, determined to employ the power at his disposal for driving the mixing machinery, and so avoided the necessity for a 40 horse-power engine originally intended to be provided for that purpose. No material change was made in the area of the tanks, but the arrangement of the supply channels was slightly altered. As a measure of economy, a short intercepting sewer, which was not included in the original scheme, was laid, to collect the sewage and storm-water from the high lying district of Pendleton, which comprises about 1,300 acres of land fairly covered with houses, which otherwise would have drained into the intercepting sewer. Reference to the ground plan of the works, shown on Plate 20, will render their arrangement intelligible.

The **main intercepting sewer** runs along the south part of the land from east to west, discharging at about the summer level of the river Irwell. Upon the sewer, and at a point near the engine-house, is constructed a chamber containing a set of penstocks. At all times, except during heavy rainfall, the penstocks, or at any rate the lower parts of them, are kept closed down, so as to raise the level of the sewage in the outfall sewer and divert it to the pump sump, which is constructed close to the side of the engine-house.

From the sewer leading to the sump, the sewage falls into a square chamber situated between two similar chambers, from which it is cut off by penstocks, which can be opened from the ground level by a capstan and suitable gearing. Into each of these side chambers the suction-pipes from one set of pumps pass from the basement of the engine-house, and either of the chambers can be cleansed, if necessity should arise, without the pumping being discontinued. In the suction-chambers are fixed floats, which have been devised to control and stop the engines before the sewage descends so low as to render it possible for the pumps to draw air. The floats, which come into action shortly before the mouth of the suction-pipe is exposed, act upon a system of horizontal and vertical shafts which gear one with another until the throttle-valve in the engine-house is reached, and the supply of steam to the engines is thus kept under control by the floats; by this simple arrangement the engines may be left unattended without any risk, as the supply of steam is regulated by the supply of sewage in the suction chambers, but as a matter of practice it would not be convenient or desirable that a pair of engines of 450 indicated horse-power should be worked in a manner so irregular.

Purification.—After passing through the pumps, which are of the simplest construction, with ordinary flap-valves, the sewage is delivered at the mixing-house, where it receives the preparation of lime necessary for its purification. The two delivery mains, which are each 30 inches in diameter, pass underneath the tower, discharge into a pair of cast-iron receivers situated in the basement, and into these receivers milk of lime is discharged, as the material at present employed for precipitating the solid matter from the sewage. From the bottom of the receivers, which are arranged in duplicate, a pair of 30-inch mains are laid to the head of the tanks, and during the passage of the sewage through these mains there is ample time for mixture of the sewage with the lime solution to take place. The mains terminate at the head of the tanks in ordinary bell-mouthed pipes placed vertically, out of which the sewage issues under a head of 6 feet 9 inches in the tower, and falls over a sill into the first tank, and so through the whole series of six tanks, until it reaches the mixing-house in a clarified condition. The tanks measure in the aggregate 246 yards in length, and the average width is 65 yards, the total area of water surface being 12,360 square yards.

The sills are so arranged that each succeeding sill is 6 inches lower than the one immediately above it. The average depth of the sewage in the tanks is 7 feet, and the total capacity of the whole series, when full, is 778,600 cubic feet. The bottom of each tank slopes slightly in a direction contrary to that of the flow of the sewage, and the slope terminates in a channel which runs parallel to the cross partition-wall.

For the emptying of the tanks, differential pipes are provided, which are lowered by a small winch, and draw off the clarified sewage, leaving the deposit behind. The liquid escapes through subsoil drains into the river. After the clear water is drawn off, men enter the tank and push the sludge into the open channels above referred to, and in these channels are provided a number of outlets with water-tight covers. As soon as the covers are lifted up, the sludge runs out into sludge pits, which are excavated in the vacant land adjoining the tanks, where it dries by exposure to the air.

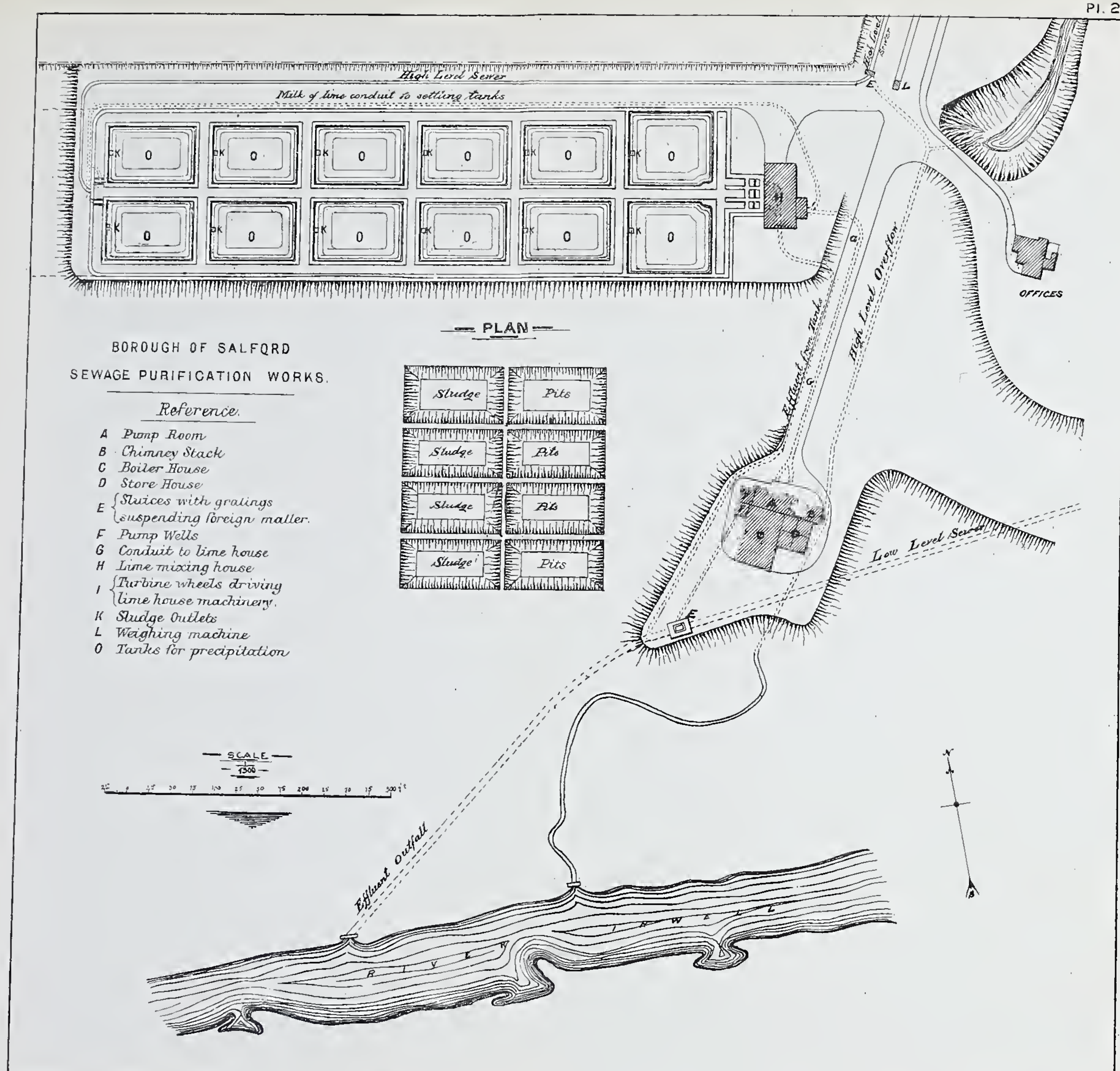
The effluent sewage, in flowing out of the tanks, has a vertical fall of 15 feet, and a pair of turbines are driven by it, which actuate the mixing machinery in the lime house.

Cost.—The intercepting sewer for the Pendleton district passes down the road leading to the works, and runs along the north side of the tanks, as shown on the plan, in an open channel constructed of concrete lined with blue Staffordshire bricks. The cost of the works at Mode Wheel has been £101,000, and that of the intercepting sewer and the subsidiary sewer for the Pendleton district, £97,000; making a total expenditure, with certain contingencies, of £200,000.

Mixing Machinery.—There is nothing very novel in the actual process of mixing at the new Salford Sewage Works, but the method of preparing the lime, or whatever other material may hereafter be employed, is worthy of notice. The whole of the mixing machinery is contained in a house 78 feet 6 inches by 33 feet, and adjoining the mixing tower. A portion of this house is partitioned off, so that the nuisance and discomfort arising from the powdered lime may be localised and kept under control. Outside the partition, or in the lime room, there is fixed a hoist for measuring the lime, in order that the exact proportion to the volume of sewage shall always be maintained. The hoist consists of a wooden casing 4 feet 6 inches by 3 feet, terminating below the floor line in a hopper. At the top and bottom of the casing there works on a horizontal axis, a drum, over which a pair of steel endless bands pass. To these bands are attached, at intervals, horizontal pieces or strips of iron, to which are rivetted wooden buckets of suitable form. As the pulleys and bands revolve, the buckets pick up the lime from the bottom hopper, which is made semi-circular in section, and carry it to the top. When passing over the top pulley, the buckets drop the lime into a funnel-shaped receptacle, which terminates below in a cast-iron pipe, into which a spray of water continually plays, and washes the lime before it along a horizontal cast-iron pipe, which passes through the wall into the adjoining room, and is connected with the mixing pans, where the lime is intimately incorporated with the requisite quantity of water for mixture with the crude sewage. Close to the bottom of the lime house there is an opening in the floor, through which the lime is shovelled into the hopper, but it is here arrested by an inclined screen, which is actuated by a simple connection with the shafting. As the screen moves, the finer portion of the lime passes through into the hopper, and whatever clinker there is, rolls off into an adjoining cavity under the floor, from which it can easily be removed. As already mentioned, the hoist and mixing apparatus are driven by a pair of turbines, which are outside the building, and are worked by the effluent water from the tanks; there are also two horizontal pumps, which are likewise driven by the turbines. One of these raises water from the turbine to the tank at the top of the tower, from which it is drawn to slake the lime and mix it in the pans. The other pump draws the cream of lime from the mixing pans and raises it to the tank at the base of the tower, where it is poured out in a continuous stream to mingle with the sewage as it surges up out of the mouth of the delivery pipes from the engine-house. As the lime-pump at first showed a tendency to clog, after a few hours' work, by a deposit of finely divided lime forming above the valves when the water comes to comparative rest, the simple expedient has been adopted of connecting the suction pipe to the clean-water pipe leading to the tank at the top of the tower. By this means the pump and valves can be completely washed out into the reservoir at the base of the tower.

The arrangement of the mixing apparatus is so simple that it is only necessary to refer to it in brief terms. The speed at which the vertical arms move in the pans is a matter which must not be neglected. If it be too slow, the lime does not become uniformly distributed through the water, but at a speed of eight revolutions per minute the whole becomes agitated, and passes to the pump in a proper condition for admixture with the sewage.

Pl. 20.



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As a large volume of sewage runs direct into the tanks by gravitation from the Pendleton district, and does not pass through the tower, a special arrangement has been made for treating it with lime. It would probably be sufficient to add an excess of lime to the sewage which passes from the engine-house, and to allow the two discharges to mingle at the head of the tanks, but a separate communication is made from the tower to the high level intercepting sewer, by which means lime is added directly to the sewage as it passes along in the open channel to the head of the tanks.

The daily sewage flow is about ten million gallons, and

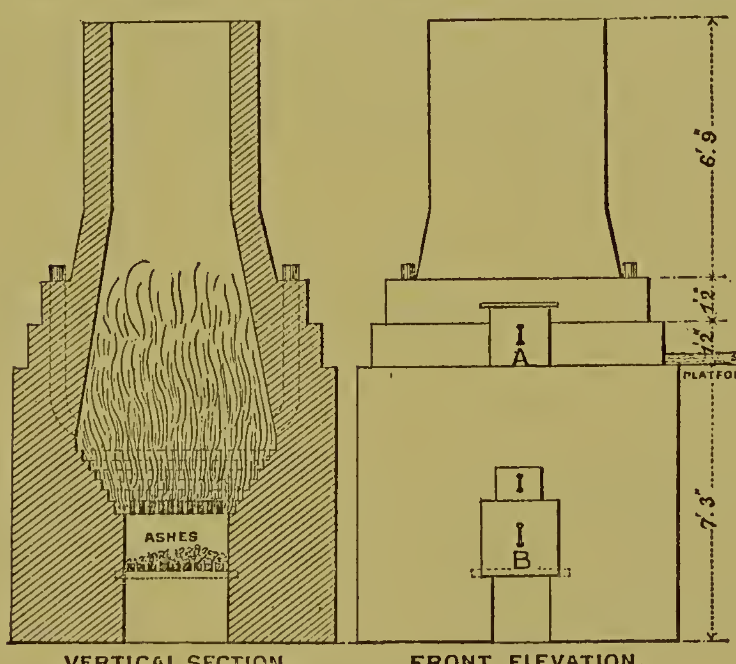


Fig. 15.

this is treated with Buxton lime in the proportion of one ton of lime to one million gallons of sewage.

The sludge is swept from the settling tanks into the shallow pits shown upon the plan (Plate 20), where a part of the moisture evaporates and part drains off; when sufficiently solidified, the sludge was dug out and placed in kilns of simple construction (see fig. 15), where it was burnt. When the kilns were first lighted, a little small coal was necessary, but afterwards the sludge was consumed without the addition of more fuel. Each kiln disposed of about 3 tons of semi-dried sludge per day, leaving 15 per cent. of ash of no practical value.*

As may be perceived, furnaces of the kind illustrated are liable to pass off offensive vapours when used for burning sludge, and in cases where the works are near houses such furnaces are inadmissible. (The furnaces at Salford have been abolished, 1894.)

In a recent letter to the author, Mr. Jacob states that filter-presses are about to be erected for the disposal of the sludge.*

Cost.—The total annual working expenses are £3,000, which includes all costs except interest on outlay.

The author is indebted to the Editor of *The Engineer* and to Mr. Jacob, Borough Engineer of Salford, for the details relating to these works.

CHAPTER XXI.

BRADFORD—PRECIPITATION.

Population, &c.—The town of Bradford has a population of 200,000 inhabitants (1885); the whole of the effluent is discharged into a small stream called the beck of Bradford, a tributary of the river Aire.

Volume of the Sewage.—The daily sewage flow is about 8,450,000 gallons, the whole of which is conveyed to the sewage purification works, which the engineer for the works, Mr. Alsing, calculates to be capable of treating a daily flow of 12,000,000 gallons. The works are in operation during

* *Note.*—The author was recently consulted by the Salford Corporation upon the question of sludge disposal. He found, upon inspecting the works, an enormous accumulation of sludge, and having regard to the difficulty of obtaining land for its disposal in either the wet or pressed state, and also to the fact that the Manchester Ship Canal now adjoins the works, he recommended the transport of the material to sea by means of steamship carriage, on the London principle. This method of disposal will soon be in operation.

the whole year, except in the time of heavy storms, when the surplus is discharged direct into the river.

Nature of the Sewage.—In addition to the sewage from 4,000 water-closets, the waste from a large number of manufactories is allowed to enter the sewers. The greater part of this waste comes from dye-works, wool-combing works, tanneries, and breweries. The manufacturers are not compelled to purify their waste waters in any way, which therefore contain, on being discharged into the sewer, all the noxious matters which are not considered worth extracting.

In consequence of the chemicals employed by the manufacturers, the discharges of refuse are of varying kinds, which make the sewage all the more difficult to treat.

Its composition varies much from one day to another, and also at different hours of the day; Dr. Wallace took a sample in 1876, during the worst portion of the day, and in a very dry season, of which the analysis showed that the sewage of Bradford is considerably more charged than that of Leeds, but less than that of Espierre. It is very foul and of offensive smell, and carries in suspension a large amount of organic and silicious matters, and a pretty large proportion of salts of lime. As regards its composition, it approaches very nearly to the water of the Espierre, which is doubtless owing to the similarity of the industries of Bradford and Roubaix; it also contains a large quantity of nitrogen, in the form of ammonia, evolved from the fæcal matters.*

Description of the System of Purification Adopted.—The system employed at Bradford for the purification of the sewage, is precipitation by lime in tanks, on the intermittent plan, with filtration of the clarified fluid.

The main sewer, which takes the sewage to the purification works, discharges at a level which enables the sewage to flow through the tanks, where the chemical treatment is applied, and from thence into the Bradford beck, without the aid of pumping machinery. There is a difference in level of 12 feet

* Report of Commission on the Espierre, 1885.

between the outfall sewer and the brook into which it discharges; this fortunate circumstance serves to very largely diminish the expenses of treatment. The main sewer is carried under the buildings at the works, and discharges direct into the beck; a sluice allows the flood waters to flow away to the brook in times of heavy storms, when the volume of sewage exceeds the capacity of the tanks.

The chemical treatment of the sewage at Bradford is precisely similar to that at Leeds. Before entering the works, the sewage flows through catch-pits situated on the line of four branch sewers off the main collector, where the heavy matters carried in suspension are deposited. Iron gratings arrest the larger foreign substances and waste of all kind carried in the water. The deposit is raised by a dredge, which passes round the building on a little prepared track, and gathered up in a heap close to the works. It makes a rich mould for the gardeners. Its production, however, is not considerable, being only about 300 tons per annum, and, therefore, very little in comparison with the quantity of matter carried by the sewer. It seems to us that the size of these pits might have been advantageously increased, as this would have rendered the current slower, and consequently caused more of the matter to be deposited before the lime was added.

These catch-pits, and the channels in communication with them, are covered with a wooden flooring, thus screening them from the direct action of the atmosphere.

Manufacture of the Milk of Lime.—The lime employed at Bradford is that of Ingleton; analysis made by Dr. Wallace of Glasgow, showed that it contained, before slaking, 95 per cent. of its weight of pure lime. Here, as at Leeds, our attention was attracted by the importance which is attached to this purity as conducive to successful purification. Two other limes, those of Knottingly and of Shipley, containing respectively 61 and 66 per cent. of pure lime, have not given such good results. We are bound to remark, in passing, that it would be possible to supply Roubaix with fat lime in good condition from the environs of Tournay, and particularly from the quarries at Crèvecœur, which contains from 75 to 80 per cent. of pure lime. It would not be possible for the Espierre to realise under practical conditions the purity of the reagent obtained both at Leeds and at Bradford. The lime is slaked in powder and sifted, it is mixed with water in the troughs, where it is mixed by agitating arms worked with an alternative movement.

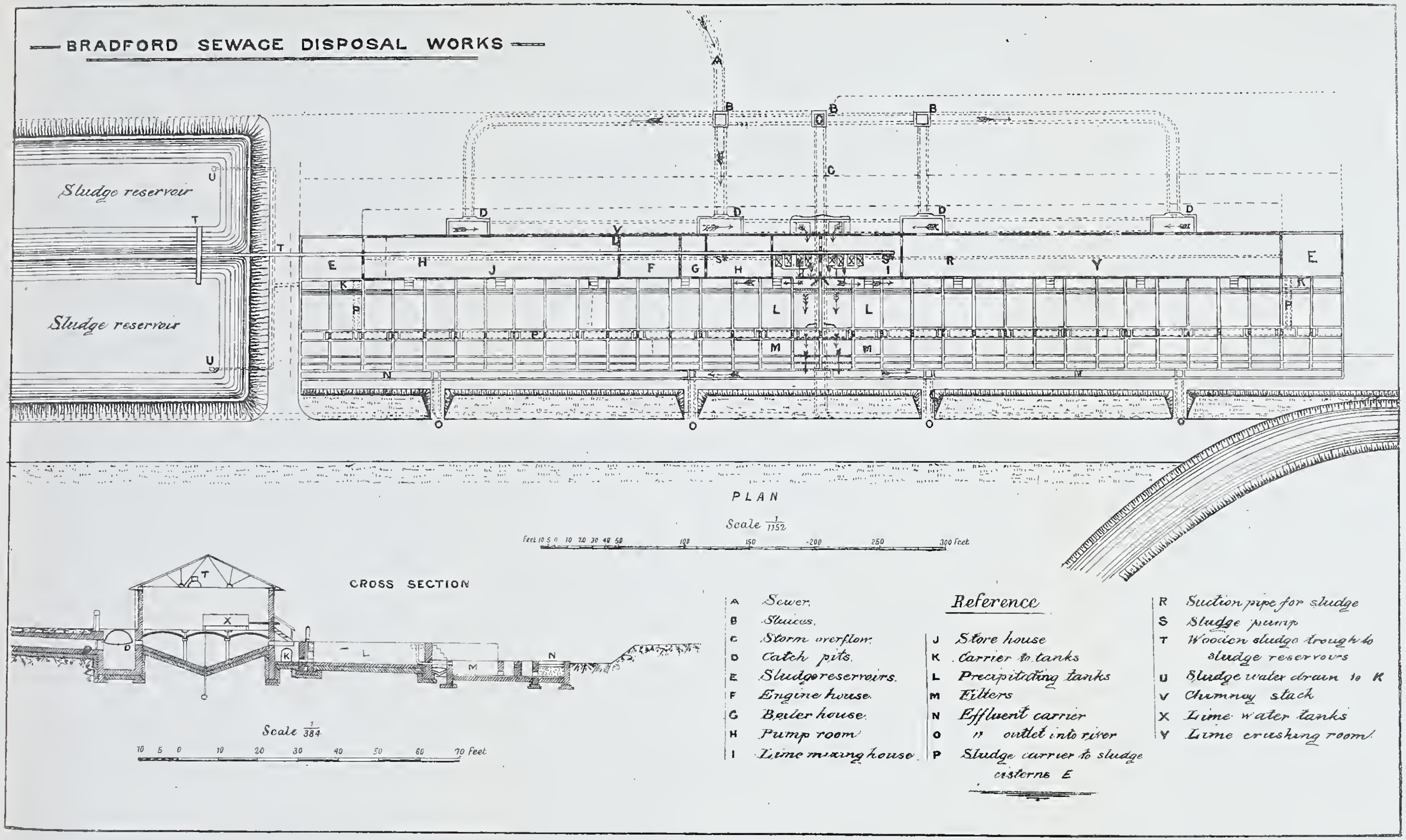
Quantity of Lime employed for the Purification.—The quantity of lime employed for the purification of the sewage varies according to its strength, it is much weaker than usual at night and on Sunday, and it is also much less in strength during wet weather. According to Mr. Alsing, the proportion recommended at Leeds is 1 ton per million gallons. This proportion is reduced on Sundays to 10 cwts.; it is also reduced every night up to midnight, after which lime is not employed. In the accounts of the town of Bradford for the year 1883, the cost of lime for the year is stated to have been £995, 7s. 10d., at the price of 9s. 10d. per ton. This represents a total of 1,990 tons of lime during the year. The annual volume of water treated, at the rate of 8,450,000 (about) gallons per day, is equal to 3,084,250,000 gallons. The average proportion of lime used is, therefore, 12·88 cwts. per million gallons.

The milk of lime being mixed at a level 2 or 3 yards higher than that of the sewage, is discharged with a certain amount of pressure into a channel of masonry, where it is mixed with the sewage without the employment of an agitator.

It will be found on reference to the plan attached to this report, that the method adopted at Bradford for the precipitating tanks presents the advantage of being capable of extension according to the increase of the volume of sewage to be purified. Two rows of tanks, independent of one another, are placed along the whole length of the front of the buildings at the works. The precipitating tanks, where the water is allowed to rest during the time necessary to allow the suspended matters to precipitate, are at a higher level. Below these are the filtering tanks in equal numbers, in which the effluent water from the tanks flows through a filtering medium, and there deposits the lighter matters, which are still held in suspension. The sewage, instead of flowing through all the tanks in succession with a continuous movement as at Leeds, flows into one precipitating tank, and after sufficient rest, passes from there into the adjacent filtering tank. Three carriers in masonry communicate with the different tanks—one distributes the sewage mixed with the lime-water in the precipitating tanks, the second takes the sludge deposited in the tanks, and the third collects the effluent coming from the filtering tanks.

The precipitating tanks are thirty-four in number, 28 feet in length, 22 feet in width, and 6 feet in depth. Each of these is capable of holding 18,000 gallons, and is filled sixteen times in the twenty-four hours. The duration of the complete operation, comprising the filling of the tanks, the precipitation of suspended matters, the drawing off of the clarified water, and the removal of the sludge is, therefore, an hour and a-half on the average. At this rate the thirty-four tanks are capable of purifying 10,000,000 gallons per day. In order to reach the quantity of 12,000,000 gallons per day, which Mr. Alsing informed us was the maximum quantity that the tanks were capable of treating per day, the duration of the complete operation is reduced to one hour and a quarter. The filling of a tank, when the sewage is flowing at the rate of 8,450,000 gallons per day (or 968 gallons per second) occupies about three minutes; the sewage is allowed to rest for from thirty to forty minutes, the remainder of the time suffices for drawing off the effluent and the removal of the sludge.

After the precipitation of the solids produced by the milk of lime, the clarified water is drawn off and passes through the filtering tanks. It is of importance to hasten as much as possible the separation of the sludge from the clarified water



West, Newman photo lith.

without causing too rapid a movement of the latter, which would carry away the lighter parts of the precipitate. This problem is said to be solved at Bradford by means of a floating arm valve; the water is taken from the surface, and is thus automatically drawn off without causing any considerable movement (see Plate 21).

It is of importance to notice that the superficial area of the water in the tanks does not exceed 1,516 square yards, it is therefore much less than at Leeds; the proportion of this surface to the volume of sewage to be purified is not more than 55·75 square yards per 222,222 gallons of the daily flow.

Filtering Tanks.—The sewage, in great part clarified on leaving the precipitating tanks, passes into an equal number of filtering tanks, which are placed at a lower level. The difference in the two levels causes a fall in which the water is agitated and mixed with the atmospheric air. The filtering tanks are 22 feet in length, 12 feet in width, and 3 feet in depth, and are formed of coke-breeze, which is placed on the bottom to a depth of from 1·30 to 1·70 feet, through which the effluent filters downward; but the last of the tanks cannot discharge into the carrier destined to receive it without syphoning under the openings of a dwarf wall in masonry, which causes the effluent from it to flow upward through an equal space of filtering matter placed at the bottom of the last channel.

The filters are renewed four times a year, while the coke-breeze, after having been used as a filtering material, is exposed to the air for the purpose of drying and oxidising it, and is then employed, mixed with coal, as fuel for the boilers at the works, in the proportion of 2 parts of coke-breeze to 1 part of coal.

Nature of the Effluent.—The continuous use of the filters does not permit of giving to the coke, which composes the filter, a supply of oxygen, so as to enable it to effect an oxidising action on the organic matters in solution in the water passed through them; it seems that the filters retain, by a purely mechanical action, the lighter parts of the precipitate which are drained off from the precipitating tanks. Nevertheless, it would appear from the result of analyses made by Dr. Wallace of Glasgow that the filtration through the coke-breeze is not without effect on the quantity of matter held in solution by the effluent. The following table gives the result of his analysis in grains per gallon :—

	Mineral Matters.	Organic Matters.	Total.
	Grains.	Grains.	
On leaving precipitation tanks, . .	18·210	1·882	20·092
Effluent from filter, ...	11·805	1·635	13·440

(It should be remarked, however, that Dr. Percy Frankland is of opinion that these small filters have a prejudicial effect on the effluent, as regards the impurities in solution.—*Congress of the Sanitary Institute, Worcester*, 1889.)

The filtration appears to retain principally the mineral matters, and especially the excess of carbonate of lime produced by the carbonic acid of the air uniting with lime in the water during the agitation which is produced by the passage of the effluent from the tanks into the filters.

The effluent flowing from the works is nearly colourless and without odour; it has no other smell than that which is given to it by the excess of lime which it contains. It flows into a watercourse which is much polluted by manufactories and the sewage of the population above Bradford; it was, therefore, impossible for us to ascertain whether the oxygen in the water was sufficient to destroy the organic matters existing in the effluent—in a word, whether the disinfection was permanent. It may be stated, however, that the amount of purification accomplished by the works at Bradford, has been sufficient to stop the complaints of a riparian owner down the river, and to satisfy the law with regard to the pollution of rivers.

Disposal of the Sludge.—Returning to the tanks where the matters in solution are precipitated by means of lime, the sludge is cleared away by means of bottom sluices into an aqueduct which carries it to tanks, from whence it is raised by means of centrifugal pumps to a height of 29 feet. It then flows by gravitation through long wooden troughs to large reservoirs in the ground at the side of the works; here it remains until by means of drainage and evaporation, it has arrived at such a consistency as will allow of its being loaded into carts and taken away. It then contains about 50 per cent. of moisture, whereas on leaving the tank it contains at least 80 per cent. The liquid from the reservoirs is drained off by means of carriers, and conveyed back to the precipitating tanks. Each reservoir is capable of holding 10,000 tons of sludge. The engineer, Mr. Alsing, calculates the quantity produced annually at 6,000 tons.

The town of Bradford has concluded an agreement with a contractor who receives the sludge gratuitously, he then carts it away and sells it to farmers.

General Arrangement of the Works.—The works and appendages occupy an area of about 10 acres, which is appropriated as follows:—

	Sq. Yds.
Building,	2,674
Tanks in masonry,	6,926
Sludge reservoirs,	9,658
Outhouses, roads, yards, storehouses, &c.,	29,232
Total,	48,490

The building consists of but one storey, and is divided into 6 parts, which are appropriated as follows:—

1. Slaking and sifting the lime.
2. Making the milk of lime.
3. Sludge-pumps.
4. Engine-house.
5. Boiler-house.
6. Stores.

There is no disagreeable odour arising from the works even in the hot season; this excellent result must, in great part, be attributed to the fact that the precipitated solids are not allowed to stop in the tanks, and do not remain in contact with the effluent. The works are situated at Manningham, one of the most beautiful suburbs of Bradford, and do not appear to have given rise to any complaints from persons living in the neighbourhood.

Both the works and the tanks are lit by gas, which facilitates work at night. The average number of workmen employed is 14. A steam-engine of 25 nominal horse-power is sufficient for driving the machinery for sifting the lime and preparing the milk of lime, and also for working the sludge-pumps. It is estimated that, if all the machinery were in operation at the same time, an effective force of 40 horse-power would be necessary.

Previous Works.—It is at once apparent upon inspecting the works at Bradford, that they were constructed for different operations than those which are at present in use. In 1868 a proprietor of land adjoining the Aire, obtained a judicial injunction against the authorities of the town, compelling them to purify their sewage. The town expended £60,000 upon works, having for their object the filtration of the sewage through peat charcoal. The Peat Engineering Company had charge of these works, which proved a failure.

Expenditure.—The Corporation was constrained in 1874 to take these works in hand, and an additional cost of £3,600 was incurred for the purpose of altering the works already erected, so as to make them available for the lime purification process. It appears from the town accounts for 1883, that the yearly cost for repayment of loans and interest on the sewage works account amounts to £3,200. The engineer, Mr. Alsing, estimates that the cost of the first establishment would not at the present time have exceeded £40,000, viz.:—

Land,	£10,000
Works,	25,000
Machinery, &c.,	5,000
	£40,000

It is expedient to remark that the expense incurred in the acquisition of land, in the immediate neighbourhood of a large manufacturing town, and in a rough and uneven country where suitable land was very scarce, is considerably in excess of what would be necessary for a similar installation in the valley of the Espierre. It also seems to us that the number of tanks could be reduced by increasing the surface of each one of them, and that by this means a further reduction in the cost might be made, and thus the cost of the first establishment might be reduced to £1,052 per 222,250 gallons of the daily sewage flow.

The following is an abstract of the annual cost of working as given in the accounts for 1883 :—

Management,	£308	17	0
Labour,	1,454	13	10
Rates,	37	7	2
Lime,	995	7	10
Coal,	120	19	2
Coke-breeze and coke,	56	16	9
Oil, grease, and tallow,	50	8	0
Gas,	33	5	7
Water,	50	17	0
Cotton waste,	6	12	10
Repairs to boilers and machinery,	69	12	10
Repairs to tools and implements,	48	19	2
Blacksmith and ironmonger,	25	0	6
Charge for railway siding,	11	5	7
Miscellaneous,	31	19	1
	£3,302	2	4

If the daily flow be taken at 8,450,000 gallons, the cost of treatment would be 2s. 2d. per 100,000 gallons.

The cost of the principal materials used are as follows :—

Lime,	9s. 10d.	per ton.
Coke-breeze,	0s. 11d.	,,
Coal,	6s. 1d.	,,

The reduced cost of working, in comparison to that of Leeds, is due to the fact that the sewage flows to the works by gravitation, whereas at Leeds, pumping machinery is required. Coal and lime are also cheaper than at Leeds. The materials are conveyed to the works by the railway, with which they are in communication by means of a siding.

The problem of chemical purification of the sewage has been solved at Bradford in a most satisfactory manner; the works which the Commissioners examined in detail, are a credit to Mr. Alsing, their designer.

Proposed Chemical Purification Works for Sheffield.—Mr. Alsing has recently been instructed by the Corporation of Sheffield to prepare a scheme for the treatment of their sewage by means of lime and intermittent filtration.

Mr. Alsing informs us that there is no important difference between the works at Bradford and those which are to be carried out at Sheffield. The Commission saw a report of the Committee appointed by the Corporation of Sheffield to inquire into the matter of sewage purification, in which the Committee deelared that the system of precipitation by lime, as practised at Bradford, was the most economical, and one that satisfied in every way the law relating to the pollution of rivers. This Committee estimated the first cost of land and works at £62,500, and the working expenses at £6,000 per annum for a daily sewage flow of 10,000,000 gallons.

The foregoing details are from the Report of the Commission appointed to consider the question of the Purification of the Waters of the Espierre, dated March 2nd, 1885. It should be mentioned that the Sheffield works have since been constructed, and the author regrets that he is unable to include a description of them in the present work.

Note.—The works have now (1894) been found to be inadequate for the existing requirements, and large extensions are in contemplation.

CHAPTER XXII.

NEW MALDEN—CHEMICAL TREATMENT AND SMALL FILTERS.

Like Kingston-on-Thames, New Malden formed one of the constituents of the Lower Thames Valley Main Sewerage

Board, and, upon its dissolution, immediately provided itself with a system of sewers, and with sewage disposal works.

Works.—Plans were prepared by Mr. Heward, Surveyor to the Local Board, and submitted to Mr. Baldwin Latham, M. Inst. C.E., for revision. The plans were subsequently approved by the Local Government Board, and duly executed, the cost of the entire scheme being £15,800, of which sum £1,320 were expended upon the purchase of 11 acres of land. The sewage is pumped by means of gas engines, and three-throw pumps, the total lift being about 30 feet.

Pumping Engines.—The pumps have strokes of 12½ inches, and diameters of 10 inches. The gas engines are of the Stockport type, and 6 N.H.P. each. The normal duty of each engine and pump is the raising of 20,000 gallons of sewage per hour. The engines are also used for working one of Bowes Scott & Read's lime-mixers.

Experiments are being made with various reagents, and the chemical treatment of the sewage to be adopted remains under consideration.

Tanks.—The tanks are of simple and good design, and of course suitable for the clarification of the sewage whatever chemical process may be finally adopted.

The tanks are six in number, each of the following dimensions:—20 feet × 20 feet, with average depth of 5 feet, and containing 75,000 gallons. Upon the large central division-wall, a carrier has been constructed provided with sluice-valves, by means of which the chemically treated sewage is diverted into any one of the tanks as desired. Under the same division-wall is constructed the sludge-culvert, and as the bottoms of the tanks are made to slope towards this division-wall, in which are suitable openings provided with penstocks, the sludge is readily removed from the tanks.

Filters.—The treated sewage is allowed a rest of about two hours, in order that the suspended matters may be separated; the clarified effluent is then drawn off by means of floating-arm valves, and discharged upon artificial filters of which there are four.

The total area of the filters is one acre, a clay dam separating them from each other. The filters are constructed with burnt ballast (burnt clay) and soil in equal proportions, well mixed together, and covered at the surface with soil, over which the tank-effluent is distributed. The filters are 4 feet 6 inches in depth, are under-drained, and are at such a level compared with the adjoining land that the effluent from them may be turned over its surface if desired; otherwise, it may be discharged into the Hogsmill stream, and thence carried to the Thames. The filters cost £400. The sludge is air-dried in small filters, the quantity being as yet too small to necessitate other treatment. When dry, it is either sold for a small sum per load or dug into the land.

Cost.—The population draining to the works numbers 3,000, and the working expenses, as given by Mr. Heward, are £195 per annum, equal to a rate of 3¼d. in the pound. The general arrangement of the works is shown on Plate 22.

CHAPTER XXIII.

FRIERN BARNET—CHEMICAL TREATMENT AND SMALL FILTERS.

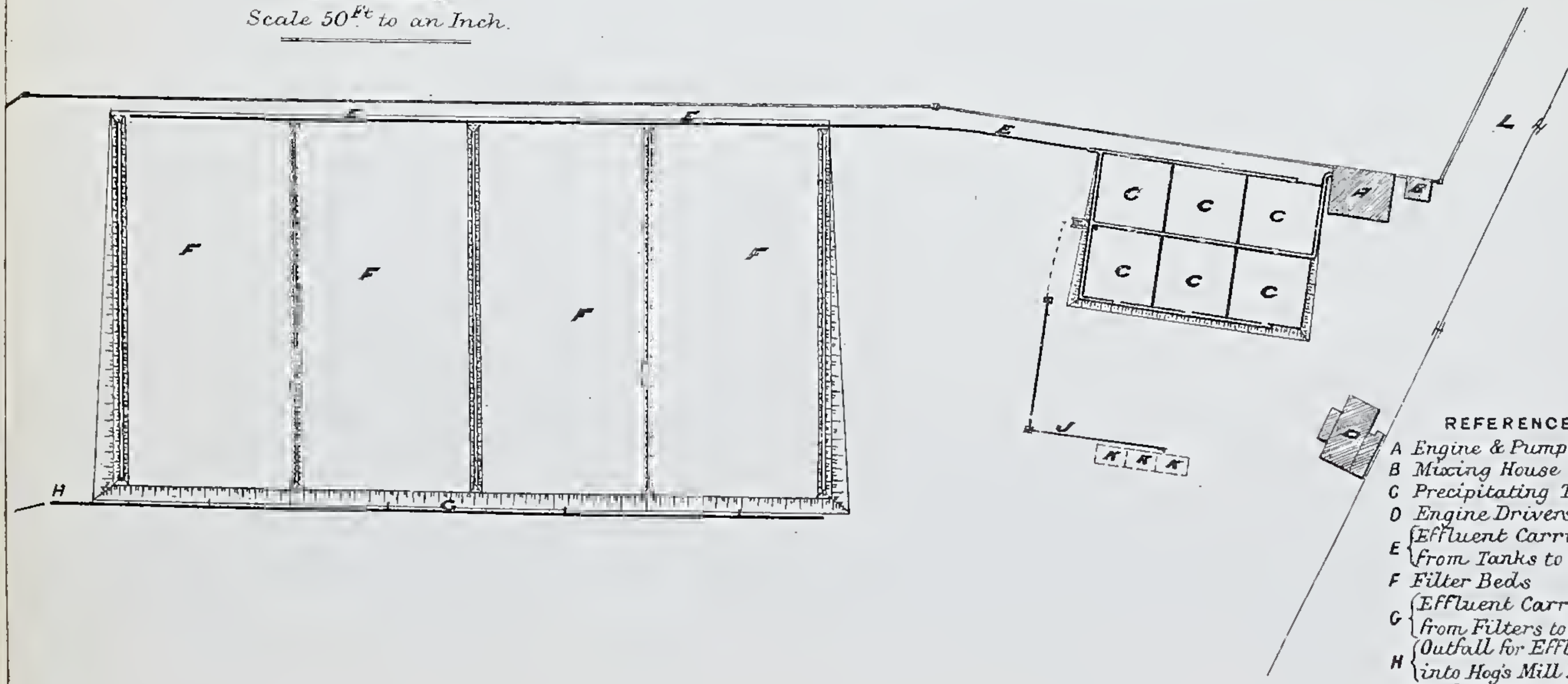
THE conformation of the surface of the Local Board District of Friern Barnet presented unusual difficulties in the solution of the sewage question, especially in the collection of the sewage into one outfall. The district is situated in the basin of the river Lea, the increasing pollution of which river eventually engaged the attention of a select Parliamentary Committee in 1886. The Lea Conservancy Board had previously put pressure upon the various authorities contributing to the nuisance, to compel them to adopt remedial measures. Private owners interested in the purity of the streams passing through their estates were engaged in litigation with the Friern Barnet

Pl. 22.

NEW MALDEN SEWERAGE

PLAN OF OUTFALL WORKS.

Scale 50 Ft. to an Inch.



REFERENCE

A Engine & Pump House
B Mixing House
C Precipitating Tanks
D Engine Drivers Cottage
E {Effluent Carrier from Tanks to Filters
F Filter Beds
G {Effluent Carrier from Filters to Outfall
H {Outfall for Effluent into Hog's Mill River
J {Sludge Carrier from tanks to Sludge Beds
K Sludge Beds
L Road from Highway

West, Newman photo-lith.

and the East Barnet Valley Authorities, the former in their turn proceeding against the Finchley Local Board higher up the stream. Under these circumstances it was of the highest importance that the sewage disposal works should be of the highest efficiency, and capable of producing an effluent of the degree of purity required by the Lea Conservancy Board.

Comprehensive interception-schemes to embrace the districts in the Lea valley, from Hertford and Walthamstow on the north and east, to Friern Barnet and Finchley on the west, have been proposed at various times, and in 1871 Sir Joseph Bazalgette, C.B., devised a scheme for an intercepting sewer for diverting the sewage of all the districts north of the Thames, from Windsor to London, but up to the present all these schemes have fallen through. So long ago as 1866 the Tottenham Local Board proposed united action, being, they said in a circular letter, convinced that without this, all attempts to place the drainage on a satisfactory and permanent basis must prove abortive; adding that the resources of some of the parishes, instead of being devoted to works of general and mutual improvement, have already been and will continue to be, exhausted in a continuous round of litigation. However, in the result litigation was abundant, but no concerted action took place. Finchley and Friern Barnet jointly entertained a proposal for dealing with their combined sewage on an irrigation farm in the latter parish, in accordance with a scheme prepared by Mr. Baldwin Latham, M. Inst. C.E., and also subsequently considered a scheme to construct a joint outfall sewer to Edmonton, where the Edmonton Local Board were prepared to deal with the sewage. The negotiations failed, as did also a proposal for an outfall sewer to Edmonton for the Friern Barnet district alone. Eventually all these districts made their own arrangements for dealing with their respective sewage.

The parish of Friern Barnet was originally in the district of the Barnet Rural Sanitary Authority; but its rapidly growing importance making separate administration desirable, with the consequent advantage of obtaining direct control over the sewerage expenditure, the Friern Barnet Local Board was called into existence in 1884, taking over the liabilities of the Parochial Committee of the Barnet R.S.A., and amongst these liabilities an injunction restraining them from the pollution of Pyrus brook. The new Board proceeded at once to the consideration of the sewerage of the district, and carried out the present sewerage and sewage disposal works, from designs prepared by Mr. Baldwin Latham, M. Inst. C.E. These works, the leading features of which will now be described, were completed in September, 1887, and have been in satisfactory operation since that date.

Nature of the District.—The district of Friern Barnet is intersected by three valleys running east and west. This necessitated the construction of three deep outfalls in tunnels of 900 yards, 330 yards, and 2,300 yards in length respectively, in order to bring all the sewage to one common point. The whole of the sewage is thus brought to the disposal works by gravitation, with the exception of that from about seventy houses in a low lying part of the district at Ely Place. Automatic hydraulic pumping machinery, actuated by high-pressure water, transmitted from the works, has been erected to lift the sewage from this district into the gravitation system. The long tunnel outfall necessary to bring the sewage from the northern valley into the middle valley by gravitation, was thought at one time to involve a cost out of proportion to the population to be served thereby ; but, it was found that the alternative of establishing an automatic pumping station similar to that at Ely Place, although the initial outlay would not have been so great, would, on account of the working expenses, have been a greater burden, especially when Oakleigh Park and the northern valley came to be developed and the population increased. Moreover, the tunnel outfall provides an outlet for the drainage of a large area not at present built upon at the northern end of the parish, that could not otherwise have been so satisfactorily dealt with. These considerations led the

Board to adopt a comprehensive gravitation scheme as being the most economical in the end.

The tunnel outfalls are in the London clay throughout, and the sewers were constructed without any difficulty. The sewer in the lower tunnel outfall is an 18-inch pipe surrounded by concrete, and the gradient is 1 in 650; the upper tunnel outfall is a 15-inch pipe surrounded with concrete, laid at a gradient of 1 in 450. The sizes of the collecting sewers range downwards to 9 inches diameter, and are generally in the London clay, except on the summits of the hills, where gravel was usually found. Extra thick glazed stoneware pipes were used throughout, the thickness being one-tenth of the internal diameter.

Drainage System.—The separate system of drainage is adopted, but provision is made for taking the rainfall from the roofs and yards into the sewers wherever difficulties are found in providing a separate outlet. All the old sewers and drains have been preserved for carrying off the surface water, and, as they already discharged into the natural watercourses, all that was necessary was to ascertain where the existing house-drains entered, and transfer their connections to the new sewer. Owing to the absence of any plans or information, searching for these old drains occupied considerable time, but only in this way could the pollution of the streams receiving these surface water-drains be prevented.

The flattest gradient is in the main outfall sewer, viz., 1 in 650, the sewer being an 18-inch pipe. In the 9-inch collecting sewers all, except a very few, have a fall exceeding 1 in 200. All the extremities of the system have 1,000-gallon flush-tanks fitted with automatically-discharging syphons. These tanks, with the exception of two, are supplied from the Water Company, the remaining two flush-tanks receive the exhaust-water from the high-pressure cylinders of the hydraulic pumping machinery at Ely Place, which is sufficient to cause them to discharge several times a day.

Much difficulty was experienced at the outset in including the sewers in private roads, not repairable by the Board, in the general scheme carried out at the cost of the Board, on account of the opinion strongly expressed in the parish that the frontage owners should bear the expense of such sewers. The latter course, however, would probably have involved much litigation in recovering the cost, and many of the sewers were outfall sewers for districts above; and under no circumstances could the Local Board make the owners pay for a sewer more expensive than the requirements of their particular road necessitated. The Board, after much consideration, decided that it would be to the public interest to sewer (as part of their general scheme, and at the expense of the district generally) such of the private roads as at that time required sewering.

The Sewage Disposal Works.—The method of treatment adopted is chemical precipitation, followed by filtration through artificially prepared filters. The works have been erected just outside the Local Board district, in the middle of about 19 acres of land, in a corner of the parish of Tottenham, and close to the Great Northern Railway. The nearest houses are about 300 feet from the works, and, so far as the author is aware, no complaints of any nuisance have been made by the occupants.

The sewage, on delivery from the 18-inch outfall sewer, passes through a Latham's rotary extractor screen, 10 feet in diameter and ¼-inch mesh, which removes the larger solids. It then passes on to a small water-wheel which is geared to the rotary extractor just referred to. The chemicals are here added, the greater portion of which passes through two mechanical regulators of vulcanite worked by the water-wheel. The amount of chemicals added to the sewage is thus made proportional to the speed of the water-wheel, and so to the quantity of sewage passing. One of these regulators is for the alkaline chemical (lime having been used up to the present), and the other is for the acid chemical. The former falls into the sewage from a notched distributing trough fixed immediately in front of the water-wheel, in passing which it gets thoroughly mixed with the sewage. The acid chemical enters the sewage about half way down a salmon-ladder channel, which the sewage traverses after leaving the water-wheel, the slate projections in this channel aiding in the thorough incorporation of the chemicals with the sewage. The sewage now enters the settling tanks, three of which have been provided, and, after depositing the solids, passes downward and upward through coke-filters, and thence to the prepared filter-beds by a suitable arrangement of carriers. The purified effluent is collected by under-drains, and finally discharged through an 18-inch outfall into the Bounds Green brook, a small tributary of the river Lea. The relative volumes of this brook and the effluent are, in ordinary weather, about 8 or 9 to 1, but in continuous dry weather the brook gets reduced much more proportionally to the effluent discharged into it.

The sludge deposited in the settling tanks is discharged through a penstock into an underground tank, 12 feet by 6 feet, and 60 feet long, extending from the buildings nearly to the settling tanks. The sludge is raised thence by a chain-pump into a lime mixing-pit, from which it is pumped by three-throw ram-pumps into Johnston's filter-presses, and converted into sludge-cake, or is pumped to a portion of the land, forming the site of the works, where it is incorporated with the soil.

The mechanical power in the works is supplied by a pair of high-pressure engines, with 12-inch diameter cylinder and 2-feet stroke, and two Cornish boilers, 15 feet long and 5 feet in diameter. Each engine, by means of shafting and pullies distributing the power throughout the building, is capable of working simultaneously the sludge-pumps and sludge-pressing apparatus, the chemical grinding-mills and mixing-vats, the high-pressure pumps for transmitting hydraulic power to Ely Place, before mentioned, and the small pumps for supplying the high-level water-tank. The machinery throughout is in duplicate.

Appliances.—Four circular vats, 6 feet in diameter and 3 feet deep, are provided for mixing the chemicals; two are of wrought-iron and two of wood, the latter being for acid chemicals. Each vat is fitted with rotatory stirring arms driven by a belt; and the chemical grinding-mills for pulverising the chemicals are arranged so as to deliver their contents into the vats.

The supply of water for the mixing-vats and also for the hydraulic power, is drawn from the effluent from the settling tanks, being pumped by a pair of 3-inch pumps driven from the shafting.

The three **settling tanks** are each 97 feet long by 21 feet wide, and the depth of sewage, when full, varies from 6 feet at the inlet end to 4 feet 9 inches at the outlet end. The capacity of each tank, after allowing for sludge-space, is about 9,300 cubic feet. Two tanks are used at a time, except in very hot weather when only one is used, the present small flow of sewage being insufficient to change the contents of two tanks frequently enough to keep the sewage inodorous when the temperature is very high, unless unduly large doses of chemicals were used. The tanks are provided with scum-boards and also with two cross-walls, over which the sewage has to flow in a thin film. The sewage on leaving the tanks is discharged over a small weir arranged so as to obtain as much aeration as possible.

The quantity of coke provided for filtration is 550 cubic feet for each tank, and this is removed from each every month and used as fuel in the boiler-furnaces.

Filter-beds.—The total area of the filter-beds is 1⅓ acres; they are divided by concrete walls into four, at different levels. The filtering material is 6 feet thick, being composed of a bottom layer 2 feet 6 inches thick of burnt ballast from clay obtained on the site, broken to pass through a 1-inch mesh sieve, and screened so as to remove the fine material. Next is a layer 3 feet thick of an equal mixture of burnt ballast small enough to pass a ¼-inch mesh, coke-breeze, and surface soil thoroughly incorporated together. The surface of the filter is covered with 6 inches of surface soil. Great care was exercised in the selection of the surface soil, so that it should be free from any admixture of clay, which would have prevented the free passage of water, and have caused the filter to get consolidated and incapable of ready aeration. The soil which has been used, was obtained in Hertfordshire, and is of a light nature. Perforated under-drains collect the effluent under the filter, and discharge it into the Bounds Green brook. The filter-beds in use are changed every three days, and it is found that they are ready for use again after an interval of about three days, but varying according to the weather, recovering, of course, more quickly in warm dry weather. Occasionally the surface is raked or harrowed with a small hand-harrow, to facilitate aeration and increase the purifying energy of the microbes in the filters. There is very little sewage-fungus in the under-drains, and the effluent discharged into the brook is very clear and bright, tending to purify the latter, which is often highly polluted by Authorities higher up the stream.

Pumping.—The special machinery, &c., for pumping the sewage at Ely Place by transmitted power, consists of an accumulator, giving a normal working pressure of 280 lbs., a pair of high-pressure pumps, a 2-inch hydraulic main 1,430 yards long, and Davey's differential hydraulic pumps, automatically controlled at Ely Place. In dry weather the pumps are working, on an average, three hours a day. They are visited daily by a boy for the purpose of oiling, and have worked without more attention than this for two or three months at a time.

The flow of sewage at present (1889) is about 120,000 gallons a day, and the amount of chemicals daily used for treatment is 1 cwt. of lime and ¼ cwt. of sulphate of alumina or ¼ cwt. of Hanson's black-ash waste. This is about 6¼ grains of lime per gallon and 1·6 grains of alum or black-ash waste.

At present the sludge is usually pumped by the sludge-pumps on to a high portion of the land, and dug in as a fertilising agent for the production of crops, but three Johnson presses are provided for converting it into cake, if at any time the above method of utilising it is not available. In January, 1888, when the sludge was all pressed, the average weight of sludge-cake obtained per day was 1 ton 12 cwts., which would be at the rate of $13\frac{1}{3}$ tons per million gallons, an unduly large amount, pointing to a very concentrated sewage.

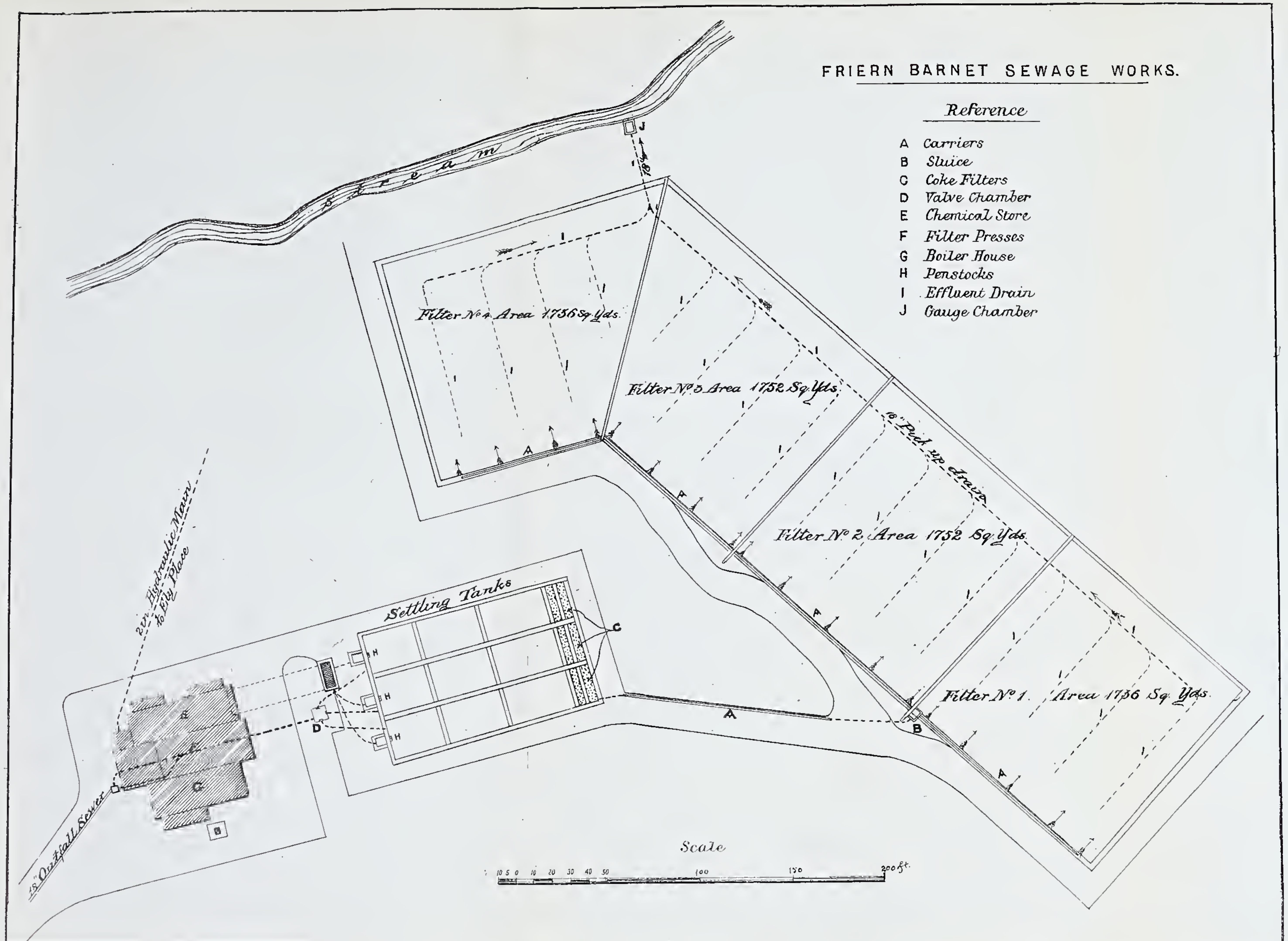
Cost.—The following are a few particulars relative to the sewerage works:—

Population in 1888 (exclusive of the Asylum) estimated .	6,400
Ratable value, 1888, ...	£32,500
Cost of Disposal Works—	
Filters, ...	£2,847
Sewage tanks, ...	1,108
Sludge-pit, ...	302
Buildings, ...	2,235
Chimney shaft, ...	237
Machinery (including accumulator and high-pressure pumps), ...	3,625
	£10,354

Cost of sewage treatment and sludge disposal for year ending March 25th, 1889 (including working expenses for Ely Place)—

	£	s.	d.
Wages—4 men and 2 boys, ...	£332	16	0
Chemicals—Lime, 18 tons 2 cwts., at £1, 0s. 6d., .	18	11	0
Sulp. of alumina, $4\frac{1}{2}$ tons, at £3, .	13	10	0
Blk.-ash waste, $1\frac{1}{2}$ tons, at £3, 12s. 6d.,	5	8	9
Fuel—Coal, $176\frac{1}{2}$ tons; coke, 86 chal., . .	170	16	10
Water, ...	21	12	6
Sundries, oil, tallow, repairs, &c., . . .	21	0	6
Insurance, rates, and taxes, ...	43	18	6
	£627	14	1

The author is indebted to Mr. Baldwin Latham, M. Inst. C.E., for permission to publish the description of these works, and to Mr. Ernest Bruges, Assoc. M. Inst. C.E., for the details. Mr. Latham designed the works, and Mr. Bruges acted as Resident Engineer during their construction. The general arrangement of the works is shown on Plate 23.



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CHAPTER XXIV.

ACTON—FEROZONE AND POLARITE PROCESS, 1889.

The Acton Sewage Disposal Works have excited a considerable amount of interest, since a new departure in sewage treatment has been successfully brought into operation at these works.

Tanks.—The settling tanks are of simple design, and do not necessitate much description. The treatment of the sewage consists in the addition to it of Ferozone—described in the chapter on Chemical Processes—and, after deodorisation and precipitation of the suspended matters, the effluent is made to pass through two small filters composed of polarite and sand.

Filter.—The tanks and works are shown upon Plate 24, whilst the woodcut (fig. 6, p. 82) represents a section of the polarite filter. Coarse gravel—intersected with drain pipes—is laid upon the floor of the filter, then pea gravel, fine sand, sand and polarite mixed, and finally sand, are built up in horizontal layers, and the tank effluent passes downwards, on the intermittent principle.

The author experimented with a filter of this kind at Wimbledon, and found ordinary top soil quite efficacious in place of the sand forming the topmost layer. The daily passing of large volumes of sewage effluent through each square yard, 1,000 gallons and upwards, soon clogs the top inch or so of filtering material, since nearly all tank-effluents contain two or three grains of suspended matters per gallon, and any plan that obviated the expense of removing and washing the sand would prove very advantageous to the system.

The greater portion of London water is filtered at the different works, before being pumped into the mains, and at one of the largest works, when it is necessary to cleanse a filter, a layer of sand about ¾-inch thick is skimmed off, the water is again admitted, and, again, when necessary, a layer of sand is skimmed off; in this manner 1 foot of sand is eventually removed in sixteen skimmings, when a foot of washed sand is re-placed upon the filter, and the operations are repeated. The entire cost of the series amounts to about £185 per acre, which is inclusive of water for washing sand at 2d. per 1,000 gallons. About 900 million gallons of water are filtered per acre per series of operations, so that the cost of filtering London water is about 4s. per million gallons. But sewage would cost a great deal more, as it contains much more suspended matter.

The author can, in this edition, give the cost of filtering sewage at Tottenham, as detailed in Mr. J. N. Worth's report of 1890, a copy of which may be seen at the Institution of Civil Engineers. It appears from the report that, as might be expected, the better the sewage was clarified before being applied to the filter, the less was the cost of cleansing the surface of the latter. The details of five months' working are given, but the results of the first month's working are omitted here, as the cost was naturally higher than after the best mode of working had been discovered.

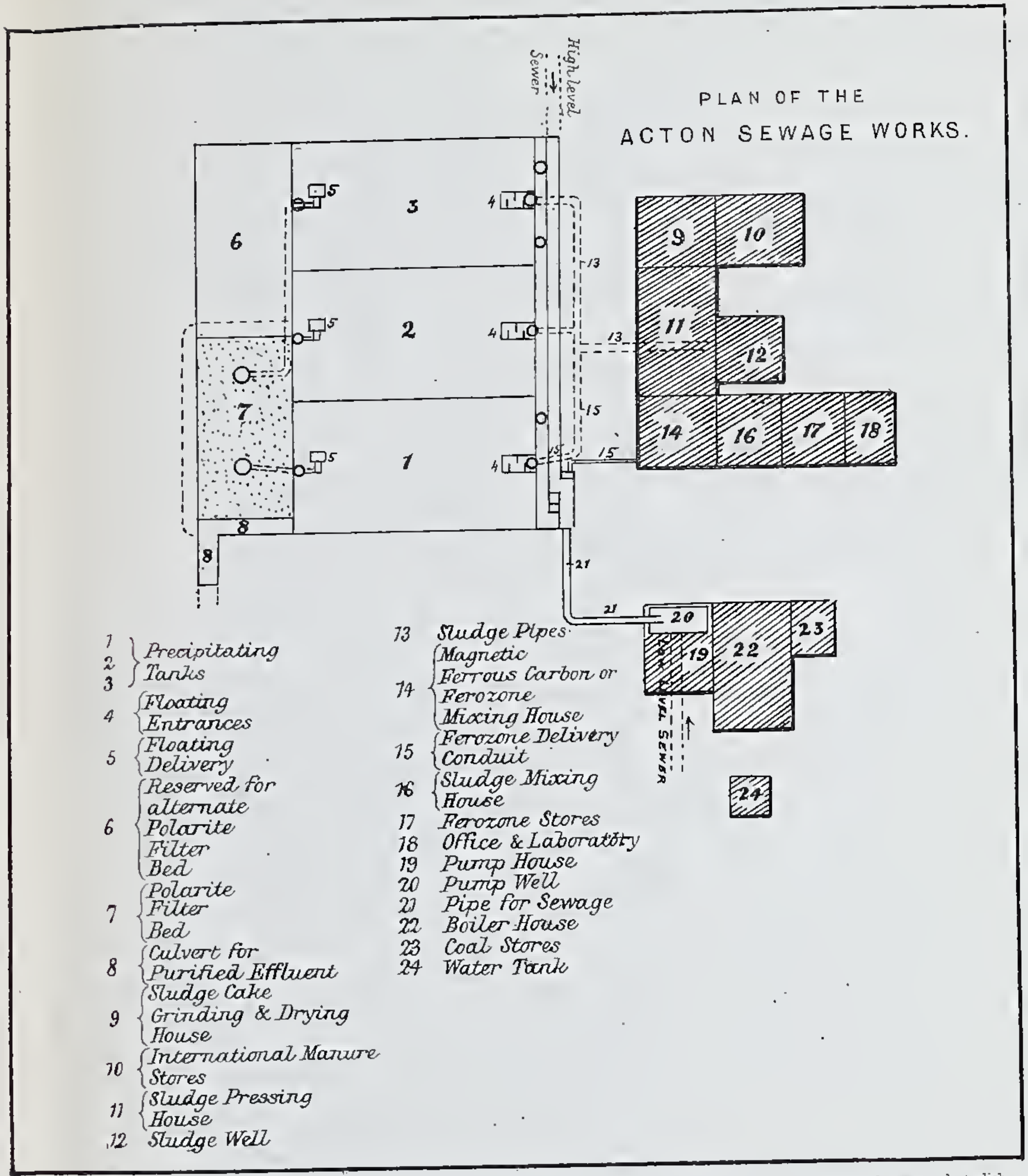
The following are the details of the last four months' work:—

Area of filters (sand and polarite), . .	1,600 square yards.
Average volume of effluent passed through each square yard per diem, . . .	555 gallons.
Cost of cleaning each square yard per annum,	£0 2 3
Cost of filtering each million gallons, . .	0 11 0

So far as the author is aware, these are the only official details with regard to the cost of filtering sewage that have been published.

The process cannot be regarded as an expensive one.

"With regard to the efficiency of the filters, the potency of a substance as a purifying, deodorising, decolorising and filtering medium is dependent upon and may be measured by its power of occluding and polarising oxygen. The occlu-



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sion, or condensation of polarising oxygen takes place upon the surfaces both interstitial and superficial, consequently, that material which presents the largest surface in the smallest cubical space, is the most powerful purifier and filterer. Spongy platinum fulfils best these conditions, and is consequently the most powerful purifier and filterer, and the best insoluble oxidiser known. Its enormous price, however, shuts it out altogether from practical use. The use of animal charcoal has been suggested, but its high price and constant necessity of re-carbonising prevent its adoption by Sanitary Engineers for the filtration of effluents, and Scientists now declare animal charcoal to be a dangerous material for filters, owing to the presence of phosphates which are known to promote fungoid growth. It is thus evident that a good and cheap filtering medium such as '*Polarite*,' possessing great oxidising powers and *quite insoluble*, is much needed."—(*Dr. Angell.*)

"As the sewage at Acton is received in the fresh state, the liquid has not yet lost its dissolved oxygen, nor has the greater part of the organic matter been broken up into soluble, and therefore more hurtful products.

"The larger portion of this organic matter is therefore removed partly by natural subsidence and partly by the precipitate formed by the ferrous sulphate. The filtration removes all the suspended matter and a further purification is effected by the porous magnetic oxide, which, on absorption of organic matter in its pores, oxidises it by help of the dissolved oxygen existing in the liquid.

"The filter-beds at Acton have now been in use for fourteen months, the only cleansing having been the removal of the surface layer of sand."—(*Sir H. Roscoe.*)

The accompanying Plate (24) shows a ground plan of the Acton works. For convenience of reference, each part of the works has been numbered. No. 20 is the pump-well, 36 feet in depth, from which the sewage is lifted into a channel, 21, and arriving at the point C meets the high-level sewage—which gravitates to the works; at this point the ferozone is added (about 8 grains to the gallon being used), and the treated sewage flows into any one of the three tanks as desired, each of which will contain 138,000 gallons, the clarified effluent being drawn off by means of floating arms. The tank inverts are segmental in cross-section, and slope towards the sewage inlets—thus the sludge is readily removed.

The sludge is first pumped into a rotary agitator, where is added more ferozone, and then it is filter-pressed, dried, and ground for manurial purposes. As no lime is used, it is claimed that the manure is of superior quality.

The Ferozone Process.—The process has been examined and reported upon by Sir H. Roscoe, M.P., F.R.S., &c., and the following is an extract from his Report to the Directors of the International Water and Sewage Purification Company:—

"Many samples of the tank liquid and the filtered effluent were taken by Mr. Lailey, the Engineer to the Acton Local Board, and also by my Assistant, Mr. Joseph Lunt, B.Sc., and these were analysed.

"I have always found that the filtered effluent was equal in appearance to the sample taken on the day of my visit—viz., bright, clear, colourless, and free from objectionable smell. Many samples of this filtered effluent have been analysed. The average results obtained are given in the following figures:—

"Analysis of Filtered Effluents.

	Parts per 100,000.	Grains per Gallon.
Chlorine,	6·4	4·48
Free ammonia,	0·406	0·284
Albuminoid do.,	0·025	0·018
Oxygen absorbed from permanganate in 4 hours,	0·325	0·228

"Samples of the effluent have been kept in absence of air for nearly two months, and have still retained their good qualities.

"They exhibit no trace of putrefactive change, but have rather undergone improvement, inasmuch as in most cases a slight green growth has taken place, showing that the effluent is in a condition to be acted upon by the natural influences which tend further to improve the water whilst flowing along a stream.

"But it is to be observed that the amount of organic matter, as measured by the quantities of the two forms of ammonia, is above the limit of a sewage drinking water. Hence whilst the effluent is an excellent sewage-effluent and may be sent into the river at the present outflow without danger, it is obviously unfit for drinking purposes.

"I consider the removal of all the suspended matter to be a very good point in favour of the system. Another is the intermittent nature of the filtration."

Quite recently, the ferozone and polarite process has been adopted at the Hendon Sewage Works, which were originally laid out for the lime and alum process, the tank effluent being discharged upon artificial filters for further purification. The treatment did not prove successful, the filters containing too much clayey material, in consequence of which they cracked freely, and admitted unpurified sewage into the drains, the outfall being into the Brent Reservoir.

Subjoined is an analysis of the sludge obtained at Hendon:—

"The International Process Sewage Manure from the Hendon Sewage Works.

"Dried sludge (not pressed) collected May 9th, 1889, from average daily samples produced during a period of two months.

Analysis of Sewage-Sludge from Hendon, Air-Dried.

	Per Cent.
Moisture (12·62),	12·62
Organic matter,	46·60
Oxide of iron,	3·60
Alumina,	2·96
Phosphate of alumina,	2·21
Magnesia,	none.
Potash,	0·29
Sand and clay,	29·20
Sulphuric acid (SO_3),	1·46
	98·94
Ammonia,	2·28

"This sludge is in a fine uniform state of division, and is of good quality in manurial properties.

(Signed) "Arthur Angell, Ph.D., F.I.C.,
"*Public Analyst.*"

At Acton the sewage of 7,000 persons is dealt with, but the author is not in possession of a statement of working expenses.

CHAPTER XXV.

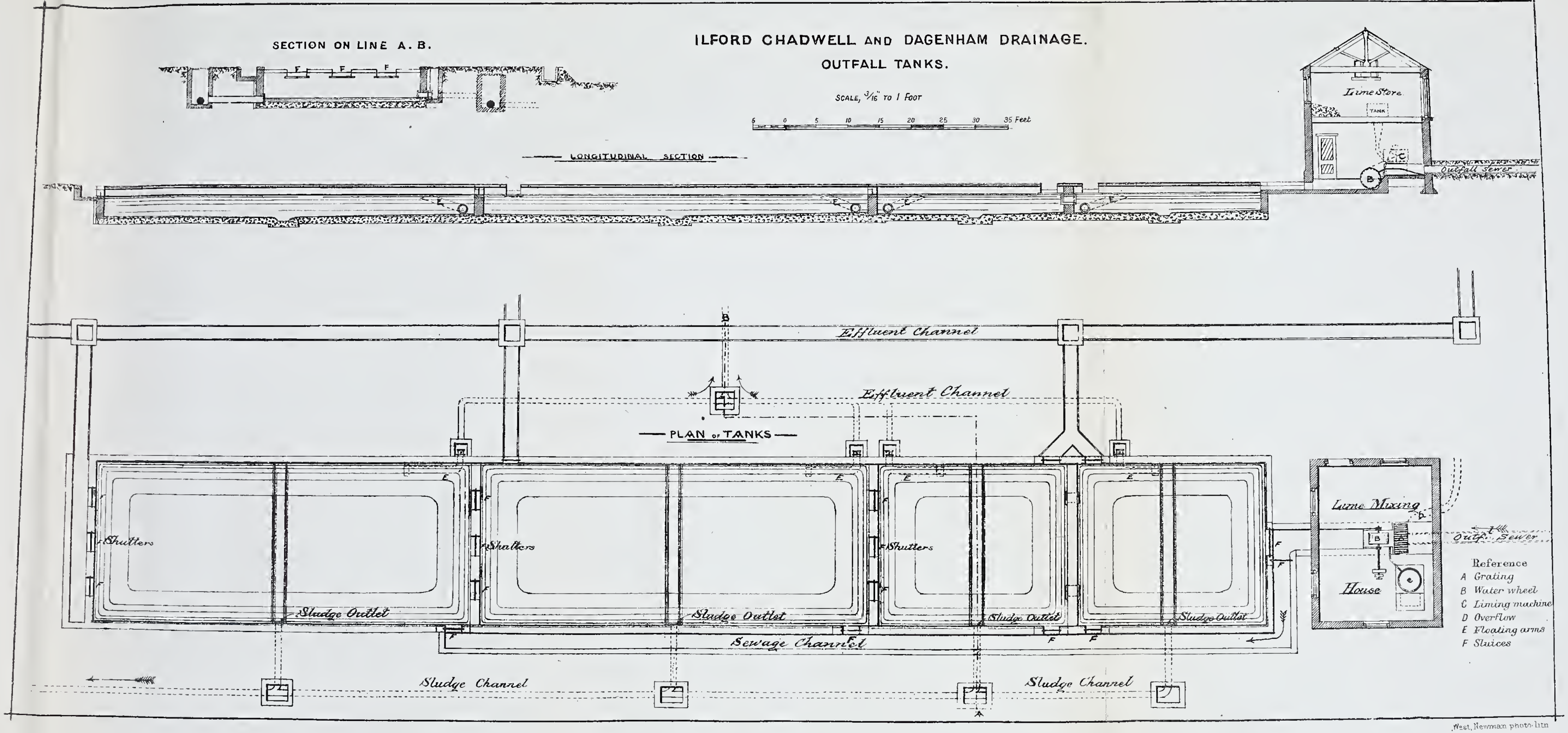
ILFORD, CHADWELL, AND DAGENHAM SEWAGE DISPOSAL WORKS, 1889.

The following details of the above works have been supplied to the author by Mr. B. S. Brundell, Mem. Inst. C.E., who designed and carried them out:—

Drainage Area.—In 1880 the question of sewage disposal came indirectly under the consideration of the Rural Sanitary Authority of the Romford Union, and at that time, the Barking Town Ward being under the jurisdiction of the Authority, it was suggested that a combined scheme for the drainage of the whole of the parish of Barking (consisting of the Barking Town Ward, the Ilford Ward, the Ripple Ward, and the Chadwell Ward) would be desirable, and Mr. Brundell of Doncaster, a member of the Institution of Civil Engineers, was instructed to prepare the first instalment of that scheme—viz., a plan for the sewerage of Barking, which is at the lowest or outfall end of the parish.

In 1881 Mr. Brundell prepared a scheme for the drainage of Barking proper, which had in view provision for the addition to it, at a future time, of Ilford and so much of Chadwell as required draining.

This scheme came before one of the Engineering Inspectors of the Local Government Board, Mr. Harrison, M.Inst. C.E., in March, and again in May, 1882, when the inhabitants of Barking objected on the grounds that if a scheme of drainage for Barking was necessary, it was desirable that it should be carried out by a Local Board to be formed for the Town Ward, and Mr. Harrison agreed to suspend his report until the Barking people had had time to petition for the formation of a Local Board; this they did, and as the Rural Sanitary Authority offered no opposition, the prayer of the petition was granted in due course, and the Town Ward became a Local



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Board District, and all jurisdiction over and responsibility for it was withdrawn from the Rural Sanitary Authority.

This brought matters to the beginning of 1883, when the Rural Sanitary Authority were called upon to consider the sanitary condition of the Ilford and Chadwell Wards of the parish, where great sickness prevailed, chiefly due, it was said, to the want of proper drainage and to generally defective sanitary arrangements. Ilford had, in fact, at this time only two or three ancient brick sewers in the old part of the town, with outfalls discharging into the river Roding; and the new building estates, of which there were several, were practically without any drainage worthy the name. Chadwell, too, had no sewers of any kind, but mere surface-water grips emptying into the nearest ditches.

Mr. Brundell was again instructed by the Rural Authority to prepare a scheme dealing with Ilford and Chadwell, and when he came to investigate the district he found that Dagenham and Chadwell were so mixed up, Chadwell Heath being in fact in the parish of Dagenham, that it was difficult, if not impossible to design a scheme that did not embrace both. He, therefore, submitted plans dealing with the whole of Ilford Ward, and so much of Chadwell Ward and Dagenham Parish as lies north of Green Lane, proposing that these together should form a special drainage district. This recommendation was adopted by the Rural Sanitary Authority, and came before Major Hector Tulloch, one of the Engineering Inspectors of the Local Government Board, at an enquiry held at the Angel Hotel, Ilford, in April, 1884.

The Local Government Board, in due course, sanctioned the scheme, but declined to form a special drainage district; the effect of which is that the whole ratable value of Chadwell Ward and the whole ratable value of Dagenham Parish contribute to the cost of the scheme, instead of its being confined to the parts to be drained, as was desired by the Authority.

One effect of the refusal of the Local Government Board to sanction the special drainage district, as asked for, was not quite foreseen at the time, and that was that it left the Ripple Ward as part of the contributing area, although no part of it was within the drainage area.

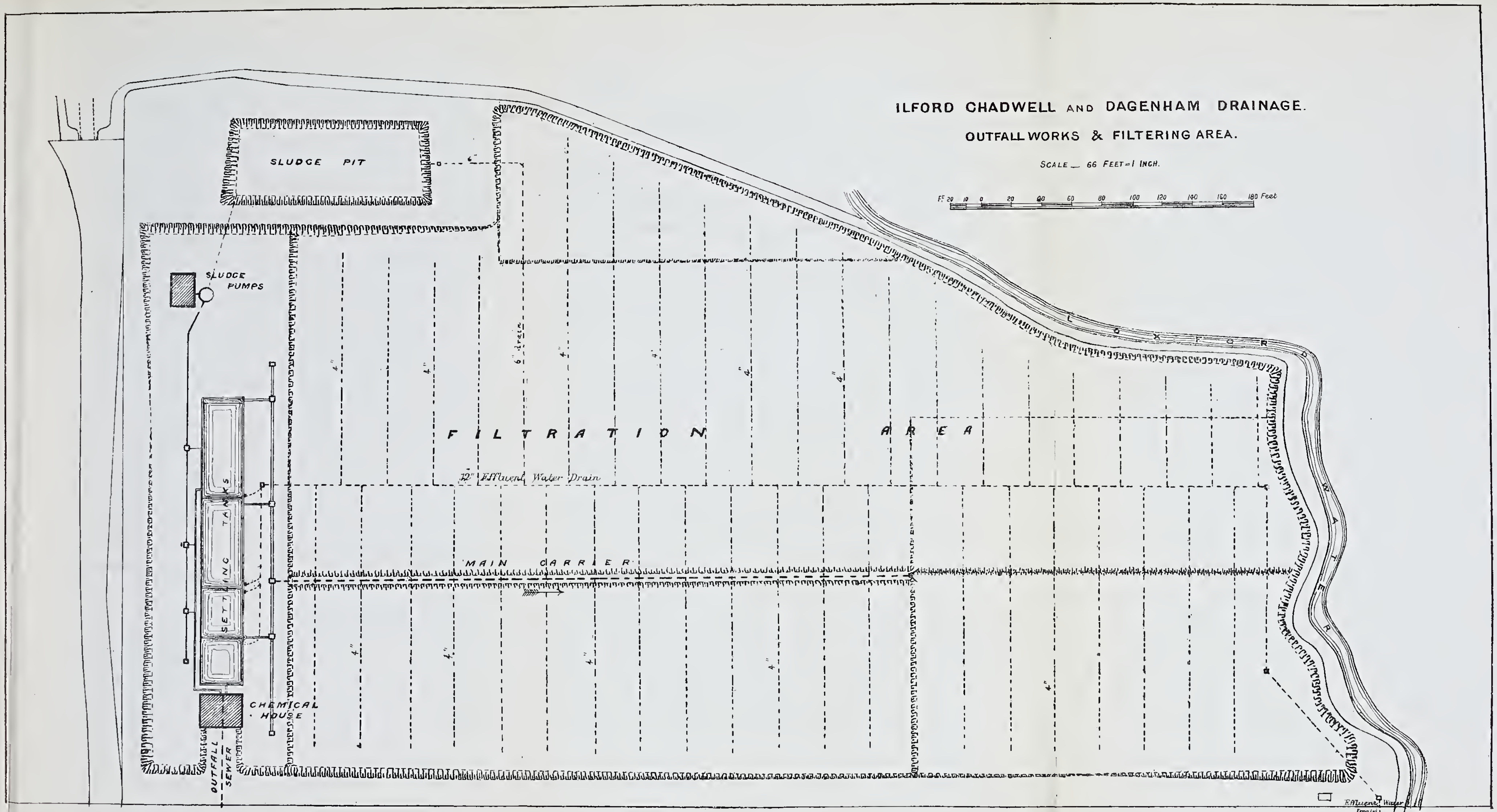
This caused some complication and considerable delay, and in the end, on the petition of the Ripple Ward, with the concurrence of the Barking Local Board, this ward was added to the Barking Town Local Board district, and now forms part of that district for sanitary and other purposes, leaving the Ilford and Chadwell Wards of the parish of Barking still under the Rural Sanitary Authority.

Works.—The Ilford Ward contains 6,194 acres, the Chadwell Ward 2,298 acres, and the parish of Dagenham contains 6,556 acres; and these 15,048 acres form together the contributing area to the scheme of drainage. The ratable value of houses is charged in full, cottages at half, and the land at one-fourth.

The site selected for the outfall works is a piece of land 7 acres in extent, about 25 feet above mean sea level.

The chief part of the sewage flows to the sewage works by gravitation, but the low lying parts of Ilford abutting upon the river Roding, near Ilford Bridge, and a portion of the St. Mary's estate, which is also very low, requires to be pumped, as well as that part of the Ilford Park estate adjoining Cranbrook.

On reaching the works the sewage is treated with milk of lime in the usual proportions, and after passing through the settling tanks, in which the suspended matters subside, the clarified water is applied to the land, on the intermittent downward filtration principle. The effluent is finally discharged into the Thames. The works are of a simple character, as will be seen on referring to the plans. One novel feature, however, is the ingenious liming arrangement of Messrs. Bradley. The sludge is swept from the settling tanks into a well, from which it is pumped to drying beds, and eventually disposed of on land. The works are a good example of those necessary for the sewage disposal of a small



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district. The author regrets to be unable to give the annual working expenses. Plate 25 shows the general arrangements of the works.

CHAPTER XXVI.

COVENTRY, 1889.

THE sewage disposal works were constructed by the General Sewage and Manure Company, Limited, in 1874, but have been altered and modified in various directions in order to meet the altered conditions of the case, due principally to a large increase of population.

Population, &c.—The population now draining to the works numbers 50,000, whilst the sewage flow is about 2,000,000 gallons per diem, which gravitates to the sewage disposal works at Whitley.

Treatment.—The sewage first passes through a screening chamber, where all large solids are separated by means of a Latham's patent archimedean extractor. About 7 cwts. of solids are removed in this way daily, and are sold as manure. The sewage is then conveyed through a building in which are the appliances for adding and mixing the chemicals employed, lime and sulphate of alumina, of which are used per 1,000,000 gallons, 6½ cwts. of lime, and 9 cwts. of sulphate of alumina. Contrary to the usual practice, the lime is added last. The sewage and chemicals are well stirred up as they pass through a mixing-well, and then the treated sewage flows to the settling tanks, of which there are eight, each being 29 feet in width, 140 feet in length, and nearly 5 feet in depth, and having an average capacity of 120,000 gallons. There were originally but four tanks, but experience had shown that smaller tanks were preferable, and the four were made into eight by means of walls placed longitudinally down the centre of each tank. The cross-walls which were built at about two-thirds of the distance from the inlets, and over which the sewage had to pass, have been removed, and the tanks perform their functions in a thoroughly satisfactory manner. In a recent reference to these works, Dr. Frankland stated that the effluent contained as little suspended matter as that from the more complicated systems of tanks on the separate system which he had examined.

Each of the settling tanks is cleared out twice weekly, the wet sludge amounting to 460 tons, which is pressed into 100 tons of cake by means of Johnson's filter-presses, and sold at 1s. 6d. per ton.

Filtration.—The effluent water from the tanks passes on to an intermittent filtration area, 8 acres in extent, freely under-drained at a depth of from 5 to 7 feet. The action of this filter is to materially reduce the amount of dissolved organic matter; although, as the effluent from the land is quite free from nitrates, the land is not of sufficient area to "completely" deal with the sewage. The fact of the works having been in operation for a long period, however, may be taken as presumptive evidence that the object sought to be attained is fairly accomplished.

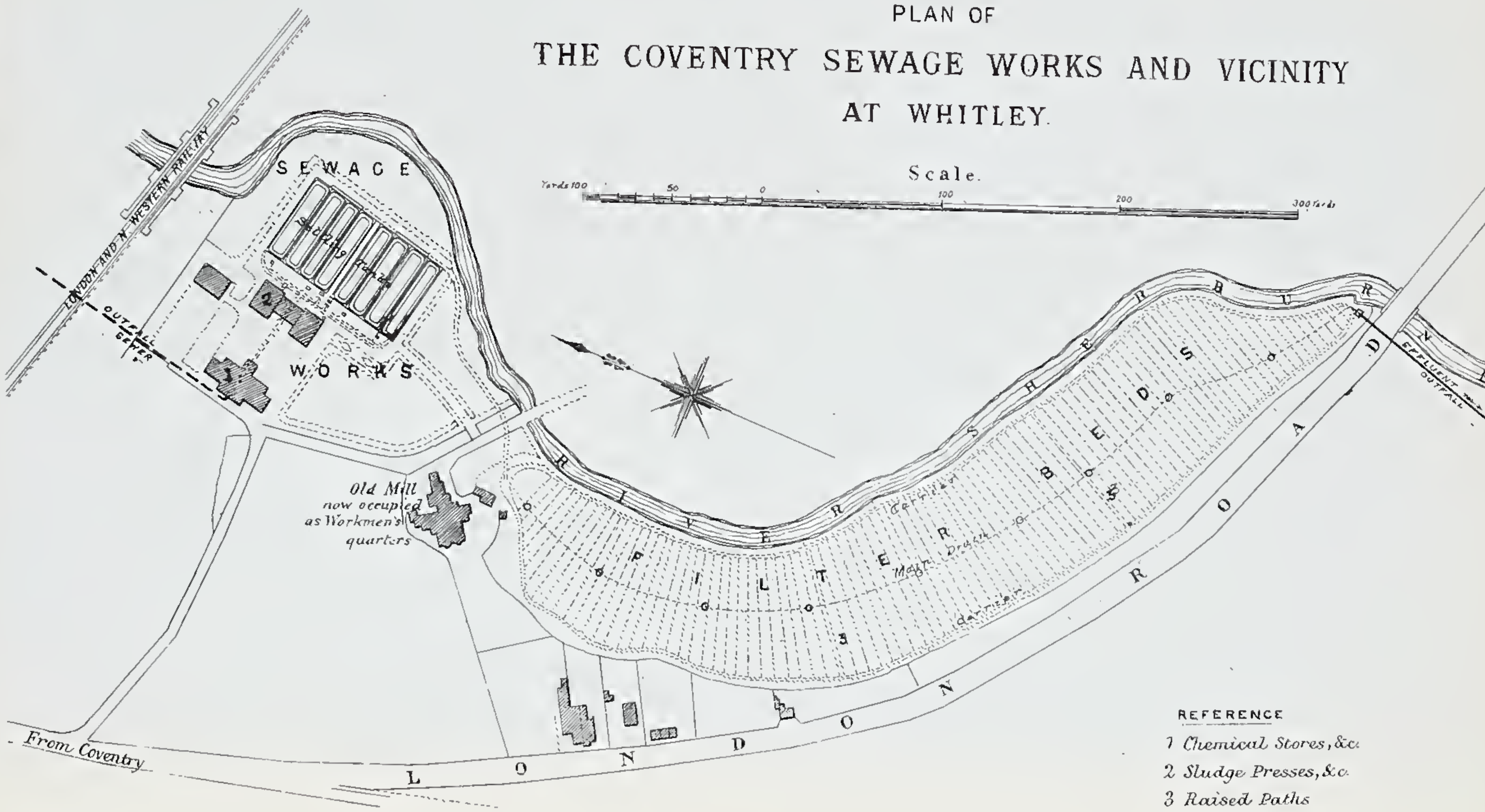
The land is under-drained by means of a central main-drain, and by lateral drains placed about 15 feet apart (see Plan). A series of manholes is provided on the main drain for the purposes of inspection, and the aeration of the soil.

The purified effluent is finally discharged into the Sherbourne, a stream of modest dimensions, but with a moderately good fall and consequent fairly rapid movement.

Crops.—The land is cropped with Italian rye-grass, the prices obtained varying from £2 to £3 per week during the season.

Cost.—With regard to the history of these works, it should be mentioned that, in 1869, the Corporation purchased 262 acres of land, at a cost of £27,000, for sewage disposal purposes, and plans for laying out this land were prepared and submitted by Mr. Hawksley, M. Inst. C.E. In con-

PLAN OF
THE COVENTRY SEWAGE WORKS AND VICINITY AT WHITLEY



REFERENCE
1 Chemical Stores, &c.
2 Sludge Presses, &c.
3 Raised Paths
o. Manholes.

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sequence of the relative levels of the land and the outfall sewer, the sewage would require to be pumped, and the cost of so doing and of preparing the land appear to have deterred the Corporation from carrying out the work, and instead a contract was entered into by the Corporation and "The General Sewage and Manure Company, Limited," with the object of purifying the sewage by means of the process patented by Dr. Anderson. The Company erected works (see Plan) costing £12,000, which, with the modifications before pointed out, are now in successful operation.

The works have, however, for some time been under the entire management of the Corporation of the town of Coventry, the annual cost of treating the sewage amounting to £3,200.

The author is indebted to Mr. J. C. Melliss, M. Inst. C.E., for many of these details. The plan of the works is given on Plate 27.

Note.—The works as described have now (1894) become inadequate for the rapidly increasing population, and recently a scheme for conveying the sewage to an area of 570 acres in the Avon Valley, and there purifying it on the irrigation principle, was devised. An inquiry was held by the Local Government Board, which lasted eight days, and subsequently that Board issued a provisional order to enable the local authority to acquire possession of the land; but, on the order being submitted to Parliament for confirmation, the opposition was so strong that the Bill was thrown out. Mr. Purnell, the surveyor, states that at present no particular course of action has been decided upon.

CHAPTER XXVII.

WIMBLEDON, 1889.

Physical Features.—Wimbledon is a well-known residential suburb of the Metropolis, situated about 5 miles to the south-west of Westminster Abbey.

The area of the district is 3,220 acres, 640 acres of which form the Wimbledon portion of the Common, which, with the 500 acres in the parish of Putney, form the well-known Wimbledon Common, one half of which is a flat table-land, the remainder consisting of beautifully-wooded slopes. The north-western corner of the Common adjoins Richmond Park, and these two beautiful open spaces form a magnificent lung, for ever available as a great health-giving function by the surrounding districts, and by the vast Metropolis. Wimbledon parish is, approximately, rectangular in plan, a little less than 3 miles in length and 2 in breadth. So far as its physical characteristics go, the parish may be divided into three zones of nearly equal area, as follows:—

(*a*.) The plateau on the south-east of the London and South-Western Railway, having a mean elevation of about 50 feet above ordnance datum.

(*b*.) The slope connecting this plateau with the upper table-land.

(*c*.) The table-land, with an elevation 180 feet above ordnance datum. Each of the three sub-districts is, for drainage purposes, provided with an outfall sewer, the sewage from two of which gravitates into the sewage tanks, whilst that from the third or low level requires to be pumped.

Population, Ratable Value, &c.—The main drainage system was very fully developed in the years 1886-7, although the extremely rapid increase of population in the district, has since rendered additional works necessary. According to the census of 1881, the ratable value was £159,137, and the population 15,947; these are now (1889)—ratable value £185,000, population 26,000.

The separate system of drainage has been carried out as far as expedient, the old sewers having been retained and improved for the conveyance of surface-water, on the sewage being diverted into the new sewers.

All new roads now made up under the 150th section of the Public Health Act are provided with duplicate means of drainage, and the entire scheme offers a good example of the "separate system," the advantages of the axiom, "the rainfall to the river, the sewage to the land," being both fully recognised and acted upon. Large quantities of roof-water are still admitted to the sewers, however, with the consequence that in heavy storms they are sometimes surcharged. The author does not consider it desirable to carry drains for rain-water to the backs of houses in close contiguity to the soil drains, as there would be great risk of unprincipled persons connecting their soil drains with the rain-water drains in the event of a stoppage of the former, and for this reason all rain-water pipes at the backs of the houses are connected with the soil drains.

The length of the main-sewers and surface-water drains and culverts is now about 70 miles.

Population Draining to Sewage-disposal Works.—The estimated number is 26,000.

Ratable value, £185,000.

Water-closets in nearly every house.

Dry-weather sewage flow, 30 gallons per head, or 780,000 gallons per diem. The yearly sewage flow exceeds this quantity by just 50 per cent.—*i.e.,* the average daily flow (which is inclusive of rainfall) amounts to 45 gallons per head.

Storm-water.—In addition to the separate system of sewers, storm-overflows are provided, two of which discharge into streams, the third into a filter-bed at the sewage works.

Sewage Treatment.—The sewage is first either filtered, or is chemically treated in settling tanks, and the liquid portion is then applied to land.

Tanks.—There are two sets of tanks for the reception of the sewage, one set for that from the high-level outfall sewer, and one set for that from the middle- and low-level outfall sewers.

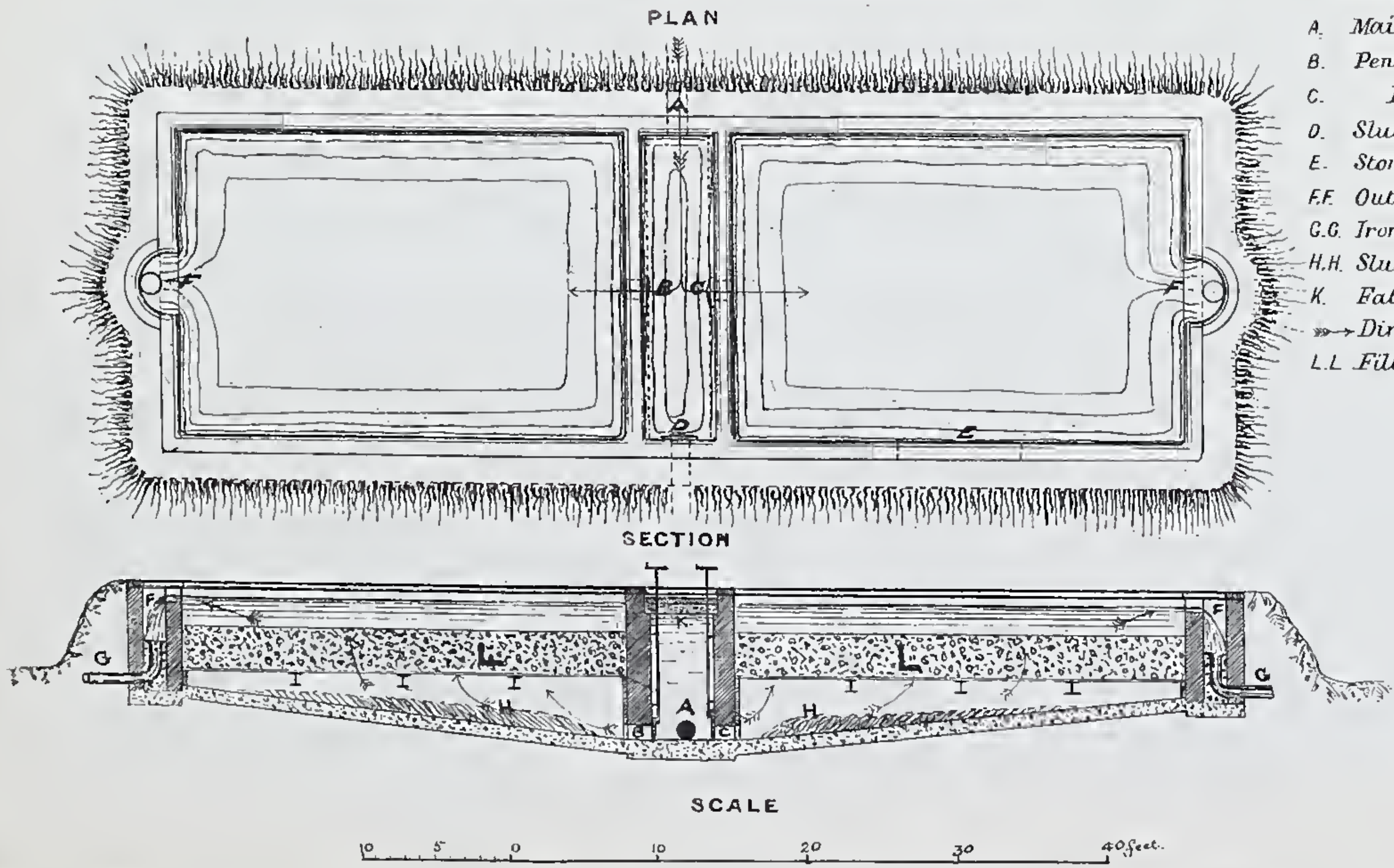
On referring to the plan, the position of the high-level tanks may be seen to be immediately adjoining the London and South-Western Railway, whilst the other set of tanks is situated at the north-east end of the pumping station.

There is a considerable amount of difference in the levels of the land composing the sewage farm, the mean levels of the highest and lowest plots being 63 feet and 27 feet above O. D. respectively. The farm is divided into two portions by the Durnsford Road, and the relative levels of the large settling tanks and of the land on the west side of the road are such as do not admit of that portion of the land being irrigated with sewage from those tanks. Unless pumping be resorted to, therefore, the high-level sewage is alone available for application to that portion of the farm.

A plan and section of the high-level tanks are given on Plate 28. It will be observed that these tanks are both settling and straining tanks, and nitrifying filters, the sewage is admitted at the point A, and on passing into the central division, the fatty and other light matters rise to the surface at K, whence they are periodically removed. The sewage next passes into one or other of the screening chambers, through the openings B and C, both of which are provided with penstocks. The chambers are provided with double bottoms, upon the upper of which rest the filters, L: these are merely formed of coarse, hard-burnt clay, but having regard to the tendency to lift in times of heavy rain, a heavy material, such, for instance, as basaltic or granitic road-stone, would be preferable. In passing upwards through these filters, the sewage is deprived of nearly all the solid matters in suspension, which settle upon the bottom at H. The filtering material becomes charged with nitrifying organisms, and as a matter of fact nitrates are found in abundance in the effluent, which is also practically free from suspended matter, and is in a highly suitable condition for application to land. An average of three analyses made recently showed that the suspended matters were less than 3 grains per gallon. The clarified water overflows at F, and passes into iron mains for distribution upon the land. The tanks are cleansed at short intervals of time by opening the penstock at D, when all the contents of one tank, or of both

Pl. 28.

SEWAGE STRAINING TANKS, WIMBLEDON.



Reference.

A. *Main Sewer*
B. *Penstock*
C. *Do.*
D. *Sludge outlet*
E. *Storm overflow*
F.F. *Outlet weirs*
G.G. *Iron sewage carriers*
H.H. *Sludge Chambers*
K. *Fat, &c.*
→ *Direction of flow*
L.L. *Filter*

West, Newman photo-lith

if desired, pass into a channel communicating with the middle level outfall, whence they are conveyed to the large settling tanks; in this manner the filters are readily washed, and all the solid matters are flushed out. The system affords a good example of upward filtration, although it should be noted that the separation of the solids and the production of nitrates is the sole object sought to be attained. These tanks serve for the treatment (by straining) of the sewage from about 4,000 persons, and have been in successful operation for about sixteen years.

The large settling tanks were originally two in number, each of a length of 150 feet, and a breadth of 50 feet, the depth available for sewage being 6 feet. The tanks were constructed with flat bottoms, which entailed much labour in cleansing them, and the outlets for the clarified sewage were situated near the bottom, thus allowing the escape of a large portion of the solid matters. In order to remedy these defects, the author divided the tanks into six compartments and provided each with a floating arm, by means of which the water is now drawn from the top. The floating arms are similar in principle to the valves, illustrations of which are given in the chapter on "Settling Tanks."

The chemicals used in treating the sewage in 1889 were lime and Spence's "alumino-ferric" or alum cake, an analysis of which is subjoined:—

Alumina (soluble), ...	* 14·00	per cent.
Peroxide of iron, ...	·75	,,
Sulphuric acid, in combination with the above bases,	33·81	,,
Free acid, ...	nil.	
Water, ...	51·44	,,
	100·00	,,

Mr. Spence states that all very white alum cake contains a large proportion of free acid, and that the slight brownish tint is a good guarantee of the non-existence of free acid.

As used at Wimbledon, the alumino-ferric was in the form

* Equal to 46·68 per cent. of sulphate of alumina.

of blocks, about 30″ × 20″ × $3\frac{1}{2}$″, which were piled on edge in a large wooden vessel through which a current of water was made to pass; the saturated solution is drawn off at the bottom and mixed with the sludge in the desired proportion; the solution (cold) stands at 66° Twaddell (= spec. gravity 1·33), and each gallon contains $7\frac{1}{2}$ lbs. of cake. The quantity used is about one-third of a ton per million gallons of sewage (about $5\frac{1}{4}$ grains per gallon), and one gallon of the solution is added to nine thousand gallons of sewage.

The lime used is a very pure material produced by calcination of the white, or upper, chalk. Half a ton of lime is ordinarily added to each million gallons of sewage = 7·84 grains per gallon, but the quantity is increased or diminished according to the condition of the sewage. The lime to be used on the morrow is first weighed and then thoroughly slaked; after standing the night over, it is conveyed into one of Bowes Scott & Read's lime-mixers, through which a stream of water is made to pass, and the milk-of-lime produced is then conveyed into the sewage pump-well, from which it is pumped with the sewage, and in passing through the pumps is most thoroughly mixed with the sewage; the middle-level sewer discharges into the pump-delivery chamber, and here the two sewages are well mixed together, and passing on to the settling tanks, receive on the way the dose of alumino-ferric or copperas.

The lime-mixer is an exceedingly effective and simple machine, and may be made to produce very large quantities of milk-of-lime if supplied with sufficient water and lime; the regulation of the quantity to be used is an easy matter.

A drawing of this machine is shown on Plate 6.

In addition to lime and alumino-ferric, manganate of soda is added to the sewage in very dry, hot weather, in order to prevent the setting up of secondary fermentation and the production of offensive odours, when the sewage is applied to the land. The manganate is dissolved in warm water, and is added to the clarified sewage as the latter leaves the settling tanks, the material being used in the proportion of about 2 grains per gallon. Its effect upon the sewage is most beneficial, and as Mr. Dibdin, F.C.S., was the first exponent of the method, it is but just that the credit attending its introduction should devolve upon him.

In addition to the chemicals mentioned above, nearly every known reagent has been tried at Wimbledon, some in solution, others in suspension, and some in the form of filters, of every conceivable shape, but up to the present the system now in operation has been found to best meet all the exigencies of the case.

The Disposal of the Sludge.—As mentioned in the chapter upon "Sludge Disposal," the sludge was originally swept from the tanks into filter-beds composed of town-ashes well underdrained. The process was found to be most undesirable, as the gases produced by putrefaction were of an exceedingly offensive character, as was also the drainage from the filter-beds, and it became necessary to devise some other mode of disposal.

At one time, acting upon the advice of the then Surveyor, the Board constructed a small tower with sludge-pumping machinery, and an attempt to deal with the sludge upon the Birmingham plan was made, but the circumstances were unfavourable to the method, the land upon which the sludge was pumped being of stiff clay, the area available being limited, and houses being near.

Acting upon the advice of the author, the Board constructed works with filter-presses in 1884, and these have been in successful operation since that date. The plans and sections are given on Plate 30, the mode of working being as follows:—

The sludge is swept from the settling tanks into the sludge-reservoir, whence it gravitates, as desired, into the iron receivers; here lime is thoroughly mixed with it, and air-pressure is applied at the surface of the sludge, which is then forced up the dip pipe and into the presses, where the separation of the liquid from the solids is effected.

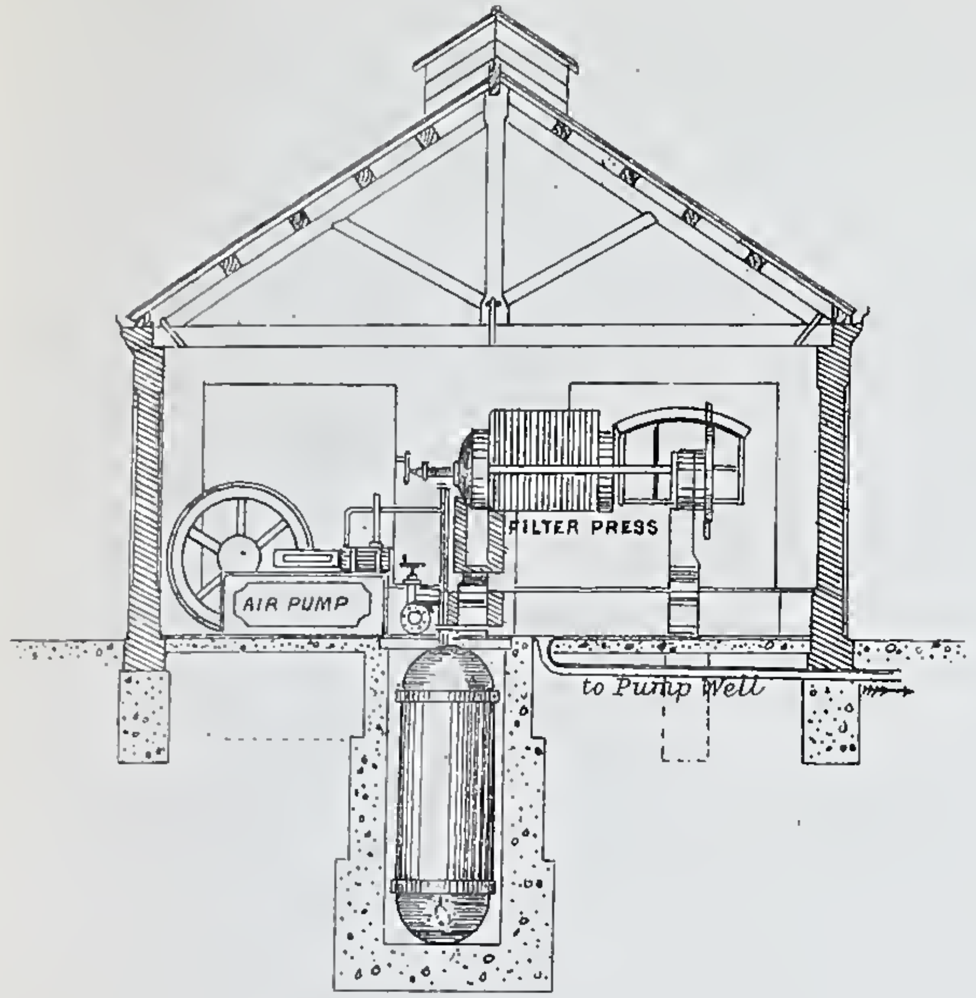
Two of Johnson's presses are employed and two of Goddard, Massey, & Warner's, the latter machines being of recent construction possess certain improvements of detail.

The subjoined notes may be of service where sludge-pressing machinery is contemplated :—

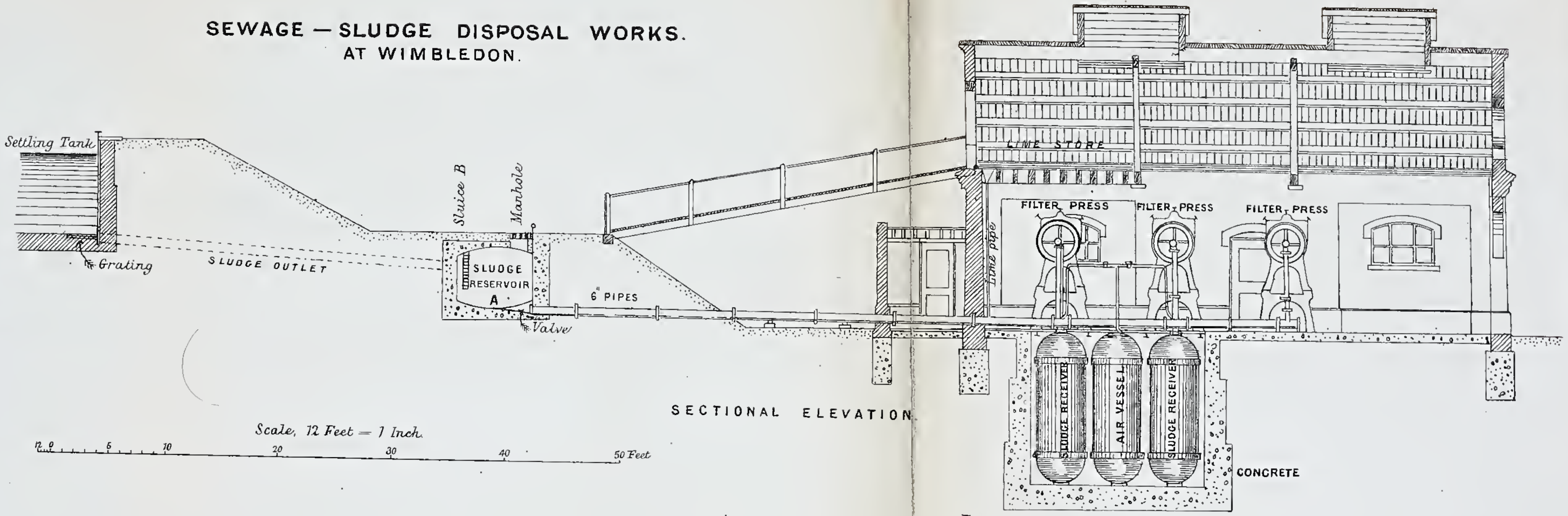
One machine, with twenty-four plates, 36 inches in diameter, will be necessary for 12,000 persons if worked by day only; the air-pressure need not exceed 60 lbs. per square inch, and it should be applied carefully and gradually on recharging each press; care must be taken to use perfectly fresh lime for mixing with the sludge, and strong grey-chalk lime, finely ground, will yield by far the best results, the quantity required will be 1 cwt. for each ton of cake produced, if rapid work is to be accomplished, say the filling and clearing of a press in 50 minutes; cakes 2 inches in thickness are produced nearly in the same period of time as those of 1¼ inches; flax canvas, costing about 5d. per lineal yard, when 40 inches in width, will be the best filtering material, the cloths may be made up by the men working the presses, care being taken to well wet the canvas before it is cut up into lengths, otherwise it will shrink and tear when first used in the presses; the liquor filtered out will be a saturated solution of lime with other constituents, and generally may best be disposed of by being mixed with the crude sewage, the solids in which it will assist to precipitate, its ratio to the sewage-flow will be about 1 per cent. when the sewage amounts to 30 gallons per head; the sludge should be pressed whilst in as fresh a condition as possible; the production of sludge-cake with about 54 per cent. of moisture will be 2¼ tons per week per 1,000 persons, very nearly, and to 8 tons per million gallons; its value as a manure, if applied as a top dressing as it comes from the presses, will be, weight for weight, slightly in excess of stable manure; the working expenses at Wimbledon now amount to 2s. 5½d. per ton of cake, being thus made up :—


LONDON & SOUTH WESTERN RAILWAY
to London
from Wimbledon
HIGH LEVEL OUTFALL
TANKS
PERMANENT CARRIER
To London
Valve
WIMBLEDON NEW OUTFALL
BYEWASH OF WANDLE
(Site of Old Garratt Paper Mills)
Sluice
Point of discharge of effluent from the Merton Sewage Farm
RESERVED FOR CEMETERY
CEMETERY ROAD
CEMETERY
Sludge Channel
MIDDLE LEVEL OUTFALL
MAIN DRAIN
STABLES
DURNSFORD ROAD
IRON DISTRIBUTING MAIN
CONTOUR CARRIER
MAIN DRAIN
STORM FILTER
Wimbledon Old Outlet
WANDLE
RIVER
Sludge Works
TANKS
SETTLING
PUMPING STATION
FARM YARD
PADDOCK
STORM FILTERS
LOW LEVEL OUTFALL
Print Works
The Willows
Fever Hospital
MAIN DRAIN
WIMBLEDON SEWAGE DISPOSAL WORKS.
Reference.
Roads
Permanent Carriers
Iron distributing main
Distributing Grips
Direction of flow
Main drains
Ordnance levels
SCALE
12·5" = 1 MILE
CHAINS
West, Newman photo-lith

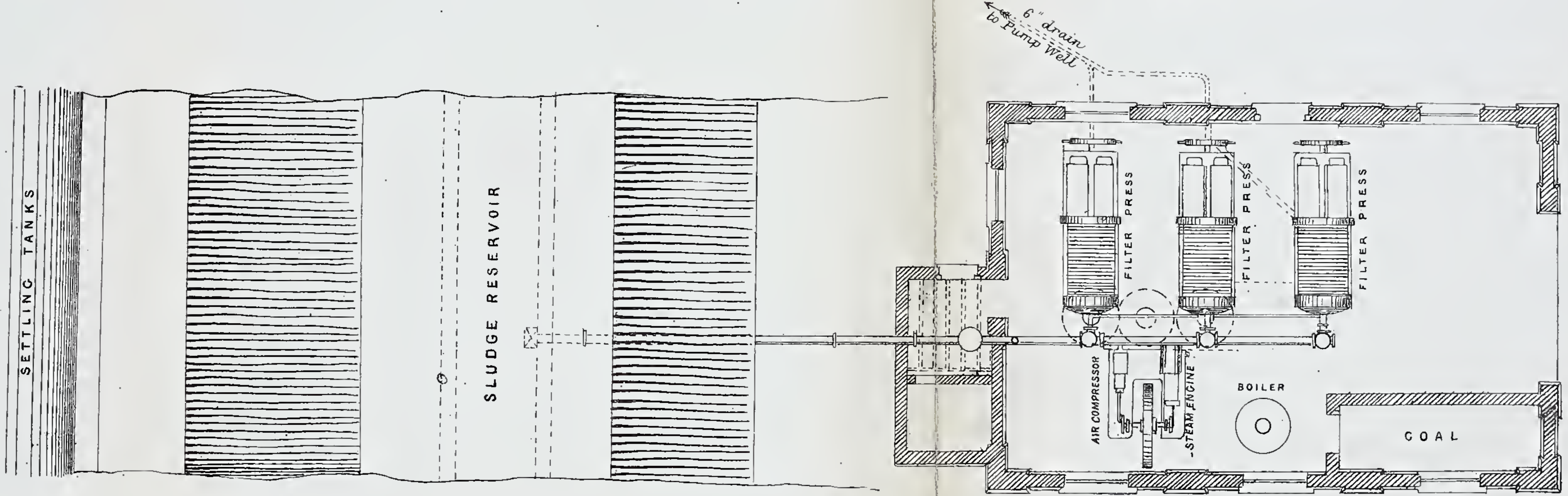
SEWAGE — SLUDGE DISPOSAL WORKS.
AT WIMBLEDON.



CROSS SECTION.



SECTIONAL ELEVATION.



PLAN.

West, Newman photo-lith.

		Pence.
Wages, ...	per ton,	9·20
Lime, ...	,,	14·20
Coal, ...	,,	2·50
Cloths, ...	,,	3·00
Oil, and incidentals, ...	,,	0·60
Total, . .	,,	29·50

Two men are constantly employed at the work, but are capable of pressing more sludge; thus the item for labour per ton constantly diminishes as the production of sludge increases.

There is now a fair demand for pressed sludge, which is sold at 1s. per ton at the works, but as vast quantities of stable and other manures are brought by market gardeners into the neighbourhood from the Metropolis, the demand will probably never be very great. During the past twelve months (1888) 953 tons were sold, out of a total production of 3,050 tons. The remainder was used partly upon the sewage farm, and partly upon the arable land forming the reserve for the cemetery.

The Sewage Farm.—When completed in 1877, the sewage farm consisted of 43 acres of land, with the two storm-water filters adjoining the settling tanks. As in the case of many other suburbs, there has been, at Wimbledon, a remarkable increase of population in recent years, and extensions of the sewage farm were soon found to be necessary. As opportunities occurred, the plots shown upon the plan (Plate 29), and numbered 27, 27, 28, 29, 29, 34, 35, and 43, were purchased, and in due course prepared for sewage disposal. The areas so added amounted, in the aggregate, to 26 acres.

The land composing the original farm is of stiff London clay, whilst that formation is also present in the newly-acquired portions, to the extent of 9 acres, the remaining 17 acres consisting, for the most part, of excellent alluvium, river drift, &c. Upon reference to the plan, it will be observed that the farm has a considerable slope to the north-east, and is bounded on that side by the river Wandle. A main road to London passes through the farm, and residences are situated within 50 yards of the irrigated land.

The land, as originally laid out, proved to be unsuccessful in the attainment of the desired object. The land was under-drained, as suggested by many different authorities, the pipes being of glazed stoneware, 4 inches and 6 inches in diameter, laid at a depth of 6 feet, the 4-inch pipes were laid in contour lines, the width between the drains varying from 1 to 2 chains. The contour drains were crossed at right angles—nearly—by 6-inch drains, laid at intervals of about 200 feet. The trenches were filled in with burnt clay, to within 2 feet of the surface. A sufficient amount of care was not bestowed upon the surface, which was left in an uneven condition, to the great detriment of both sewage and crops.

Immediately below the trench in which the contour carriers were laid, an earthenware carrier was constructed, the materials used consisting of a half-pipe with specially made stoneware sides (see sketch, p. 126).

The ground, upon being drained, cracked in all directions, but the cracking was intensified near the drains.

Here, then, were three conditions unfavourable both to sewage farming and sewage treatment; in the first place, the surface was badly prepared; in the second place, the land was, one might almost say, ruthlessly under-drained; and, lastly, the stoneware carriers interfered very much with ordinary farming operations. Still more drains were added by an adviser of the Board, who had the subsequent charge of the farm, until the land was rendered as unfit for sewage disposal as possible.

Upon the farm being placed under the superintendence of Mr. James Snook, the shallow drains were rooted up, the burnt ballast was removed from the drain trenches, many of the drains were cut off, and the surface was most carefully graded. All the stoneware carriers were removed, and, generally, the farm was much improved, the effects of the mistakes of the past being too palpable to admit of more being made. At that period the effluent from the farm passed into the Wandle at the Wimbledon old outlet, shown upon the plan.

The plans for laying out the more recently acquired portions of the farm were prepared by the author in concert with Mr. Snook, and the work was carried out under the superintendence of Mr. Snook. The surface was most carefully graded, and the only drains laid were those under the centre of each road, these roads being 12 feet in width. In order to render the surface more amenable to the implements used in cultivation, and also more porous, to the advantage of the sewage, the ashes collected from the dust-bins during the summer are taken to the farm, where they are placed in a large heap, then screened, the rubbish is burnt, and during the winter months the screened ashes are spread upon the surface of land to be cropped in the spring. The ashes are spread to a depth of about 4 inches, and are then ploughed in, a second dressing being applied to the broken surface. The cost of disposing of ashes in this manner is about 9d. per cubic yard.

Three filters, composed of burnt clay, have been constructed for the purpose of receiving the flood-water during periods of heavy rainfall. Each of the settling tanks is provided with an overflow, by means of which the excess due to sudden storms of rain escapes and is discharged upon the filter-beds. The low-level outfall is also provided with an overflow, which discharges into the middle filter. These storm-water filters are used probably, on an average, ten times per year.

Carriers.—In consequence of the irregularities of the surface of the farm, the main carriers are of cast-iron pipes, the sewage being allowed to escape where desired by means of sluice valves. The remainder of the permanent carriers are of concrete, and of stoneware half pipes with specially made stoneware sides. The distributing channels, or "grips," are cut with the plough, and are then finished by spade labour; as a general rule their direction is in that of the greatest fall. The grips are cut at distances apart of half-a-chain, in order that the grass-cutter may readily know the area of the piece he is supplying, the rye-grass being always sold by the rod ($30\frac{1}{4}$ square yards).

The stoppers used in the grips are of $\frac{1}{8}$-inch sheet-iron, with a piece of angle iron rivetted to the top edge, which stiffens them and admits of their being fixed firmly in the ground by the boot of the water-man. The positions of these stoppers are frequently changed, so that the sewage is changed about from place to place on the plot under irrigation.

Distribution.—All the effluent sewage from the fields on the west of the Durnsford Road, is intercepted at the point marked A on the plan (Plate 29), and is conveyed by means of a stoneware culvert to the point B, when it is again applied to the surface of one or other of the plots numbered 43, 35, and 34. The drainage from the fields numbered 46, 48, and 50 is discharged into the contour carrier at the point C, from which it may be disposed of upon any of the plots on the north-east of the carrier, thus all the drainage from the older portion of the farm is made to pass over or through the newer portion; a great deal of the sewage passes through the soil and into the drains of the newer portion, but the portion not so passing through is admitted into the effluent drains at convenient points. It would be difficult to say with certainty whether all the sewage actually passes through soil or not, but in consequence of the attention paid to the surface and of deep cultivation, it is certain that lateral filtration takes place to a very large extent, and as a matter of fact sewage-fungus is never seen in those channels of the newer portions of the farm, which "pick up" the effluent from the surface after its second application. The fact that these channels show no signs of pollution at any period of the year, but contain quantities of green confervæ, are practical indications of the success of the process of sewage purification. In the carriers at the head of these plots, the green confervæ may sometimes be seen striving for the mastery with the sewage-fungus, but the latter always holds its own until the sewage is applied to the land for the second time. Except in flood time, when part escapes into the Wandle at the old outlet, all the effluent water from the farm is discharged into a back-water of the river

Wandle, near the site of the old Garratt Paper Mills. Experiments by the author during hot weather, showed that upwards of half of the sewage was lost by evaporation, absorption, &c. The question of evaporation has been investigated by the Committee of the British Association, Bretons farm, near Romford, being selected for the experiment. Professor Corfield* states that the average daily quantity of sewage pumped amounted to 1,182 tons (average of 399 days) whilst the effluent water discharged amounted to 513½ tons, or 47·3 per cent. only. These facts should be borne in mind by chemists, when comparing effluents from sewage farms with those from chemical-treatment works, since the total amount of impurity entering a river per day, rather than the amount contained per gallon of effluent, should be considered when effluents are compared.

TABLE XXVI.—WIMBLEDON SEWAGE AND EFFLUENT. AUGUST, 1888.

PARTS PER 100,000.

Description.	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.			Remarks.
								Mineral.	Organic.	Total.	
Crude Sewage, .	109·44	3·79	·593	3·65	0	3·60	7·70	8·40	10·64	19·04	Neutral.
From tanks after lime and sulphate of alumina, half an hour's rest, .	83·82	1·88	·282	2·40	0	2·25	7·35	2 20	2·30	4·50	,,
Effluent from land, . . .	81·70	·92	·23	·027	·727	·96	6·95	·31	·25	·56	,,

Although analyses of sewage and of effluent water, taken at haphazard, at uncertain intervals of time, may not be of much practical value, the preceding analyses by Dr. Percy Frankland may be of interest.

The samples were taken after a week of dry weather, but as the subsoil under the town was charged with water in

* *Treatment and Utilisation of Sewage.* Corfield and Parkes, 1887; p. 369.

consequence of the exceptionally wet July, and heavy fall of rain on the first day of August, the sewage was, at that time, about one-third more in volume than the water-supply.

Crops. — In consequence of the large volumes of sewage applied per acre per annum — in 1888, the quantity was 5 million gallons—Italian rye-grass, mangolds, and osiers are the three main crops grown. The weight of the sewage applied to each acre in 1888 was 22,300 tons, whilst the rainfall—26 inches—made the total amount of liquid received by each acre equal to 24,900 tons, or to a depth in inches of 249.

Italian rye-grass (*Lolium italicum*) is one of the most important crops grown upon this, as upon the majority of sewage farms. As its name indicates, the plant was originally found in Italy; it was introduced into this country in 1831, by the late Mr. Charles Lawson. The following botanical description and analysis of the plant are by Mr. M. J. Sutton :—

" Annual or biennial. Root fibrous. Stems 2 to 4 feet, erect, stout, smooth. Leaves long, broad, glabrous, and succulent; sheaths slightly rough; ligule short and obtuse. Spikelets many-flowered, sessile, distichous on a long rachis. Upper empty glume only present in the terminal spikelet; lower empty glume persistent, lanceolate, obtuse, scarcely reaching to middle of spikelet. Flowering glumes lanceolate. Awn as large as glume. Palea ciliate at base. Flowers, June and July. Not known in a wild state.

" ANALYSIS.

	Dried at 212° F.
" *Soluble albuminoids,	·75
**Insoluble ,,	3·31
Digestible fibre,	29·30
Woody ,,	28·32
†Soluble mineral matter,	3·47
††Insoluble, ,, ,,	2·81
Chlorophyll, soluble carbo-hydrates, &c.,	32·04
	100·00

		Dried at 212° F.
*Containing nitrogen,	. . . . .	·12
** ,, ,,	. . . . . .	·53
	Albuminoid nitrogen, . .	·65
Non-albuminoid nitrogen,	. . . .	·50
	Total nitrogen, . . .	1·15
†Containing silica, .	. . . . .	·61
†† ,, ,, .	. . . . .	2·33
	Total silica, . . .	2·94"

On heavy clay lands, the ground to be sown with rye-grass seed should be deeply ploughed in the autumn, and allowed to remain in the rough state through the winter, in order that the disintegrating action of frost may be availed of. Frequent doses of sewage may be applied during this period. In March, if practicable, the land should be brought to a fine till, and carefully selected seed should be sown, the quantity per acre being not less than 4½ bushels. The grass grows very rapidly, and in favourable weather the first cutting may be made about eight weeks after being sown. The cuttings immediately succeeding will be the heaviest, the plant deteriorating somewhat rapidly after five or six crops have been removed. Care must be taken not to allow the plant to flower, as it is not a perennial, and a loss of at least 50 per cent. in weight will follow the flowering stage. With a carefully levelled surface and sufficient applications of sewage, at least eleven cuttings, weighing in the aggregate, and in the green state, about 100 tons, may be obtained in the two seasons following the planting of the seed. Deep ploughing, and, if necessary, subsoiling, should then be resorted to, and the operations commenced *de novo*. With good and careful cultivation, the same ground may be used for rye-grass several years in succession.

The plan adopted for disposing of the produce of the Wimbledon Sewage Farm is to cut the grass and sell it at so much per square rod, the price varying with the state of the crop, and the demand. The bulk of the crop is sold to cow-keepers, who keep animals in large numbers in the south-west of the Metropolis. Small quantities of hay are made, but the farm is too small compared with the volume of sewage applied, to admit of hay-making operations being conducted on a large scale.

The average price obtained for the rye-grass amounts to about £20 per acre per annum.

Mangolds.—This root does well on the sewage farm. The land is treated as for rye-grass, and by means of the plough, roughly ridged. Sewage is applied during the winter and the ridges are twice split during that period. The seed is planted as early as the weather will admit, the land being ridged in the direction of its greatest fall. Care is taken to apply the sewage in small quantities whilst the plant is young, as the cooling of the wet ground, consequent upon the application of large volumes, would be detrimental. When the nights become warm and the plants are vigorous, large quantities of sewage may be applied. The average weight of the crop is, at Wimbledon, about 40 tons to the acre. Many of the rye-grass customers are also purchasers of mangolds. The prices obtained vary with the seasons, but average about 18 shillings per ton. Cabbages are grown in small quantities only, the farm being too cold and heavy to admit of profitable early crops of vegetables being produced

The willow, or **osier,** may with very great advantage be introduced upon sewage farms. Large quantities, for basket making and for other purposes are yearly imported from Holland and from the north of France, although there is no apparent reason why this country should not at least grow its own osiers. The plant likes moisture, and will grow upon any kind of land except, perhaps, peat bog. It is among the first in the list of economic plants. "The bark and leaves of the willow are astringent, and the bark of most sorts of willow may be used for tanning, and it is a fact worth noticing, that the tanners of Norway and Russia use willow-in preference to oak-bark, and much of the excellence of Russian leather is said to be due to the use of willow-bark.

M. Lennox, a Frenchman, discovered a substance he named 'Salicine,' in willows. It is in the form of greyish crystals, and extremely bitter. M. Magendie says he has known three doses of six grains stop a fever; and Prof. Burnet says it is equally as efficient as Peruvian bark in cases of fever, and speaks of the wise provision of Providence in placing the remedy for agues and other low fevers in moist situations where those diseases are most prevalent. It is not quite certain which variety of willow produces salicine in the greatest abundance, but it is most likely the *salix purpurea*, and its varieties, as being the bitterest of willows, and it is a noteworthy fact that all the varieties of the bitter willow will grow in the wettest soils" (*Scaling*).

The kinds found most suitable at Wimbledon are the "New Kind," and the "Golden Willow." The first named is a dark-skinned osier, very suitable for the basket-maker. The setts or cuttings are very carefully selected from willows grown upon the farm, they are cut in lengths of about 16 inches, and planted 1 foot apart in one direction, and 1½ foot in the other, although, if light rods are in demand, the cuttings may be planted closer together, when the crop will be of a lighter, finer quality. The cuttings should be planted with their ends nearly level with the ground, in order to ensure straight shoots being obtained. The Continental method of planting the tops of the cuttings level with the ground, is not advisable on sewage farms, because of the rank growths of weeds which prevail. The ground should be thoroughly cleansed in the spring before the new shoots appear, and any surface depressions visible should be filled in with soil, in order to prevent stagnation of the sewage.

Osier-plantations come into full bearing in the third year, although a fair crop of rods is obtained the first year. The plant is said to attain its maximum usefulness at the tenth year, from which period it slowly declines. The crop is gathered soon after the fall of the leaves, by cutting as close to the parent stem as possible. The annual yield per acre averages 6 to 7 tons in weight. For the London market, the osiers are bundled into the trade "bolt," having a girth around the part near the base of 16 inches. The price obtained at Wimbledon is about £12 per acre for the unpeeled rods. Best white peeled rods are much more valuable, but must be properly manipulated in order to obtain a good return. The rods to be prepared for the market in this condition are, after being cut and bundled, set upright in shallow tanks containing water; in the spring, shoots will appear, and at the proper time the bundles are removed from the water, and may be readily peeled.

The golden willow is of much smaller and finer growth than the osier, and a ready market for the small twigs and rods will be found with market-gardeners, who use large quantities for the purpose of tying up vegetables. When this willow is boiled, with the bark on, the wood takes a pretty dye, and is very suitable for the fancy-basket maker. The bark is intensely bitter. The weight yielded per acre is not so great as in the case of the osier.

Cost.—The costs of the sewage farm and works have been as follows:—

Pumping station, machinery, tanks, buildings, &c.,	£20,866
Seventy-three acres of land,	24,432
Draining, levelling, and preparing land,	8,141
	£53,439

The items in the first line would be common to any scheme at Wimbledon, and as the money paid for the purchase and laying out of the land could be borrowed upon the security of the rates, at 3¾ per cent. rate of interest for an indefinite period of time, we may take that as a basis in estimating the annual cost of the farm:—

3¾ per cent. on £32,573, =	£1,222
Average annual working expenses during past three years, inclusive of every expense,	901
	£2,123
Average annual receipts during last three years, =	1,307
Cost of farm to ratepayers per annum,	£816

This sum is equal to a rate of one and one-sixth of a penny in the pound, and it may fairly be said to represent the actual cost of the sewage farm. As a matter of fact, the land is being purchased year by year by the operation of a sinking-fund.

The annual repayment of capital and interest on the cost of land and works, £53,439, is . . .	£2,869
Pumping and maintenance of machinery, . .	520
Precipitation of sewage and sludge-pressing, including insurance, rates, taxes, chemicals, and every expense,	923
	£4,312
Cr. By profit on farm on sales, ...	406
Cost to ratepayers, . . . =	£3,906

This is equal to a rate of 6·4d. in the pound, taking the basis of assessment as for general district rate purposes, or 5·1d. in the pound on the poor-rate assessment.

About seventy-five persons live upon the sewage farm, but up to the present their health has been good, and there have been no outbreaks of zymotic disease.

The Effluent flows into the river Wandle, which joins the Thames at a point about 3 miles below the farm. The relative volumes of river-water and effluent are, in dry weather, in the ratio of 25 to 1.

Note.—Some alterations and additions have recently been made, mainly in extending the burnt-ballast filters and the sludge-pressing plant. The Amines system of sewage treatment has also been extensively employed, but whilst the sewage is effectively deodorised by the treatment, the sludge produced has increased by something like 60 per cent., in consequence of the enormous quantity of lime used. At the present time (1894) lime and copperas are being used for sewage treatment in the proportions of 12 grains and 4 grains per gallon of each respectively.

CHAPTER XXVIII.

BIRMINGHAM. 1889.

The works at Birmingham are chiefly remarkable for their magnitude, and for the extreme simplicity of detail.

The liming shed is a large square building divided into three sections on the ground floor, and having a second floor over the central section. The engines, of the portable type, are placed in one section, in another are a pair of pumps, which raise sewage to the floor above for the lime-mixers, which consist of a pair of large edge-runner mortar-mills with specially constructed high sides. The lime-shed or third section, is a large room, into the ends of which the lime is deposited and slaked, each end of the building being cleared on alternate days. The slaked lime is fed into an elevator, consisting of an endless chain and buckets, by which means it is conveyed to the mortar-mills and converted into milk of lime.

Long troughs, supported upon trestles, convey the milk of lime to the outfall sewers, in which it is well mixed with the sewage as the latter flows towards the settling tanks.

The arrangements for dealing with the sludge are simple, almost to crudeness. After being elevated to a sufficient height to command the most distant part of the farm used for sludge disposal, the sludge is conveyed to the site where it is intended to trench it in, by means of a long wooden trough, made up in sections 22 feet in length, and supported upon scaffold poles. Each section of the trough is formed of two boards $1\frac{1}{4}$ inches in thickness, and 11 inches in width, bolted together for the bottom, then one board of like dimensions is spiked on each side; small pieces of board are then nailed on the outside of the trough at one end, and each section looks like half of a rectangular socketted pipe. The sections are readily taken down when it is desired to convey the sludge to a fresh field, being merely dropped into their places on the supports, the joint being made by the sludge itself.

The accumulation of sludge on the land is not large, the work of trenching in being carried on continuously, as the sludge becomes partly solidified.

Although some improvements might be made as regards the means of conveying the sludge to the land, on the occasion of the author's visit to the works the operations were remarkably free from offensive odours, having regard to their magnitude.

Works.—The history of the works as given by Mr. Till, M. Inst. C.E., is full of instructive matter:—

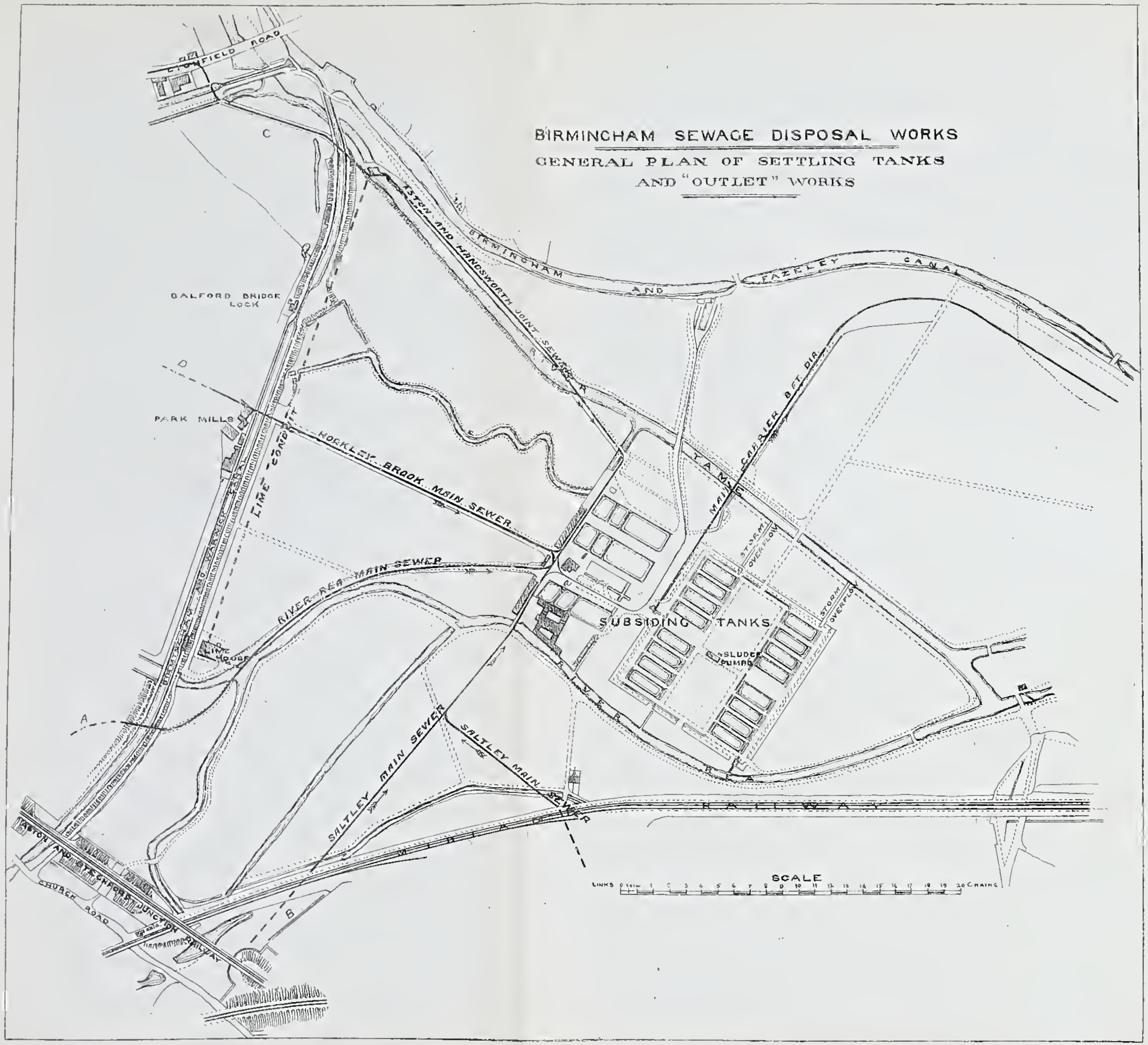
"In giving an account of the formation and work of the Drainage Board, the works of sewage purification previously undertaken by the Corporation of Birmingham form so important a part that any general description of the Drainage Board would be incomplete without some reference thereto; but, inasmuch as the efforts of the Birmingham Corporation to deal with the sewage difficulty have been so prominently before the various bodies interested in sanitary work, both from the proceedings in Parliament and from several published statements, it has not been thought necessary to make further allusion thereto than may be required for giving a complete history of the position and work of the Board.

"It may perhaps be desirable to glance briefly in the first instance, at the sanitary condition of the district generally, prior to the formation of the Board, with a view of setting forth more clearly the advantages the various Authorities now comprising the Board were intended to derive from their union.

"The Borough of Birmingham, together with the towns of Walsall, West Bromwich, Wednesbury, Darlaston, Tipton, part of Wolverhampton, and a number of other urban or rural sanitary districts, forming the major part of what is known as the 'Black Country,' is situated near the summit of one of the great watersheds of England, that of the Trent, being drained by the river Tame, which, with its various feeders, forms a small stream discharging into the Trent, about midway between Tamworth and Burton. Whatever may have been the benefits derived by the large population of the Black Country from being situated high up in the watershed, one great disadvantage, that of sewage pollution, soon became apparent, owing to the naturally diminutive character of the watercourses and the large amount of liquid refuse poured into them. The Corporation of Birmingham, as the principal Local Authority, was early made aware of the responsibility thus incurred, and was earnestly combating the sewage difficulty at a time when the Authorities of many towns considered it, if not exactly the right thing to do, at any rate only a venial offence, to discharge their sewage into the rivers or streams that flowed in their vicinity.

"At the time the formation of the Drainage Board was suggested, none of the Authorities of the towns or districts draining into the Tame had made, so far as the author is aware, any really systematic attempt at sewage purification, except those of Birmingham and Wolverhampton.

"The Corporation of Birmingham constructed as far back as 1853, main intercepting sewers (marked A and B on the diagram submitted herewith) whereby the sewage from those portions of the Borough draining to the river Rea, and Hockley brook, was conveyed to the general outlet at Saltley, where subsequently a system of tank purification had been adopted, and which was developed from time to time until, at the period when the Drainage Board was formed, the Corporation possessed land and works thoroughly capable of purifying, so far as precipitation by lime could purify, the sewage of the Borough. The Manor of Aston Local Board had caused plans to be prepared in 1874, for the intercepting sewers, for diverting the sewage of its district from the river Tame and the Hockley brook, and by agreement the Handsworth Local Board, whose district is situated



West, Newman photo-lith.

on the same watersheds, but higher up, became joint owners of such sewers. These sewers were constructed in 1876, and although the sewage was thus diverted in detail, it was only to cast it into the Tame again in one united volume, pending the decision of these Boards as to the method of sewage treatment to be adopted, a problem that threatened to be very difficult of solution had not the Drainage Board been formed about that time, and so relieved those Authorities of further trouble. The Authorities of the District of Balsall Heath, a small, but somewhat thickly-inhabited area draining to the rivers Rea and Cole, immediately above the Borough of Birmingham, had established some precipitating works of an elementary character at the outlet in the river Cole area, but owing to the great increase of population all around, the use of these works had become objectionable, and as the only outlets for this district lay through the Borough of Birmingham, it became necessary, if great expense were to be avoided, that some arrangement should be made for the Corporation to provide the requisite outlets. The district of Harborne, likewise situated in the watershed of the Rea, above the Borough of Birmingham, had also established a system of tank purification, but open to similar objections to those above named in Balsall Heath, this district also suffering from precisely the same difficulties as to outlet. These, then, were the only districts in the neighbourhood of Birmingham, of which the Authorities had made any efforts to deal with their sewage; whilst on the other hand there were several districts urgently in need of sanitary reform, that had been unable, owing to their positions in relation to other districts, to take independently the necessary step, except at a prohibitive cost.

"Birmingham and its Sewage Farm, holding by virtue of its position, the key of the situation, and the Corporation anticipating that great expense and inconvenience must ultimately arise if some united action were not taken, it was decided to apply to the Local Government Board, under the Public Health Act, 1875, for an order to form the following urban and rural sanitary districts, or portions of them, into a united district for the purposes of sewage disposal—viz., the Borough of Birmingham, the Local Government Districts of Aston Manor, Handsworth, Smethwick, Balsall Heath, Harborne, and Saltley; the contributory places of Aston, King's Norton and Northfield, and Perry Barr; and portions of the Districts of the West Bromwich Improvement Commissioners, and of the Solihull Rural Sanitary Authority; the principle of selection adopted being to choose only those districts lying round Birmingham, which were restricted in their outlets, or which had no reasonable facilities for establishing purification works of their own.

"An inquiry, lasting several days, was held by J. T. Harrison, Esq., the Local Government Inspector, at the Public Offices, Birmingham, in which the West Bromwich Commissioners proved to the Inspector's satisfaction that they were in a position to establish their own purification works; and the Rural Sanitary Authority of Solihull, having also recently prepared a scheme, was likewise omitted by the Inspector.

"All the other districts were formed into a United District under the title of the Birmingham Tame and Rea Main Sewerage District, the Provisional Order coming into operation on the 29th September, 1877.

"The Joint Board consisted at first of twenty elective members, chosen from the members of the various Constituent Authorities, of which the Borough of Birmingham sent eleven and the other one each, and two *ex-officio* members—viz., the Mayor of Birmingham and the Chairman of the Aston Manor Local Board. The District was enlarged in 1881 by the addition of the Parish of Sutton Coldfield, but no alteration was made in the constitution of the Board until Sutton Coldfield was incorporated early in the present year, when the number of members was increased to twenty-four, Sutton Coldfield sending one member and the representation of the Borough being increased to the same extent.

"The duties of the Board are the acquiring of such lands and the construction and maintenance of such outfall works as may be necessary for the purification of the sewage of the various Constituent Authorities, so that it may be discharged into any streams or watercourses without breach of the Rivers' Pollution Act, 1876. It is incumbent on each of the Constituent Authorities, either to construct such intercepting sewers as may be required for conveying the sewage of its district to the outfall works, or otherwise to arrange terms with one or other of the Constituent Authorities for the user of such sewers as may be necessary for that purpose. The Joint Board exercises supervision over the size, character, and direction of new intercepting sewers, so that they may be laid down with general reference to the requirements of the United District at large, and in the case of its being desirable that one Constituent Authority should use the existing intercepting sewers of another Constituent Authority, it devolves on the Joint Board to say whether such sewer can and ought to be so used to the extent of, but not exceeding, 40 gallons per head per day of the population of the district.

"The costs of the Joint Board are divided into the costs of management, and the costs of outfall works (outfall works being the land, tanks, and works for purifying the sewage).

"All the Constituent Authorities, with the exception of Perry Barr, are liable to the costs of management, but no Constituent Authority is liable to the expenses of outfall works until some portion of such Authority's district has been placed in connection with any of the said outfall works.

"The various districts contribute to the expenses of the Board in proportion to the number of rated tenements in each district or contributory place, such number being ascertained from the poor rate made last, before the times for issuing the Board's precepts.

"The total area of the Drainage District is 47,275 acres; the population in 1885 was estimated at 619,693, and the ratable value £2,401,093.

"Appendix A gives a detailed statement of the area, population, and ratable value.

"In accordance with the Provisional Order, the Drainage Board purchased, as going concerns, all existing lands and works for treatment of sewage owned by the various Constituent Authorities, such being Birmingham, Aston Manor, Harborne, and Balsall Heath. Of these, the works at Harborne and Balsall Heath were abandoned as soon as arrangements for outlets had been carried into effect, and the sites of such works were ultimately sold. From the Borough of Birmingham, the Board acquired about 159 acres of freehold, and 103½ acres of leasehold land, together with the extensive system of tanks, machinery, plant, farm implements, and stock, situated at the general outlet at Saltley, point E on plan; and from Aston Manor about 6 acres of land, also situated at Saltley, and surrounded by the Corporation Farm.

"As the outlet at Saltley is the natural point of discharge for fully nine-tenths of the total population of the Drainage District, one of the first cares of the Drainage Board after its formation, was to assist the various Constituent Authorities in their endeavours to put themselves in communication with the outfall works purchased from the Birmingham Corporation. Accordingly arrangements were speedily made for the Corporation to receive into their main sewers A and B, the sewage from the districts of Harborne and Balsall Heath on payment of an annual sum for user; the Manor of Aston Local Board entered into a contract for the construction of a sewer for conveying its sewage from the temporary outlet into the Tame to the Board's tanks, the Aston Rural Sanitary Authority becoming joint owner with Aston Manor and Handsworth, and thereby procuring an outlet for the Erdington and Witton portions of its districts; the Handsworth Local Board extended one of the Aston and Handsworth joint sewers so as to accommodate the northern portion of its district, and has since, in conjunction with Smethwick, extended the other joint sewer, thereby completing for the present the intercepting sewers of its own district, and providing for Smethwick an outlet for the larger portions of that district. The Saltley Local Board constructed intercepting sewers and the Rural Sanitary Authority of King's Norton, after arranging with the Corporation of Birmingham for an outlet through their main sewer marked B, constructed intercepting sewers for the drainage of portions of its district. For those portions of the Drainage District that could not conveniently be brought down to the common outlet at Saltley, the Corporation of Birmingham constructed a sewer for accommodating the area draining to the Cole comprised in the districts of Birmingham, Balsall Heath, King's Norton, and Aston Rural, this sewer being tunnelled across the ridge dividing the watersheds of the Tame and Cole, and discharging on to the new farm. The Aston Rural Sanitary Authority also constructed a sewer for the drainage of Sutton Coldfield, this sewer likewise discharging on to the new farm.

"As the result of the intercepting works just described, the whole of the populated areas of the Drainage District, with one exception, are now placed in communication with the outfall works. The one exception is the District of Smethwick, which, being situated at the summit of the watershed, has had to await the development of the intercepting system, but it is believed that arrangements are contemplated whereby this difficulty will shortly be removed.

"In the meantime, pending the completion of these intercepting arrangements, the Drainage Board had been proceeding with the very important duty of extending its outfall works, so as to meet efficiently the additional strain that would in due course be brought upon them. It had been generally understood at the time the Board was formed, that an extension of the outfall works would be necessary, and after due consideration it was decided that the application of the sewage to land, after treatment by lime in the tanks, would be the most satisfactory method of purification. The Board accordingly directed its attention to the acquisition of the required area of land. An opportunity that presented itself in 1880 of obtaining the unexpired term of 102 years of a lease of 96 acres of suitable land at Tyburn, about 2½ miles below the existing tanks, when embraced, and shortly after, a lease for 99 years of 123 acres of adjoining land was obtained, while 250 acres of freehold from the Right Hon. the Earl of Bradford, 350 acres from the Trustees of W. W. Bagot, Esq., and 118 acres from various other owners were acquired by mutual arrangement, and more recently a further plot of 18½ acres has been leased from the Right Hon. Lord Norton for 21 years, thus making a total of 955½ acres of additional land, or, including the land already occupied by the Board at Saltley, a total area of 1,227 acres available for works of sewage disposal. The rent of the leasehold land is at the rate of £4 per acre, and the average cost of the freehold, including timber, buildings, mill wrights, tenants' compensation, law charges, &c., £152 per acre.

"The nature of the land is very favourable for the purification of sewage, the natural surface of the ground being as a rule even and unbroken, and the level such as to admit of the irrigation of the whole by gravitation, with the exception of about 100 acres. The subsoil is of gravel and sand, varying from 6 feet to 10 feet in thickness. To reduce risk of flooding from the river, the Board removed the mills and weir, and straightened the river at Minworth, at the lower end of the farm lands, thereby lowering the water level of the river several feet; and by the construction of outfall cuts, carried to suitable outlets into the river, the subsoil drains are placed beyond the influence of backwater, the result being that no inconvenience is experienced from the proximity of the river, except during unusual floods. For conveying the sewage to the land, a conduit, 8 feet in diameter, and about 3¾ miles long, has been constructed, capable of discharging 38 million gallons per day when running half full, or double that quantity when running full, the fall being 2 feet per mile. This conduit commences at the outlet end of the large tanks at Saltley, and terminates at Tyburn, valves being placed at suitable intervals for discharging the sewage on to the land passed through. Below Tyburn the capacity of the conduit has been reduced, a conduit 3 feet 6 inches in diameter being sufficient for the remainder of the farm. The sewage is drawn from these conduits into open brick carriers, which again discharge into secondary carriers of earth, and thence into the flooding carriers. The brick carriers are constructed with a slight fall, ramps being provided at the inverts at suitable intervals for drawing down the water. The land is drained to a minimum depth of 4 feet 6 inches, but in many cases, owing to the level nature of some of the land, a greater depth has been found necessary at the lower ends of the drains. The subsoil drainage consists of 3-inch and 4-inch agricultural drain pipes, placed from half to three-quarters of a chain apart, and discharging into main drains of 9-inch, 12-inch, 15-inch, and 18-inch stoneware socket pipes, which in turn discharge into the outfall channels. Roads generally 12 feet wide, with passing places at intervals, have been laid out with the view of meeting the requirements of the steam-cultivating operations, as well as for the conveyance of produce. In addition to the farm buildings at Saltley purchased from the Corporation, farm buildings in a central position at Tyburn have been erected, together with entrance lodge, manager's house, and six labourers' cottages; also smaller buildings at Minworth, and four labourers' cottages. The various farm-houses and buildings originally existing have also been repaired and extended.

"**Cost.**—The total cost of the land and works to the present has been £403,695, of which the purchase of original land and works is £170,544; new land, £110,800; new works, £113,299; farming stock and implements for new land, £9,052. The details of cost are given in Appendix B.

"**The method of treating** the sewage as now carried on is as follows:—

"The sewage, on arriving near the liming sheds at the upper end of the works, is mixed with lime, both to neutralise the acids (present to an unusual extent in Birmingham sewage) and also to assist precipitation, which, however, is not now necessary to so great an extent as formerly; the sewage then passes through the large or roughing tanks, where the grosser impurities are precipitated, and from thence it is conveyed by the main conduit to the land, and disposed of by ordinary irrigation. The sixteen small tanks required at one time for completing the precipitation process are still used under certain circumstances, and are a valuable auxiliary when rainfall has increased the normal quantity of sewage. The sludge from the tanks is elevated by bucket-dredgers and pumps into movable wooden carriers, and flows into beds formed in the land at the Saltley or western end of the farm. The sludge contains about 90 per cent. of water as it comes from the tanks, but after lying on the ground for about fourteen days, much of this water drains away, or is evaporated, leaving the sludge in a layer about 10 inches thick, and of a consistency that admits of its being trenched into the land. Crops are then planted, and after a time the sludge becomes pulverised, and the land with which it has been incorporated is capable of being irrigated. About 50 acres of land were required for the sludge last year, and the same land may receive a dressing of sludge every two to three years.

"A few words may be said as to the difficulty at one time experienced in dealing with the mud from the tanks. After the construction of the first two large tanks in 1859, the mud therein deposited was dredged out and run on to the adjacent land, where it accumulated for some years, forming at one time a large mass of foul matter about 7 acres in area, and over 4 feet deep. In consequence of the nuisance arising therefrom, proceedings were taken about 1871 by the residents in the vicinity, and an injunction was obtained restraining the Corporation from depositing the mud so as to cause a nuisance. Great efforts were made by the Corporation to reduce the amount of mud, large quantities being conveyed away in boats, but it was not until the experiment had been tried, of trenching the mud into the land, and found perfectly satisfactory, that the present system was adopted, about the end of 1872, and the difficulty finally overcome.

"Practically, the whole of the sewage of the drainage district, amounting to 16,000,000 gallons per day, flows by gravitation to the outfall works. Only a very small area requires its sewage lifted by pumping, the cost of such pumping being £104 per annum.

"The Board farms the whole of the land, no portion of it being sublet.

"**Produce.**—Of the produce, milk is a large and increasing item, 128,995 gallons, realising £4,406, being sold last year. During the present year, about 280 acres of land are devoted to mangolds, swedes, and kohl rabi; 250 acres to market garden produce; 100 acres to Italian rye-grass; 130 acres to cereals; and about 340 acres are pasture.

"The total amount realised last year from the sale of stock and produce was £20,008. During the same time stock was purchased to the extent of £7,760.

"**Cost.**—With regard to the financial aspect of the Board's works, it is perhaps needless to say that a considerable sum of money has annually to be obtained from the rates. The total amount raised by the Board's precept last year was £33,089, of which interest and repayment of loans absorbed £17,516; management expenses, rent, rates, taxes, &c., £5,594, the balance of £9,979 representing the loss on the year's working of the farm.

"Appendix C is a detailed statement of the actual income and expenditure of the farm and works during 1885. The great loss, as will be seen from the statement, is in the work at the outlet (which comprises the lime, wages, machinery expenses, and other charges connected with intercepting and dealing with the mud from the tanks). The amount expended under this head (exclusive of rent) was £10,715, for which sum 4,778 tons of lime were provided for precipitation, and 135,476 cubic yards of mud were arrested in the tanks, and dug into the land; the corresponding income is practically nil." At the date of the author's visit (August, 1889) a gang of twenty-four men were constantly employed in dealing with the sludge. Since the opening-out of the irrigation land, the expenses at the outlet have undergone some reduction, and there is every prospect not only of a further reduction in the future, but also of a gradual increase in the receipts from the irrigation land, as the demand for the farm produce is developed; but, bearing in mind the large initial outlay in purchase of land and the construction of works, and the annual working expenses in disposing of so large a volume of sewage, it is not to be expected that assistance from the rates can be dispensed with until, in the somewhat distant future, the large annual sum now required for interest and repayment of loans shall cease. It should, however, be remembered in dealing with sewage farm accounts that, after all, the great item on the credit side of the balance sheet (although it is one that cannot be represented by a money value) is the satisfactory disposal of the sewage.

"In conclusion, it is only fair to observe, with reference to remarks made in the first part of this paper as to the sanitary condition of the Tame Valley, that, since the date then referred to, considerable progress has been made in sewage purification, Walsall, West Bromwich, Wednesbury, Darlaston, and other towns and places having taken up the question in a practical and energetic manner."—1886.

NOTE.

Area of Sewage Farms .... { Freehold .... 888 acres; Long Leasehold .... 219 "; Short Leasehold ... 120 " } Total .. 1,227 "

Dry weather Sewage .... 16 million gallons per day

Average quantity of Lime used per day in 1885, for precipitation &c. ...... 13 tons

Quantity of Mud arrested in the Tanks at Saltley during 1885. .... 135,476 cub. yards

Area of Land used in 1886 for digging in the Sludge from the Tanks. ... 40 acres

PARTICULARS OF TANKS.

Description	Length	Width	Average Depth	Capacity in cub. feet
Large Tank, North	328 ft. 0 in.	92 ft. 0 in.	3·86 ft.	116, 400
" " Middle	338 ft. 0 in.	98 ft. 0 in.	5·11 ft.	169, 400
" " South	322 ft. 0 in.	90 ft. 0 in.	5·34 ft.	154, 600
16 Small Tanks	150 ft. 0 in. each	50 ft. 0 in. each	6·07 ft. each	728,960 combined
		Total capacity of Tanks, 1,169,360 cub. feet		

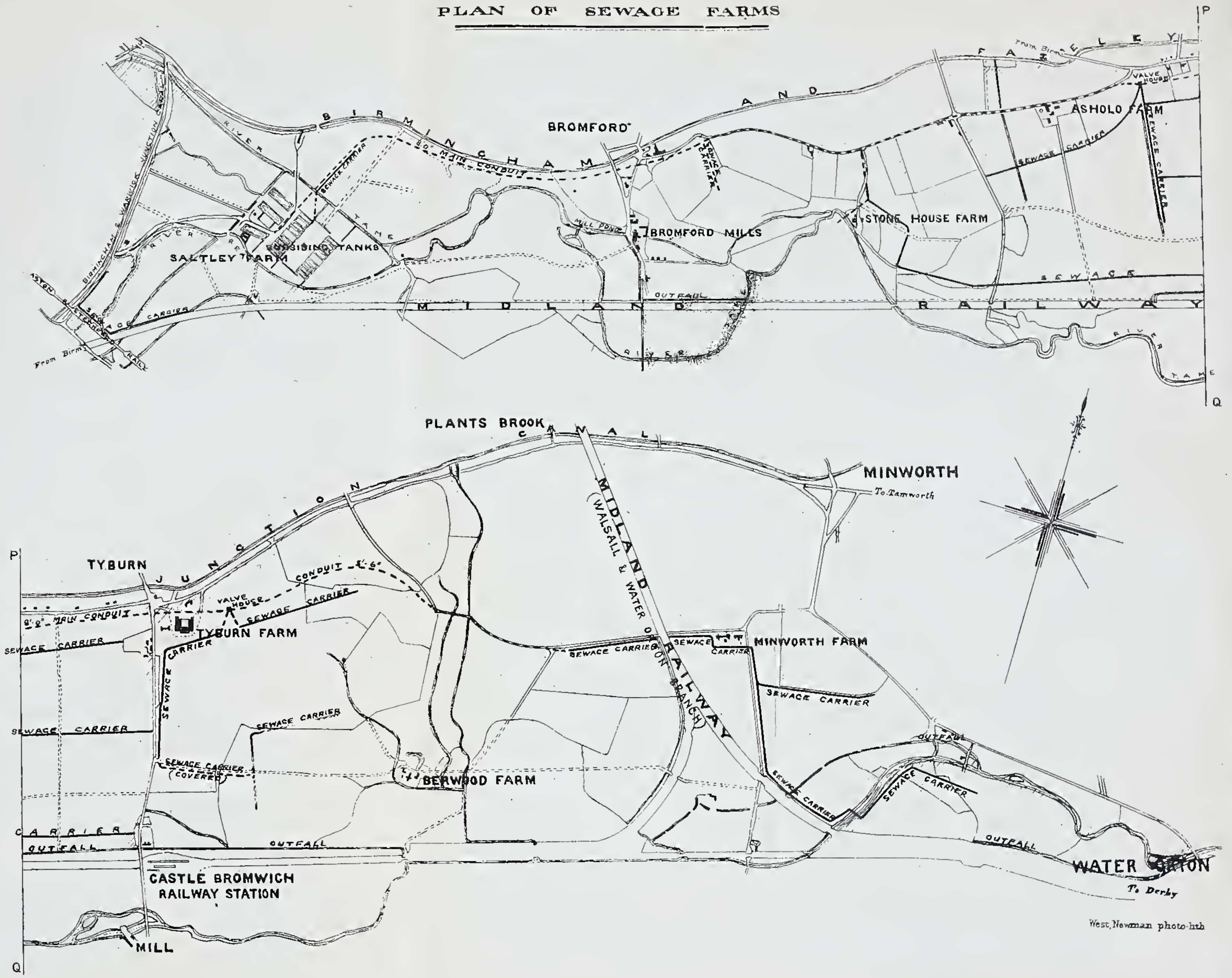
Total Area of Drainage District .... 47,275 acres

" *Population in 1885 (estimated)* 619,693

Rateable Value in 1885 .... £ 2,401,093

SCALE

PLAN OF SEWAGE FARMS



West, Newman photo-lith

APPENDIX A.

Name of District.	Area in Acres.	Estimated Population in 1885.	Ratable Value in 1885.
Borough of Birmingham, . . .	8,420	427,769	£1,621,701
Smethwick, Local Government District of, .	1,882	26,000	113,667
Harborne, ,, ,, ,, .	1,412	7,422	31,334
Balsall Heath, ,, ,, ,, .	453	25,300	69,803
Saltley, ,, ,, ,, .	1,039	7,100	47,514
Aston Manor, ,, ,, ,, .	943	62,510	171,875
Handsworth, ,, ,, ,, .	3,638	27,300	125,601
Aston Union, Contributory Place of Aston, .	8,916	10,552	63,198
King's Norton Union, Contributory Places of King's Norton and Northfield, .	3,500	15,275	84,476
West Bromwich Union, Contributory Place of Perry Barr, ...	4,042	1,655	19,208
Borough of Sutton Coldfield, . . .	13,030	8,810	52,716
Total, . .	47,275	619,693	£2,401,093

APPENDIX B.

Old Farm.

Land, ...	£56,337 0 0	
Works, Tanks, &c., ...	91,479 0 0	
Stock and Plant, ...	22,728 0 0	
		£170,544 0 0

New Farm.

Lands.—*Re* Wiley's Lease, . . .	£1,500 0 0	
,, Perkins' ,, . . .	164 0 0	
,, Housman (Freehold), . .	6,249 0 0	
,, Earl of Bradford (Freehold), .	38,484 0 0	
,, Bagot ,, .	49,498 0 0	
,, Newton ,, .	11,173 0 0	
,, Goldingay ,, .	3,732 0 0	
		110,800 0 0
Works.—Main Conduit, . . .	£33,256 0 0	
3 ft. 6 in. ,, . . .	3,544 0 0	
Laying out and Draining, . .	46,979 0 0	
New Buildings, . . .	20,119 0 0	
Repairs to Old Buildings, . .	599 0 0	
Permanent Carriers, . .	8,802 0 0	
		113,299 0 0
Live Stock and Farm Implements, ...		9,052 0 0
		£403,695 0 0

APPENDIX C.

INCOME AND EXPENDITURE FROM JANUARY 1st TO DECEMBER 31st, 1885.

INCOME.

Outlet.

Sale of Manure,	£7	0	0
Pumping Sewage,	104	0	0
Sundries,	0	4	9
	£111	4	9

Farm.

Sale of Rye-Grass and other Crops and Cattle, Ley,	£4,960	15	10
,, Milk,	4,406	18	7
,, Stock,	10,641	0	3
	£20,008	14	8

EXPENDITURE.

Outlet.

Wages, including Lime for Disinfecting,	£9,025	12	0
Horse Keep, Veterinary Attendance, Repairing Harness, Carts, &c.,	356	11	6
Timber, Ironwork, Bricks, Tools, Coal, Coke, and Repairs to Machinery,	1,064	14	7
Horse Hire, Boat Hire, and Tonnage,	174	9	5
Rent, Rates, Taxes, and Gas,	787	0	9
Miscellaneous,	94	2	9
	£11,502	11	0

Farm.

Wages,	£5,047	1	5
Seeds, Plants, &c.,	508	18	11
Horse Hire, Keep, and Cattle Keep,	4,768	14	5
Stock Purchased,	7,760	7	6
Miscellaneous, including Tools,	930	8	2
Rent, Rates, and Taxes,	3,806	18	5
	£22,822	8	10

APPENDIX D.

OUTFALL WORKS, OUTLET AND FARM.

Estimate of Income from January 1st to December 31st, 1889.

OUTLET.

Income.	Estimated Income 1888.	Actual Income 1888.	Estimated Income 1889.
Sale of Manure, . . .	£10 0 0	£12 14 0	£10 0 0
Sale of Horses, &c., . .	...	...	...
Pumping Sewage, . .	104 0 0	104 0 0	104 0 0
Sundries, . . .	10 0 0	...	10 0 0
	£124 0 0	£116 14 0	£124 0 0

FARM.

Sale of Rye-Grass and other Crops and Cattle, Ley, .	£5,500 0 0	£5,964 7 3	£5,750 0 0
Sale of Milk, . . .	4,000 0 0	4,092 18 6	4,000 0 0
Sale of Stock, . . .	10,000 0 0	10,359 6 9	10,000 0 0
	£19,500 0 0	£20,416 12 6	£19,750 0 0
Totals, . .	£19,624 0 0	£20,533 6 6	£19,874 0 0

APPENDIX E.

OUTFALL WORKS, OUTLET AND FARM.

Estimate of Expenditure from January 1st to December 31st, 1889.

OUTLET.

Expenditure.	Estimated Expenditure 1888.			Actual Expenditure 1888.			Estimated Expenditure 1889.		
Wages, . . .	£5,800	0	0	£5,814	0	7	£5,800	0	0
Lime for Disinfecting, .	2,700	0	0	2,512	4	8	2,600	0	0
Horse Keep and Veterinary Attendance, . .	400	0	0	470	14	6	450	0	0
Timber, Ironwork, Bricks, Tools, Coal, Coke, and Repairs to Machinery, .	1,100	0	0	1,225	3	9	1,350	0	0
Tonnage, . . .	150	0	0	31	17	2	50	0	0
Rent, ...	370	0	0	363	7	7	360	0	0
Rates and Taxes, . .	275	0	0	277	18	2	280	0	0
Gas and Water, . .	70	0	0	94	9	10	100	0	0
Miscellaneous Expenses, .	150	0	0	141	7	4	150	0	0
Horse, ...	50	0	0	56	0	0	50	0	0
	£11,065	0	0	£10,987	3	7	£11,190	0	0

FARM.

Expenditure.	Estimated Expenditure 1888.			Actual Expenditure 1888.			Estimated Expenditure 1889.		
Wages, . . .	£5,500	0	0	£5,894	6	9	£5,500	0	0
Seeds, Plants, &c., . .	500	0	0	582	12	5	600	0	0
Horse and Cattle Keep, .	4,500	0	0	4,635	16	10	4,700	0	0
Stock Purchased, . .	8,000	0	0	7,997	17	6	8,000	0	0
Implements, Tools, &c., and Miscellaneous Expenses,	1,000	0	0	862	16	6	1,300	0	0
Rent, ...	2,850	0	0	2,584	5	2	1,375	0	0
Rates and Taxes, . .	900	0	0	819	8	5	780	0	0
Gas and Water, . .	150	0	0	183	14	4	200	0	0
	£23,400	0	0	£23,560	17	11	£22,455	0	0
Totals, . .	£34,465	0	0	£34,548	1	6	£33,645	0	0

CHAPTER XXIX.

MARGATE, 1892.

In 1888, Mr. Baldwin Latham was instructed by the Margate Corporation to prepare a scheme for the drainage of the district.

The report, which accompanied the scheme, has been presented by Mr. Latham, together with a joint report by Sir Frederick Bramwell, C.E., F.R.S., &c., and Sir Douglas Galton, R.E., K.C.B., &c., to the author, for the purposes of this chapter.

Both reports are of the greatest interest, and will be found of great value by those who may have to advise on the disposal of the sewage of seaside towns.

Mr. Latham's report states that the **area of the district** is 994·889 acres; of this area 235·450 acres are comprised in the foreshore, so that the absolute area of this district, after deducting the area of the foreshore, for which drainage arrangements will not at present be required, is 759·439 acres. It will also be observed that the lands adjacent to the Borough, if ever they come to be built upon, would, from the natural configuration of the district, have to drain in the direction of Margate, and this fact must not be lost sight of in considering the sufficiency of the scheme to meet all future contingencies.

Population.—At the census of 1871, the Borough of Margate contained 11,995 persons, and at the census of 1881, it contained 15,889 persons, but in the interval between these two periods, the Borough had been enlarged, and, therefore, the increase of 1881 was not due to the natural increase of population in the district. In order to arrive, however, at what has been the rate of increase in this district, if we take the population living in the Registration District of Margate, which remains the same in 1881 as it was in 1871, we find that the population at the census of 1871 was 13,903, and in 1881 it was 18,226, showing that, in the decade, the rate of increase had been 31·09 per cent.

"If we assume that the Borough of Margate is to increase at the same rate in the future as has been shown to be the increase in the Registration District, then the population at the middle of the following years will be as under:—

Year.	Population.
1881, ...	15,987
1891, ...	20,943
1901, ...	27,435
1911, ...	35,940

"These populations, however, are based upon a period when Margate is empty of visitors, and in all probability a time would arrive, especially when the district is provided with proper sanitary arrangements, and becomes more attractive in consequence, when a population of not less than three times these figures might fairly be expected. It is true that the element represented by the visitors will not contribute so large a proportion of sewage as the resident population, since the area of the district as representing the rainfall and a large portion of the water supply will be proportionately greater for the resident than for the non-resident portion of the inhabitants. The dry-weather volume of sewage should not be calculated at less than 30 gallons per head per day, half flowing off in six hours.

"**Rainfall of District.**—I have received from J. Stokes, Esq., of Apsley House, and from T. Twyman, Esq., of Renfrew Villa, Margate, very valuable information with reference to the rainfall of the district. I have also found that there are other rainfall records in Margate and neighbourhood to which I have referred. The following figures show the state of the several records:—

TABLE XXVII.—RAINFALL AT MARGATE.

	Years of Observation.	Average quantity per annum.
1. E. S. Lenden, . . .	1864 to 1881	20·6 inches.
2. T. Twyman, ...	1878 to 1887	24·9 ,,
3. W. L. Sear, ...	1869 to 1875	22·6 ,,
4. J. Stokes, ...	1881 to 1886	24·0 ,,

"Having regard to the fact that the rainfall varies with the elevation of each portion of the district, it is probable that the average rainfall for the Borough of Margate, over a long series of years, would amount to about 24 inches, and that the fall on the average would take place on 160 days in the year. The amount of rain which would have to be admitted to the sewers, however, depends not so much on the volume of rain which falls in a day, as upon the rate at which the rain falls and flows off the areas which receive it. It is also dependent upon the geological character of the district, as a very large portion of the rainfall in this district would not flow off the surface, but at once penetrate it, and it is only from roofs, yards, roads, or artificially prepared surfaces that the rain would flow off.

"I am now carrying on, and have been carrying on for over ten years, observations upon the sewers of Croydon, which has a similar geological formation to that at Margate, and at the same time I have recorded, continuously, observations upon the rate at which rain falls and the period in which it flows off in this particular town, which, I believe, is the only instance on record where any such observations have been made, and from these results it is possible to arrive at correct conclusions as to the way in which rain affects the discharge of the sewers. As a rule, it is found that the quantity of rain which is put down as falling on a particular day often falls in a few minutes; the fall rarely extends into many hours. It is this rate of fall which affects the sewers, It is by no means, therefore, an uncommon thing in the case of Croydon to find the average dry-weather flow increased to a quantity exceeding twelve times that of the average flow, and yet in Croydon a very large portion of the surface-water —namely, from the roads and streets—is entirely diverted from the sewers, and it is practically only the rain which falls on the roofs and yards of houses that has to be dealt with.

"In the case of Margate it appears there is never a year passes but what more than an inch of rain falls upon one or more days in the year; there are a considerably larger number of days when ¾ inch or more falls, and a larger still when ½ inch falls, and on one day, namely, December 26th, 1886, nearly 2½ inches of rain and snow fell. It will be observed that unless the rain from the roofs and yards of houses is admitted to the sewers, it will be necessary to have two sets of house drains from each house in the district, one for carrying the sewage proper, and the other the rainfall. This would be attended with double cost to the inhabitants in carrying out their private drainage works, and even then it would probably be only partially successful owing to the probability of the slops occasionally finding their way into the wrong system of drains.

"It appears to me that there is nothing to be gained in the scheme which I am proposing for your adoption, by carrying out a separate system on what I call the high level district of Margate. If the sewers are proportioned (as will be the case) to the fluctuating work they will have to perform, the admission of rain or its absence will be no drawback to such a system of sewers. And although it is true that larger sewers are required where the rainfall is admitted than in cases where it is not, yet even this in the case of Margate is not absolutely correct, as owing to the fact that it will be requisite to construct the outfall for Margate in tunnel, in order that the work may be economically performed, it is necessary that it should be made of a particular size so as to be convenient for execution. In the scheme, therefore, which I have shown on the accompanying plan, it is contemplated that all the rainfall of all the high level or gravitation district shall pass into the sewers. The rainfall of the low level district being conveyed away from the streets by means of the existing and improved surface water drains, but that rainfall which could not be conveniently excluded without the expense of making separate house drains should be admitted to the sewers.

"**Geological Character and Physical Outline of District.**—The district is located on the chalk, in some cases covered with drift, but mostly in the higher portions of the district the chalk appears on the surface. This particular geological formation is extremely absorbent, so that only the rainfall which falls on the roofs and artificially prepared surfaces will be likely to pass into the sewers of a larger part of the district.

"Of course such things as floods from the chalk have been known, but they are not likely to occur in such a district as Margate, as these floods generally arise from the surface having become frozen while rain is falling and so having been made impervious to moisture, the rain then flows off; but in a district so near the sea as that of Margate, such a condition as this is not likely to arise. The physical outline of the district is such that it is severed by two valleys, namely, the Dane Valley, passing down the district to the sea, from south-east to north-west, and the Tivoli Valley, passing through the district from south to north. The former of these valleys is by far the smaller, but is the more populous. On the accompanying plan I have shown by red colour the boundary of the high level district, the sewage of which would be dealt with by gravitation, and which, therefore, clearly defines the valley lines flowing through the district and the general arrangements which become necessary in consequence of the peculiar outline of the country.

"**Mode of Disposing of the Sewage.**—In a seaside town the mode of disposing of the sewage is a matter of vital importance. There is so much sentiment in the minds of the public that any method of disposing of the sewage by which it is either retained in the district—as in the cesspool system, —distributed on the surface—as on a sewage farm, or on a filtration area,—or by deposition into the sea, must be fully considered. From my knowledge of Margate, and from a number of observations which I have had to make in the neighbourhood of Margate upon the directions of tidal currents, I am most clearly of opinion that, in this case, the best and the only safe mode of disposing of the sewage effectually, is by its discharge into the sea at a point suitable for that purpose, and in making this recommendation, I wish you to distinctly understand that I have not one word to say against the principle of the utilisation of sewage by irrigation, or its comparative destruction by natural or artificial filters, as for years I have been the exponent of these methods of disposing of the sewage of inland towns, and have carried out in this country and abroad some of the most extensive works of the kind which have been brought into existence.

"Margate, however, from its natural position, has enormous advantages for disposing of its sewage, without nuisance, and in a most economical manner. On the other hand, it is clear that, in order to apply sewage either by irrigation or intermittent filtration, it would be necessary to convey it some distance from the town, where it would be applied to a very porous soil, so porous that it would almost disappear at once, with very little change probably in its natural character. This sewage would, therefore, almost immediately make its way down to the underground water level of the district. Having regard, therefore, to the fact that both the present and future water supply of Margate and the neighbouring towns must continue to be derived from the chalk, very serious risks of underground pollution would arise were any sewage works established within some miles of them. It would be improper on my part to recommend you, and suicidal on yours, to attempt to carry out any such scheme of disposing of the sewage, under the conditions as regards the water supply that exist in your neighbourhood. And, even were it feasible, the cost of the works would be enormously increased, as duplicate systems of sewers would become necessary throughout the whole of the district, and the whole of the sewage would have to be pumped to a considerable elevation in order to be so disposed of. Again, as there is no area within the limits of the Borough itself, you would have to convey the sewage into the district of an alien authority, and, even if compulsory powers could be obtained, you would have to purchase a considerable area of land with its protecting cordon, which I fear would prove to be a very expensive undertaking. The question of the pollution of the underground water supplies, if sewage was applied to land in the neighbourhood of Margate is no mythical conclusion. For over twelve years I have been conducting experiments on the movement of the underground waters in various geological strata, and have been collecting statistics in reference to this subject, and I may say there exists at the present time ample evidence to show that the dangerous pollution of underground water may traverse the ground for miles without losing any of its baneful properties. Under such circumstances it would therefore be extremely imprudent to attempt to apply sewage to land in the neighbourhood, even if it could be done without cost to the inhabitants.

"My recommendation to you is, that the sewage of the town of Margate should be conveyed, by direct gravitation, to a point distant about 2 miles east of Margate Jetty or to Foreness, and be there discharged at the outer extremity of the Long Nose Ledge, where it should be discharged into deep water. The formation of the coast line at this particular point is extremely favourable for effectually disposing of sewage in the sea.

"If a line is drawn directly east and west, the coast on the west or Margate side of Foreness Point will be found to recede at an angle of about 8° from such line, while on the east side the coast recedes at an angle of 47°. The effect of this recession of the coast is that the currents are deflected off the shore at the proposed point of sewage discharge. The direction of the tides is also extremely favourable. The published records of these tides at this very spot shows that the young flood flows direct south, the first quarter flood flows to

TABLE XXVIII.—METEOROLOGICAL OBSERVATIONS AT MARGATE.

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
January. .	1·8	2·6	7·0	5·8	7·2	17·0	8·8	2·2	9·6
February, .	3·6	2·0	10·2	4·4	11·2	17·2	3·0	1·4	3·4
March, . .	5·4	8·6	12·2	5·4	6·4	9·0	5·6	3·6	5·8
April, . .	6·4	13·0	11·2	4·4	5·2	6·4	5·4	1·4	6·6
May,. . .	8·0	7·0	8·0	4·4	5·8	11·6	7·0	3·8	6·4
June, . .	9·4	9·8	7·8	2·6	7·0	8·2	6·0	3·0	6·2
July, . .	2·4	2·2	7·6	4·4	8·4	16·8	11·8	1·8	6·6
August, . .	5·2	3·2	8·2	3·8	6·6	10·6	7·4	3·2	13·8
September,.	5·0	5·4	7·0	2·2	6·4	16·8	8·0	3·8	5·4
October, .	5·0	1·8	5·0	4·8	7·4	11·8	10·8	8·0	7·4
November,.	3·6	1·8	9·0	5·4	7·4	14·4	7·2	4·2	7·0
December, .	7·0	2·6	7·0	1·4	7·2	16·2	9·2	5·2	6·2
	62·8	60·0	100·2	49·0	86·2	156·0	90·2	41·6	84·4
Percentage,	8·6	8·2	13·7	6·7	11·8	21·4	12·4	5·7	11·5

the south-west, the half flood flows to the west, the last quarter flood flows to the north-west; the first of the ebb flows north-east by north, the half ebb flows to the east, while the last quarter ebb flows to the south-east. It will be noted that there is only one particular stage, viz., the first quarter flood, which is not so favourable as the other directions of the tidal current, the flow being to the south-west, or almost directly on to the shore at the point at which it is intended to discharge the sewage. But, on the other hand, it will be observed from the table (XXVIII.) of the direction of the winds, that the prevailing winds which affect the tidal currents materially are south-westerly and westerly, the exact opposite direction to the most unfavourable tidal current. The preceding table shows the direction of the wind at Apsley House, Margate, for the years 1883 to 1887 inclusive, from the observations by John Stokes, Esq.

"**Tidal Observations.**—In 1877 a series of tidal observations was made at this particular point, and from these observations I have written the following description of the direction which the floats took :—

TABLE XXIX.—TIDAL OBSERVATIONS AT MARGATE.

TIDAL OBSERVATIONS, MARGATE, MADE BY MR. G. N. ABERNETHY, MEM. INST. C.E., AND MR. A. LATHAM, MEM. INST. C.E., in 1877.

10th March.—H.W. 8.51 a.m. and 9.36 p.m. Float put in commencement of ebb. Went to east and south-east with velocity of 65 feet per minute.

25th May.—H.W. 10.34. Float put in commencement of flood moved in a south-westerly direction parallel to the coast. Velocity 28 feet per minute. Wind slight S.

25th May.—H.W. 10.34. Float put in quarter flood, velocity 62 feet per minute. Moved to south-west parallel to shore. Wind slight S.

26th May.—H.W. 11.23 a.m. and 11.46 p.m. Float put in between $\frac{1}{4}$ and $\frac{1}{2}$ ebb. Went off to the east and slight tendency to south-east with a velocity of 111 feet per minute. Wind slight S.

26th May.—H.W. 11.23 a.m. Float put in $\frac{1}{2}$ to $\frac{3}{4}$ ebb. Went off to east and slight tendency to south-east with a velocity of 93 feet per minute.

26th May.—H.W. 11.23. Float put in at half flood. Went off in a north-westerly direction with a velocity of 50 feet per minute. Wind W.

26th May.—H.W. 11.23 a.m. and 11.46 p.m. Float put in at termination of flood and commencement of ebb. Went off in a northerly direction with a tendency to north-east at a velocity of 51 feet per minute. Wind W.

2nd July.—H.W. 3.57. Float put in 8 hours after high water. Went first to south and then to west, outside rocks with a velocity of 36 feet per minute to the south and subsequently a velocity of 50 to 72 feet per minute to west. At 2.50 p.m. float near eastern side of jetty. Wind slight S.W.

2nd July.—H.W. 3.57. Float put in about noon. Went direct to west and passed about 300 yards outside of jetty. Velocities varying between 69, 59, and 102 feet per minute. Wind slight S.W.

2nd July.—H.W. 3.57. Float put in 12 minutes before H.W. Went off to the north-east with a velocity 119, 166, and 191 feet per minute. Wind slight S.W.

3rd July.—H.W. 4.36. Float put in about 7 hours after H.W. Went first in south-westerly direction, then north-westerly and westerly, and turned 1 hour before H.W. and then went to the east.

3rd July.—H.W. 4.36. Float put in about 42 minutes after H.W. Went to the east and south-east with a velocity varying from 132 feet to 41 feet per minute.

5th July.—H.W. 6.6. Float put in 1 hour before H.W. Went first to north-west and then to east with varying velocity, but before turning to east the float was out ¾ mile. Another float put in at the same hour went off to north-west with velocity varying from 39 to 49 feet per minute.

5th July.—H.W. 6.6. A float put in 3½ hours after H.W. Went to east and south-east, ran 600 yards outside White Ness and North Foreland at velocity varying from 55, 77, and 93 feet per minute.

18th Sept.—H.W. 9.13 a.m. Float put in 11.45 a.m. or 2½ hours after H.W. Wind strong from north-east. Float went to east and south-east. Heavy sea on shore. Float passed White Ness at a distance of about ½ mile from shore.

19th Sept.—H.W. 10.0 a.m. Float put in 12.45 p.m. or 2¾ hours after H.W. Wind north-north-east, strong, with sea on shore. Float went to east and south-east and passed North Foreland a mile from shore.

20th Sept.—H.W. 10.42 a.m. Float put in 2.40 p.m. or 4 hours after H.W. Went off to the east and south-east at velocity of 132 feet per minute and went past North Foreland a mile out.

"It will, therefore, be seen from the prevailing direction of the tidal currents, the general direction of the winds and the particular outline of the coast at the point which has been selected for the outfall, that all the conditions are extremely favourable for the discharge of sewage, but I may point out also that, owing to the fact that there is only one particular phase of the tide which is not altogether favourable (and that occurs while the tide is rising), I have so arranged the levels of the sewers that there will be a slight check to the discharge of sewage at the outfall only at this very phase of the tide, and by this means I shall avoid the possibility of sewage ever coming on to the shore.

"It is well known that sea water has a remarkable power both of destroying and precipitating the matters discharged from sewers in a fresh state. It contains one of the most potent chemicals that are at present used for the purpose of precipitating sewage, its antiseptic properties are well known, and, further, it has been pointed out by one of the highest agricultural authorities of this country, that probably you get more indirect return by the discharge of sewage into the sea than you would by utilising it upon land.

"In December, 1884, and January, 1885, Sir John Bennet Lawes pointed out the beneficial influence of sewage upon the fisheries of the country, and in this he was corroborated by other eminent authorities in the correspondence which then took place in the columns of the *Times*. He showed that so long as sewage is discharged fresh into the sea, and is got rid of so as to avoid decomposition, it is a benefit to the fisheries, and, therefore, would be no waste. In order to get the full advantages of the discharge of the sewage I have designed a system of sewers, so that there shall be a continuous discharge, and that there shall be no stagnation either in the outfall or in the sewers of the district.

"I propose to construct a system of intercepting sewers contouring the high level district at a sufficient elevation to secure the drainage of the whole area, and so as to be capable of continuously discharging the sewage, even at the highest water level of the highest spring tides. The rainfall and sewage of the whole of the district above the intercepting sewers will flow by gravitation at all states of the tide to the outfall.

"The low level district I have divided into three separate areas, the sewage from which, I propose, shall be automatically pumped just as fast as it is produced and discharged into the intercepting sewers; it will then rapidly find its way by gravitation to the outfall.

"The most populous of the low level districts is the Dane area, which contains 34·94 acres. The Tivoli Valley is divided into two areas, the upper containing 59·82 acres (which is the most sparsely populated of all the areas), and the lowest part of the Tivoli Valley contains 35·61 acres. Of the 759·439 acres, the total area of the Borough, from 629·619, the sewage will be conveyed by direct gravitation, and from 129·820, the sewage and rain which falls upon the houses, and is admitted to the sewers, will require to be pumped. The main outfall for the district is intended to be a brick and concrete sewer, the invert lined with blue Staffordshire bricks, 4 feet 6 inches high and 3 feet wide; the lower section of it forms part of a section of an 18-inch sewer. The main sewer will run parallel to the coast, and in that portion of the district in which it is constructed, which is outside the Borough, there cannot be the slightest doubt that hereafter it will tend to increase the value of the lands through which it passes by providing an efficient sewage outfall for them, and it is placed in such a position as will in all probability be the natural direction that a further extension of the roads of Margate would be likely to take eastwards. This sewer will diminish in size as it approaches the west end of Margate, being graded according to the work it is to perform. Its invert would have a level of 18½ feet above Ordnance Datum at the Royal Sea Bathing Infirmary, and at this level it would pick up the existing drains of that establishment.

"The sewage at Foreness Point would be conveyed across the Long Nose Ledge by a 27-inch* iron pipe in an excavated trench; it would be carried 550 yards into the sea (measured from the cliffs) before it was discharged. The trench which would receive the outfall pipe would be filled in and con-

* The outfall as constructed was 30 inches in diameter.—(*Author.*)

creted so that the presence of the sewer or sewage could never even be known or suspected when the works were completed. All the rest of the intercepting sewers are adjusted in size and inclination to the work which they would have to perform.

"The lateral sewers of the town are all of small size, and have very rapid falls, so that they would discharge their contents very quickly into the intercepting sewers, and these intercepting sewers have all of them such falls in the district which they have to traverse, that the daily flow of sewage through them in the driest weather will keep them clear and cleansed.

"**Low Level District.**—In this district I propose that three automatic pumping stations shall be provided, each fitted with two hydraulic pumping engines. By dividing the low level district in this way, a considerably increased fall is given to the sewers, and they are reduced in size so that the sewage will be got rid of as quickly as it is produced.

"The actual power required to be maintained in these districts is comparatively small, for in order to raise the sewage at the rate of 600,000 gallons a day out of the three combined districts, a little over 2 horse-power would be required, but the six engines intended to deal with the sewage of these districts would be capable of raising 3½ million gallons of sewage per day out of the district into the gravitation sewers. The water which has been used in actuating these engines, after use, will be employed for flushing both the high and low level sewers of the district, and in addition to this arrangement for flushing, I have provided in the estimate a number of flush tanks so as to secure the thorough cleansing of all the sewers of the district. With reference to the low level district of the Dane, it appears that, at the present time, if a rainfall occurs at the period of high tide, the district is liable to be flooded; no scheme, therefore, would be complete that did not provide against this flooding of the district. In the scheme, therefore, I have proposed and included in the estimates the construction of a new surface-water drain right through the district, consisting of a proper penstock chamber, with its tide valve and penstock arrangements in connection with the present outfall, and, in addition to that, I propose to provide a chamber containing two automatic pumps, actuated n the same manner as the sewage pumps in the district are intended to be worked, so that whenever the surface-water of the district rises to an inconvenient level, these pumps will start to work of themselves, and relieve the district from flooding.

"I have also in the estimates concluded that to make the scheme complete in itself, you should know what will be the cost of making everything self-dependent; therefore, I have assumed that it is necessary to construct engine houses, boiler houses, &c., on the site of the yard (now your property) in the lower portion of the Dane district; in the estimates the cost of these buildings and everything in connection with the complete scheme has been included. I should, however, point out that, in the event of the present Tivoli pumping station being used as the site of the power works, the cost of the scheme would be reduced, as a saving would accrue in the buildings and in other directions which would tend to reduce the cost of the works."

REPORT BY SIR F. BRAMWELL AND SIR DOUGLAS GALTON.

MARGATE DRAINAGE.

1. Provision for the Future.—Assuming the figures in Mr. Baldwin Latham's Report to be correct, it appears that the Borough of Margate includes about 995 acres, of which about 235 are foreshore, leaving about 760 acres as the area of which the drainage has to be dealt with. The population in 1881 appears to have been, in round numbers, 16,000, exclusive of visitors.

The plan provides for a future (in 1911) permanent population of about 36,000, being about two and a quarter times the present number of inhabitants: and it assumes that during the season this number will be increased to three times that amount by visitors.

This provision for as much as 108,000 inhabitants in the season, in the future, appears to be ample.

The amount of sewage allowed for in the scheme is 30 gallons per head of the prospective population, including visitors. This appears to us larger than necessary.

It would probably be safe to take the sewage of the resident population at 30 gallons per head; but from information which we have obtained regarding the water supply, it seems clear that 10, or at most 15, gallons per head, for the visitors, would be an ample quantity to allow.

Calculating on this latter basis, the sewage would amount, when the population had attained its maximum, to a total of about 2,000,000 gallons per day, equivalent to 320,000 cubic feet; but, for the next ten years, it is reasonable to suppose that the amount would not much exceed 1,400,000 gallons in the twenty-four hours.

The levels of the ground within the Borough involve the necessity of employing mechanical means for raising the sewage in two districts—namely, that of the Dane Valley, and that of the Tivoli Valley, comprising together 130 acres; while the sewage from the remaining part of the area, which is 630 acres in extent, can flow off by gravitation.

The rainfall, as well as the sewage, will be removed by the sewers from the gravitation area, but only that part of the rain which falls on roofs and yards, and the sewage proper, will be removed by them from the 130 acres of low level area; the rest of the rainfall on such area being allowed to pass through the present water-courses, or, where necessary, through improved channels to the sea.

This general design appears to be satisfactory.

2. Method of Sewage Disposal.—The disposal of sewage on land is always a matter of difficulty and expense.

When sewage is delivered on to a favourable soil, covered with growing crops, the subsoil water may not be affected by the distribution of sewage on land; but, in a chalk district, at certain times of the year, the infiltration of sewage applied to land may become a source of danger.

In the case of Margate, the water supply of the district is obtained from the underground water stored in or passing through the chalk.

It is in the highest degree advisable to avoid even a suspicion of pollution in this underground water by percolation from a sewage farm, and it is also important to avoid the first cost of the acquisition and of the preparation of the land, and also to avoid the annual cost of pumping the whole of the sewage on to that land.

There is every facility for the discharge of the sewage into the sea, and, therefore, in consideration of the local conditions which obtain at Margate, we are of opinion that the sewage should be discharged into the sea, and that its disposal by application to land should not be resorted to.

3. Position of Outfall.—The spot selected for the outfall, viz., Foreness Point, is the most favourable locality on the coast in the vicinity of Margate for the discharge of the sewage into the sea.

An examination of the chart appears to show that it is at this particular point where the tides change their direction, and where the north and south and the east and west tides meet.

During the whole ebb the currents set away from the shore to the east and south-east, then, during the ebb, there is no probability of the shore to the west and south of Foreness being affected by sewage flowing out of the outfall.

As regards the currents of the flood tides and their probable effect,—these currents appear to be sluggish at, and for about an hour from, low water; but after this time they begin to make, and until half-flood the set of the currents is to the south-west and west, and parallel to and near the shore.

During the remainder of the flood the currents flow away from the shore to the north-west.

Whilst, therefore, on the one hand, during the last three hours of flood tide, and during the whole of the ebb, the set of the currents is away from the coast near Margate; on the other hand, during the first three hours of the flood, the set of the tide is along the shore; hence, during those three hours, it is necessary that the sewage should be prevented from being discharged at the outfall, and that it should be retained in a storage reservoir. When, in the future, the summer population reaches the 108,000, and the sewage the 2,000,000 gallons a day, then on those occasions when the first three hours of the flood occur during the time of maximum flow of sewage, the quantity to be stored would amount to 80,000 cubic feet. A chamber of such capacity would not afford any storage for rainfall in the time to come, when the full number of the population will have been reached, but we are of opinion that there is no need to exceed this storage capacity with the present population, and that it will be well to make the chamber of the capacity indicated, leaving it to be duplicated when the increase of population requires it.

A reservoir can be formed by deepening and enlarging the sewer for the last 200 or 250 yards of its length, so as to make an elongated chamber near its mouth. The bottom of the chamber would be a little above the level of low water neap tide; if the sewer be widened throughout this length to about 12 feet, the chamber would suffice for the storage of the sewage generated during three hours of maximum flow, when the full number of the population was reached, and this storage would in no way interfere with the continuous flow of the sewage from the sewers within the Borough.

The underground water level rises inland, and the flow of underground water is towards the sea; hence the temporary storage of sewage at the outfall cannot cause any risk of pollution of underground water.

4. **Outfall Sewer.**—This sewer, which is 3 feet by 4 feet 6

inches, and is built of concrete lined with brick, is carried from the junction of Edgar Road and the Eastern Esplanade (at which junction it receives the general system of town sewerage), parallel to the shore, and at a depth of 60 feet, for a distance of about 1½ miles, to Foreness Point, terminating, as proposed, in a penstock chamber, the bottom of which is on the level of ordnance datum.

This chamber, it will have been seen, we suggest should be enlarged so as to store some 80,000 cubic feet.

From the penstock chamber an iron pipe, 27 inches diameter, is to be laid from the foot of the cliff across the foreshore, buried in the chalk, and extending in all about 550 yards to low water mark, spring tides.

With the object of reducing the head needed for discharge, we suggest that this pipe should be increased to 3 feet 3 inches in diameter.

The size of the sewer is sufficient to allow of the removal of the prospective sewage, together with a little over ½ inch of rainfall in twenty-four hours. For cases of exceptional rainfall, storm-overflows are provided.

This capacity of discharge we consider to be sufficient.

The range of spring tides is nearly 15 feet—that is, from about 8 feet 6 inches above to about 6 feet below ordnance datum.

Having regard to the relative levels of the outfall sewer and of the tides, the sewage would be backed up during every spring tide very nearly to the Borough boundary, which, however, would render it necessary to provide very full ventilation for the outfall sewer.

This may be easily arranged by means of the shafts shown on the line of this sewer. We are of opinion that this construction will work perfectly well, and we think a wise discretion has been exercised in keeping the outfall down at this level, so as to embrace as large an acreage as practicable within the gravitation area, and thus diminish as far as possible the areas involving pumping.

5. Town Sewerage.—(1) *Gravitation Area.*—The main intercepting sewer commences at the west end of the Borough with an 18-inch earthenware pipe sewer, which is enlarged to a 21-inch pipe sewer between the junction of the Canterbury Road and the Marine Terrace. In consequence of the low levels of the Marine Terrace, it is deemed expedient that the part of the sewer which passes along it should be formed of an iron pipe having a diameter of 21 inches, the remaining portion of the sewer thence to its junction with the outfall sewer is constructed of concrete, brick lined.

All the other sewers in the gravitation area are proposed to be earthenware pipe sewers.

The details of the system of sewerage are not fully shown. It is, however, clear from certain sections which have been furnished to us, that the several town sewers may be laid with rapid falls, and at an adequate depth to drain the basements of the houses; therefore, with suitable flushing arrangements, and with proper precautions for the exclusion of road grit, the gravitation sewers may be kept free from deposit.

(2) *Low Level Area.*—The two low level districts—that in the Dane Valley and that in the Tivoli Valley—are to be relieved of the sewage proper by mechanical means.

As has already been mentioned, the low level sewers are not designed to remove rain water other than that which falls on yards and roofs, and thus these new sewers will not be affected by road grit.

(*a*) *Dane Valley.*—In the Dane Valley the sewage is to be brought by means of earthenware pipe sewers to a pumping station near the gas works, where it is to be lifted by an automatic hydraulic pump through a 12-inch iron pipe, 400 feet long, into the high level system.

These sewers would, as already mentioned, carry off the rain falling on roofs and on paved yards, while the other part of the rainfall would pass off along existing drains; but, inasmuch as a portion of this area is now liable to be flooded when heavy rain occurs at the time of high water, provision is made for a new rain-water sewer, leading to a penstock chamber on the beach, close to the back of the pier, whence the storm water arriving at the time of high water would be discharged by means of an automatic hydraulic pump.

(*b*) *Tivoli Valley.*—In the Tivoli Valley it is proposed to have two pumping stations—one close to the eastern end of the Marine Terrace, the other close to the railway crossing at the bottom of Frog Hill.

The sewers at the back of Marine Terrace (where the ground is said to be water-logged and below high water) are proposed to be constructed of iron pipes; the remainder of the sewers are to be earthenware pipe sewers.

The rain water, other than that which falls on roofs, is proposed to be passed through existing drains to the sea.

(3) *Ventilation of Sewers.*—The estimate shows a provision for 145 ventilators. It is understood that these are in addition to 264 manholes and 15 shafts.

These together would give a ventilator for every 90 yards of sewer. It is understood that one of these ventilators is to be placed at the dead-end of every sewer.

With the gradients shown, the whole of the sewage ought to be removed rapidly, and to be discharged at the outfall within two or three hours of its being generated; so that if no deposits are allowed in the sewers, there would be no probability of offensive smell arising.

To prevent deposit there are 22 automatic flushing chambers provided for the principal sewers.

We consider that it would be advisable, in order to avoid accumulations in the smaller sewers, that a flushing tank corresponding to the size of the sewer, should be placed at the upper termination of every sewer.

The estimates provide 5,038 junctions for house connections on the line of sewer.

The adaptation of the house drainage to the new sewerage is not included in the plan; but it would be advisable that there should be invariably a disconnecting trap between the sewer and the house drain, and that the latter should be provided with independent ventilation.

6. Mechanical Appliances for Lifting the Sewage in Low Level Areas.—With respect to the raising of the sewage from the Tivoli Valley and from the Dane Valley into the outfall sewers, and to the construction of the local sewers within these valleys we agree that this construction will be facilitated, and these local sewers will be better kept free from deposit by there being more than one pumping station; and we also concur in the provision in the Dane Valley of a means for mechanically raising the rain water coming upon that valley, which at present occasionally floods it if a time of very heavy rain happens to be coincident with high water.

In this manner several pumping stations of very small power, however, are required.

Having regard to this smallness of power, it becomes practically impossible to bear the wages expense incident upon making each of these pumping stations independent, and thus it points towards the working of all these small pumping stations from some central source of power.

There are one or two models by which this could be done, viz.:—

1. By compressed air employed in working engines of the construction of the ordinary steam engines and driving pumps.

2. By applying the compressed air to act directly on the surface of the sewage in receptacles provided for the purpose. (Shone's system.)

Another convenient mode of distributing power from a central source is to do so hydraulically, and that is the mode Mr. Baldwin Latham has proposed.

More than a quarter of a century's experience has shown that the hydraulic mode of distribution is entirely trustworthy. By its means the various pumping stations will automatically start when needed, will continue to work as long as needed, and will stop automatically when the working is no longer required. The machinery is of the simplest character, and the chance of mishap and the cost of repair are of the very smallest. As regards mishap, however, the scheme and estimate provide for a duplication of the hydraulic engines at each of the pumping stations.

This plan of the hydraulic distribution of power from a central source has our entire approval.

7. **Estimates.**—We have satisfied ourselves that the dimensions of the main outfall sewer . . . are sufficient, and have adequate falls.

With respect to the remainder of the sewers, we have no further information than that of the sizes given on the plan. As well as we can judge these are adequate, assuming fair falls, about which, having regard to the level of the outfall sewer, we imagine there can be no difficulty. We are thus (with the exceptions we have mentioned, and that are again referred to below) satisfied with the dimensions of the sewers and with the other provisions in Mr. Baldwin Latham's plan, and we presume he has assured himself that such work can be executed in Margate at the various prices mentioned in his estimate, but on this point we express no opinion.

In our judgment the sum of £3,486 (say, Three thousand four hundred and eighty-six pounds) should be added for increasing the outfall pipe from 27 inches to 39 inches, and for providing the chamber to contain the three hours' delivery during the first half of the flood tide.

FREDERICK BRAMWELL.
DOUGLAS GALTON.

9th August, 1888.

It may be mentioned that the outfall, as constructed, consisted of 1,583 lineal yards of 4 feet 6 inches by 3 feet sewer, 590 lineal yards of 7 feet 6 inches diameter reservoir sewer, and 530 lineal yards of 30-inch diameter cast-iron pipes. At the junction of the reservoir sewer with the outfall from the town, means were provided for preventing the sewer-air from passing into the town outfall from the reservoir (see fig. 16). The cost of the works, including a large number of flushing

MARGATE SEWER OUTFALL.

Scale of One Inch to a Statute Mile — 1/63360

West, Newman photo lith.

tanks, street gullies, and other surface-water works, was about £75,000. The author is indebted to Mr. Baldwin Latham for the details given.

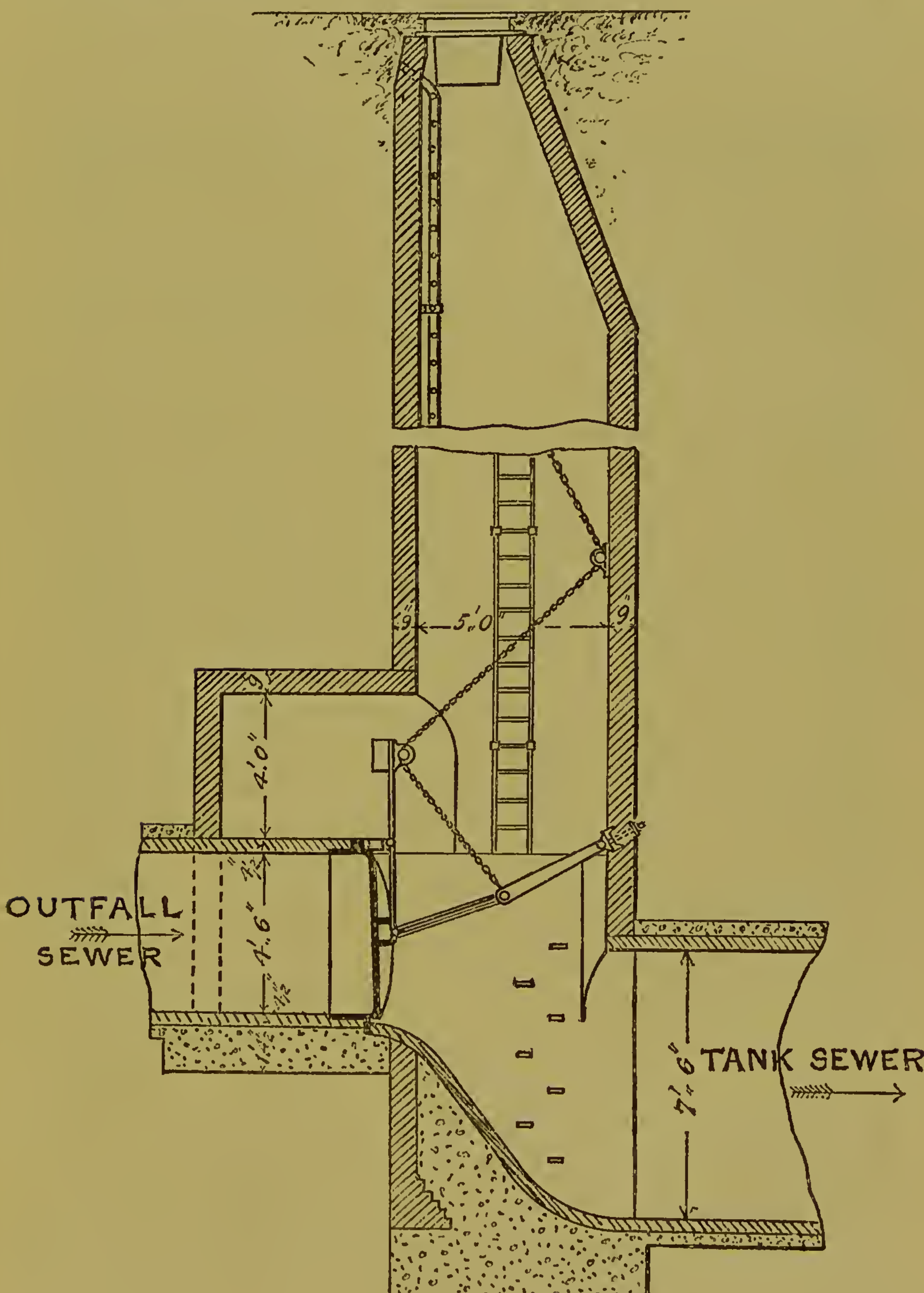


Fig. 16.

CHAPTER XXX.

PORTSMOUTH, 1889.

Population, &c.—Population draining to works, 130,000; ratable value, £500,000; water-closets, 26,000; daily dry-weather flow of sewage, 4,000,000 gallons. There are two storm-overflows.

The separate system of drainage is partly in operation, but in designing the outfall works, provision was made for a considerable amount of rainfall per hour.

Works.—The sewage-disposal works are in some respects both novel and interesting. The district drained is very flat. "The highest, busiest, and most densely populated portion of the Borough is elevated about 12 feet only above the tidal range, while about one-third of the Borough is very little above the level of ordinary spring tides" (*Angell*). In order, therefore, that the sewers should be provided with sufficient fall, the sewage has to be pumped.

There is a small pumping station at Stamshaw, containing pumping machinery operated by a pair of 4 N.H.P. Otto gas engines, by means of which the sewage of the sub-district is raised and discharged into the main outfall sewer. All the main sewers discharge their contents into the pump-well of the main pumping station, which is situated near Eastney Fort. This pumping station, with a long length of new outfall sewer, a rising main, the tanks, and other works, were designed and carried out by Sir Frederick Bramwell, Mem. Inst. C.E., F.R.S., &c., with the assistance of his chief assistant, Mr. Harris, Mem. Inst. C.E. The old system, designed by Mr. Lewis Angell, Mem. Inst. C.E., had in 1882 become in part inadequate for the requirements of the Borough, and the works to be described were in substitution of such of them as required alteration.

Before definitely deciding upon the point of discharge of the sewage, Sir Frederick Bramwell caused experiments to be made in order to ascertain the course that would be taken by the sewage under the diverse conditions prevailing. It was found that the floats were carried many miles out to sea, when placed in the tide-way soon after high-water, and the works were designed so as to admit of an exceedingly rapid discharge of the sewage, in order to take full advantage of this circumstance.

A reference to the plan will show that there is an exceedingly large land-locked harbour, that of Langstone, immediately to the north of the outfall works. An enormous volume of water fills this harbour at high-water, and as a consequence, the velocity of the water passing through the narrow channel communicating with the sea is, both on the ebb and flood, very high, the range of the tide varying from 13 feet 6 inches at spring, to 10 feet 9 inches at neap.

The point of discharge which was selected by Mr. Angell when first designing the works, and subsequently approved by Sir Frederick Bramwell, is peculiarly well-situated, having regard to all the circumstances of the case.

The new main pumping station contains a pair of 150 I.H.P. compound condensing rotary beam-engines. Each engine works two pumps by means of connecting-rods, one at each end of the beam. The pumps are each capable of delivering 500,000 gallons of sewage per hour when doing full duty.

The rising main leading from the pumping station to the sewage tanks is 3 feet 6 inches in diameter, and about 1,500 yards in length.

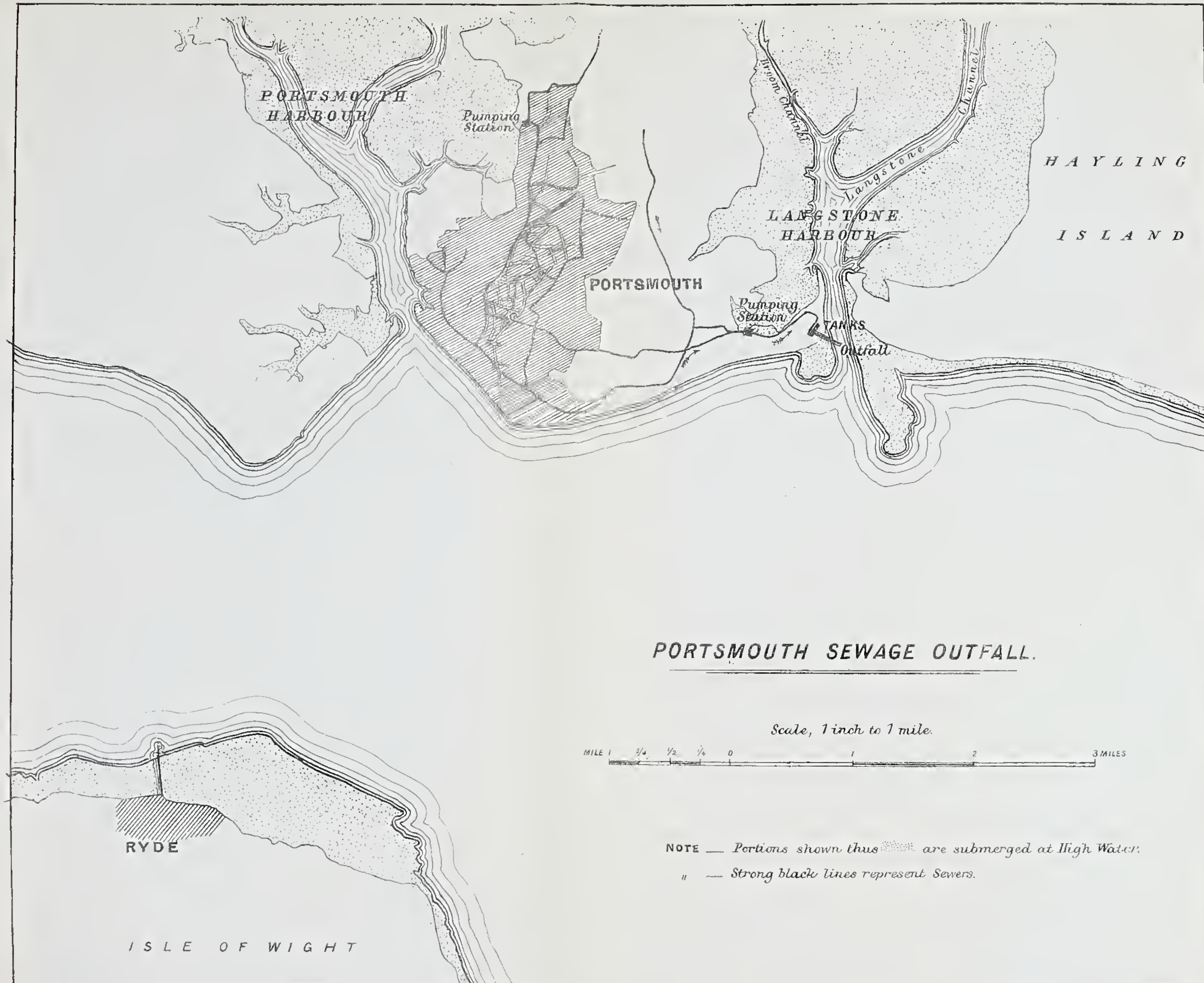
Tanks.—There are three storage tanks, side by side, having a collective capacity of 4,500,000 gallons, and covering an area of $3\frac{1}{4}$ acres. Each tank is 160 feet in length and 150 feet in breadth. As shingle was found in profusion upon the site, the tanks are constructed of concrete, with brick facings; they are arched over and soiled. The inverts of the tanks are segmental in cross-section, with a longitudinal fall of 1 in

150 to the outlets. With the object of allowing their contents to be discharged as soon as desirable after high water, the tanks have been constructed with inverts at a level of 1 foot below ordinary high-water mark. The tanks are provided with sluices at the upper end, in order to admit of part of the contents of a full tank being discharged into an empty one for the purpose of flushing out deposits.

Ventilation of Tanks.—The ventilation of these large tanks is provided by means of twenty-seven fresh-air inlets in the crown of the arch on the shore side of the tanks. Along the land side of the tanks is a flue 4 feet high by 2 feet 6 inches wide, which runs the entire length, and is connected with the under-side of a coke furnace about 3 feet square at the bottom, and enlarged to 6 feet square at the top of the fire. The fumes are passed into a chimney shaft about 100 feet in height.

Rapid Discharge of Sewage.—The rapid discharge of the whole of the impounded sewage is an essential feature of the scheme; the outlets are sufficiently large to admit of all the sewage being discharged into the outfalls, and thence into the sea, within a period of one hour. The tanks first discharge into a culvert 7 feet by 6 feet in size, from which three lines of cast-iron pipes, 3 feet 6 inches in diameter, proceed well into the tide-way, their mouths being just below low-water mark. The arrangements by means of which the large penstocks situated between the tanks and the large culvert are operated, are of an exceedingly ingenious nature. On the arrival of the period when it is desirable to allow the sewage to be discharged into the sea, a small penstock is opened, the escaping sewage operates a turbine which, in its turn, sets in motion the machinery by means of which the large penstocks are opened, thus one man can readily open these ponderous appliances, and attend to the tanks as well.

Obligation not to foul the Foreshores.—The Corporation of Portsmouth are under an obligation to the War Department to dispose of the sewage without creating a nuisance by fouling



West, Newman photo-lith.

the foreshores, and it would be difficult to devise a scheme which would better meet the exigencies of the case.

Up to the point where the sewage enters the sea, the disposal works are similar in principle to many of those established with a view to the purification of the sewage by land treatment. Political economists would probably say that the discharge into the sea of so much fertilising material is a waste of the nation's resources, but the ratepayers of Portsmouth cannot be expected to pay for the recovery of such fertilising ingredients, as they would inevitably be compelled to do, should land treatment be resorted to, merely in order to satisfy the political economist.

Cost.—The pumping station and rising main cost £25,000; the tanks and outfall works £45,000. The annual working expenses at the pumping station amount to £2,450, and at the tanks to £250.

The author is indebted to Mr. H. Percy Boulnois, Mem. Inst. C.E., the late Borough-Engineer of Portsmouth, now Borough-Engineer of Liverpool, for the opportunity of inspecting the works, and for all the details relating to them.

CHAPTER XXXI.

BERLIN.

The Berlin sewage farms have attracted much attention recently, mainly in consequence of the enormous area which has been provided for the purpose of purifying the sewage of the city.

The city of Berlin is divided into two portions by the river Spree; these two areas have, for drainage purposes, been subdivided into twelve separate districts, each with its own pumping station, from which the sewage is pumped to the northern and to the southern farms respectively, the distances of these farms from the city being 6 miles as regards those in the north, and about 12 miles those in the south.

The area of the city is about 24·5 square miles; its population was in 1890, 1,578,800; and its ratable value at the same date was £10,968,000; there were 180,000 water-closets, 25,000 urinals, and 17,000 private baths.

There is an excellent water supply, but as the water is supplied by meter* at a price of 16½d. per 1,000 gallons, when the supply per house does not exceed 17,600 gallons per quarter, for larger quantities the price is reduced to 11d. per 1,000 gallons, its use is much restricted; compared with London, for instance, with its supply of about 32 gallons per head per day, the consumption of water in Berlin is only 13·42 gallons per head. This fact is important from the land-treatment-of-sewage point of view, because sewage is, in dry weather, about equal in volume to the water supply of the town from which it is derived, unless there is much leakage into the sewers from the subsoil, or the sewage is largely augmented in volume by the discharge of water and other liquids from factories, &c. The comparatively small volume of rain water, again, pumped with the sewage to the Berlin sewage farms, shows that the Berlin sewers are amply provided with storm-overflows; for example, the total volume pumped to the farms is not quite 24 gallons per head per day; London, on the other hand, sends at least 40 gallons per head to its sewage disposal works on the north of the Thames, and 50 gallons to those on the south. It must not, therefore, be hastily concluded that because Berlin has solved its sewage problem by applying its sewage to land, that London could as readily do the same.

In 1890, the sewage farms of Berlin to which sewage was regularly applied were as follow:—

On the south—

Osdorf, 3,055 acres,		sewage first applied 1876.
Gross Beeren, 2,362 acres,		,, ,, 1882.
Schenkendorf, Sputendorf, and Klein Beeren,	3,860 acres,	sewage not yet applied.

* "Sale of Water by Meter in Berlin," Gill, *Min. Proc. Inst. C.E.*, 1891.

On the north—

Falkenberg, 2,382 acres, ...	sewage first applied	1879.
Malchow, 3,216 acres, ...	,, ,,	1882.
Blankenfelde, Hellersdorf, } 3,914 acres, . . .	sewage not yet applied.	

Physical Characteristics.—The sewage farms are situated on flat, or slightly undulating, sandy plains, well adapted for sewage utilisation, because of the porous nature of the subsoil, the small expenditure necessary in laying out the land, and the low price at which the land was procurable. The following details refer to the four farms which are used for sewage disposal. The average price paid per acre for the four farms, Osdorf, Gross Beeren, Falkenberg, Malchow, was £40, 10s., very nearly, the gross acreage of these farms being about 11,015 acres. The land was laid out in three different ways, namely, those portions of an undulating character, amounting to about 2,080 acres, were merely surface graded for broad irrigation; an area of about 5,330 acres of more level area was laid out in level terraces and underdrained for treatment of the sewage on the intermittent filtration principle; whilst a part has been devoted to the formation of shallow tanks for use during periods of heavy rainfall, and in times of hard frost. This latter area is about 410 acres, so that about 7,820 acres are used for sewage disposal purposes, whilst an area of about 120 acres was not utilised in 1890. The cost of preparing the land was as follows, the figures being inclusive of levelling, and forming roads, embankments, and effluent channels:—

Osdorf,	2,190 acres, . . .	cost of preparing	£28,770
Gross Beeren,	1,422 ,, ...	,, ,,	19,757
Falkenberg,	1,818 ,, ...	,, ,,	21,103
Malchow,	2,510 ,, ...	,, ,,	25,226

The drainage of the land was carried out after the sewage was applied, and in such a manner as the different character of soils met with demanded. There are a number of open drainage channels running into and through the farms, and the subsoil drains, laid generally at a depth of about 3 feet to 4 feet 6 inches, discharge into these open channels, so that the effluent from any portion of the farms may be readily examined. The subsoil drainage works on the 7,810 acres drained had in 1890 cost £66,590.

The sewage is pumped to the farms from the pumping stations in the city through cast-iron mains, which terminate at the highest points of the various farms, so that the whole of the land is commanded. There are drawing-off valves upon the mains at various points, and the arrangement generally is similar to that to be met with on many sewage farms in this country, there being cast-iron distributing mains laid under the ground which convey the sewage from the pumping main to the various earth carriers and grips.

The total expenses in connection with the purchase and laying out of the land may be thus summarised :—

TABLE XXX.—COST OF SEWAGE FARMS, BERLIN.

Description.		Cost per Acre	
		Of Land Laid Out.	Of Total Area.
		£ s. d.	£ s. d.
Purchase of land,		...	40 10 0
Cast-iron mains,	about	19 0 0	13 10 0
Laying out land,	,,	12 0 0	8 10 0
Draining land,	,,	8 0 0	6 0 0
Incidentals,*	,,	...	4 10 0
Total capital expenditure,		...	73 0 0

Crops, &c.—The comparatively small volume of sewage per head to be dealt with gives a considerable amount of latitude as to the crops that may be grown. We find, for

* Inclusive of sums expended in buildings, implements, and improvements to streams.

instance, that the number of acres employed in the treatment of 1,000,000 gallons of sewage per diem varies from 223 in the case of Osdorf to 403 in that of Malchow, the average of all the farms being 268. The number of persons contributing sewage to each acre varies from 198 at Osdorf to 122 at Malchow, but the limit has been considered to have been reached at Osdorf. At Wimbledon the sewage flow is now about 1,000,000 gallons per day, which is applied to about 74 acres of land; and there are other cases—Birmingham, for instance—where the proportion is about the same, although it should be mentioned that in both these cases the sewage is clarified before being applied to land; still the volume per acre is so large that ryegrass, osiers, and mangolds are within narrow limits the only kinds of crops that can be grown. On the Berlin farms, on the other hand, the largest acreage was in 1890 under cereals, namely, 2,820 acres; grass was grown upon about 1,785 acres; roots and vegetables on 1,013 acres; and oil-producing plants on 237 acres. These details refer to the 5,933 acres farmed by the Municipal Authorities of Berlin, the remainder of the farms are let to a number of tenants, who paid an average rent of 86s. 3d. per acre, whilst ordinary land, not prepared for sewage disposal, was obtainable at 35s. 3d. per acre; we see, therefore, that by the application of the sewage to land from an average number of persons of 156 to each acre, its value is improved by 51s., so that the value of the sewage yielded per head per annum is by this method of calculation about 4d., and curiously enough, this figure compares very closely with the value obtained at Wimbledon, when calculated upon the basis of working expenses and gross returns.

An interesting fact in connection with the Osdorf and Gross Beeren Farms is that relating to the employment of lime, in quantities of from 1 to 2½ tons per acre, in order to accelerate the process of nitrification, which appears to have been interfered with in consequence of the large volumes of crude sewage applied per acre. This fact seems to point to the necessity of clarifying the sewage before applying it to the land.

Financial Results.—The average gross income from the three classes of land during the years 1887–8, 1888–9, 1889–90 may be thus tabulated :—

From the grass plots, ...	£6 18 0	per acre.
,, filtration area, . . .	7 14 0	,,
,, tanks, ...	4 9 0	,,

We have seen that the total cost of the land to the municipality, with its laying out, was £73 per acre; the working expenses are about £5, 10s. per acre, or about £1 per acre less than the returns, so that, broadly, there is a return of £1 per acre towards the repayment of capital and interest account. The farms on the north, however, which are much nearer the city, and, consequently, the markets, than those on the south, show the best financial results, a fact which must not be lost sight of when comparing Berlin with other towns.

Sanitary Results.—From the sanitary point of view, the farms are eminently successful. The sewage is, in the first place, much stronger than average English sewage, because of the small volume yielded per head, due to a relatively small water supply. The following figures show approximately the character of the Berlin sewage :—

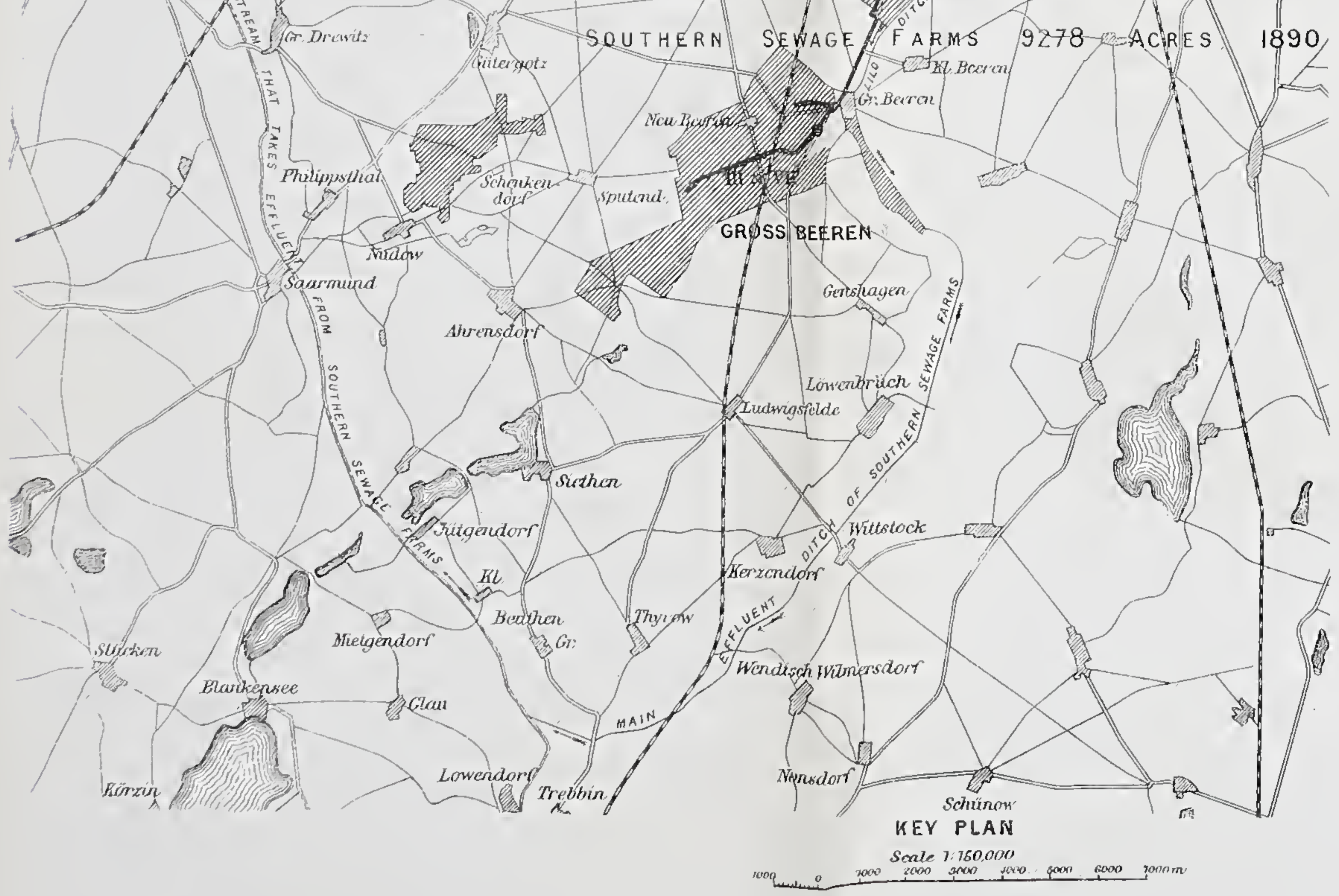
Suspended matters, . . .	111	parts per 100,000.	
Mineral, = 80 } Organic, = 31 }	111	,,	,,
Ammonia, ...	11·8	,,	,,
Chlorine, ...	22·4	,,	,,

Of the ammonia, 98·87 per cent. is removed on the irrigation plots, and 97·82 per cent. on the filtration plots, and as much as 86·12 per cent. from the tank plots, the two former methods showing a high degree of purification.

The general health of the persons living upon the farm—about 1,580 in number—is extremely good, the average death rate for the five years, 1885-9, being only 9·75 per thousand.

The author is indebted to Mr. Roechling, Assoc. M. Inst. C.E., for many of the details given in this chapter, and to Mr.

THE SEWAGE FARMS OF BERLIN.



SEWERAGE & SEWAGE DISPOSAL WORKS OF BERLIN.

AREA OF RADIAL SYSTEMS

	Acres.	Position of Pumping Station.
Radial System I.	674·059	Reichenbergerstrasse 66
" " II	863·009	Gitschinerstrasse 7·11
" " III	963·054	Schönebergerstrasse 21
" " IV.	2117·646	Scharnhorststrasse 9·10
" " V	1996·190	Holzmarktstrasse 31·32,
" " VI	912·124	Urbanstrasse 177
" " VII	1026·504	Genthinerstrasse 4
" " VIII	1515·556	Alt Moabit 67
" " IX	1279·779	Seestrasse Ecke Strasse 10b
" X	1138·653	Bellermannstrasse 7
" " XI	1034·222	not yet determined upon
" XII	726·763	Strasse 47
Total	14,247·559	

AREA OF SEWAGE FARMS

	Acres
Osdorf (for Radial Systems I, II, & VI 2449·192 Acres)	3055·52
Gross Beeren (for Radial Systems III & VII. 1989·558 ")	2362·51
Schenkendorf & Sputendorf not yet sewage farmed	2691·61
Klein Beeren Do	1168·57
Total of Southern Sewage Farms	9,278·21
Falkenberg (for Radial System V. 1996·190 Acres)	2,381·95
Malchow " " " " IV. 2117·646 ")	3,216·62
Blankenfelde (for Radial Systs VIII, IX & X. 3933·988 ") not yet sewage farmed	2851·92
Hellersdorf (for Rad. System XII. 726·763 Acres) not yet sewage farmed	1062·12
Total of Northern Farms	9,512·01
Total of all Farms	18,790·22

LENGTH OF PUMPING MAINS.

	Lengths in miles	Diameter in Feet
Radial System I from Pumping Station to junction piece	2·61	2·46
" " II " " " "	0·60	3·28
" " III " " " "	1·81	2·46
" " VI " " " "	0·79	2·46
" " VII " " " "	1·04	2·46
" " VIII " " " "	3·44	3·28
" " X " " " "	0·43	2·46
" " I, II, & VI from Junction piece to Stand pipe on Farm	7·17	3·28 and 2·46
" " III & VII " " " " "	11·57	3·28
" " IV. from pumping Station to Stand pipe on Farm	8·89	3·28
" " V. " " " " "	4·96	3·28
" " VIII & X from Junction piece to Stand pipe on Farm	5·23	3·28
" " Total length of all Pumping Mains together	48·17 miles	

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Note of Explanation.

- Pumping Main
- Standpipe
- Sluice Valve
- Cut off Sluice
- Effluent ditches
- Outlet of Subsoil drain

Scale of Feet.

E SEWAGE FARMS OF BERLIN.

Hobrecht, the City Engineer of Berlin, for the plans and some of the details, Plate 35. Should the reader desire further information on the subject of the Berlin farms, he cannot do better than consult the paper by Mr. Roechling, printed in the Minutes of the *Proceedings of the Institute of Civil Engineers*, vol. cix., 1892.

CHAPTER XXXII.

SEWAGE PRECIPITATION WORKS, DORTMUND (GERMANY), 1889.

Population, &c.—The town of Dortmund contains about 85,000 inhabitants, and is drained on the water-carriage system, but no fæcal matter enters the drains. The fæces are collected in cesspools and taken away by the farmers and peasants of the surrounding district. In addition to the rain-water the sewers take the ordinary street-water and also the waste liquors from the manufactories. Dortmund contains an immense number of breweries, and the waste therefrom is one of the chief difficulties to be contended with in any attempt to purify the sewage, not only on account of its great volume, but more especially by reason of its disagreeable property of fermenting and giving off bad odours. It is of the utmost importance that the effluent should be as pure as possible, as the brook into which it is discharged only contains a small quantity of water, especially in summer, and has, moreover, a large quantity of mill weirs occurring on its course.

In consequence of the bad odours emanating from this stream (called the Emster), complaints against the Town Council were of frequent occurrence, and in the year 1882 the Government compelled the town to construct precipitation works. These were the first works of the kind constructed in Germany.

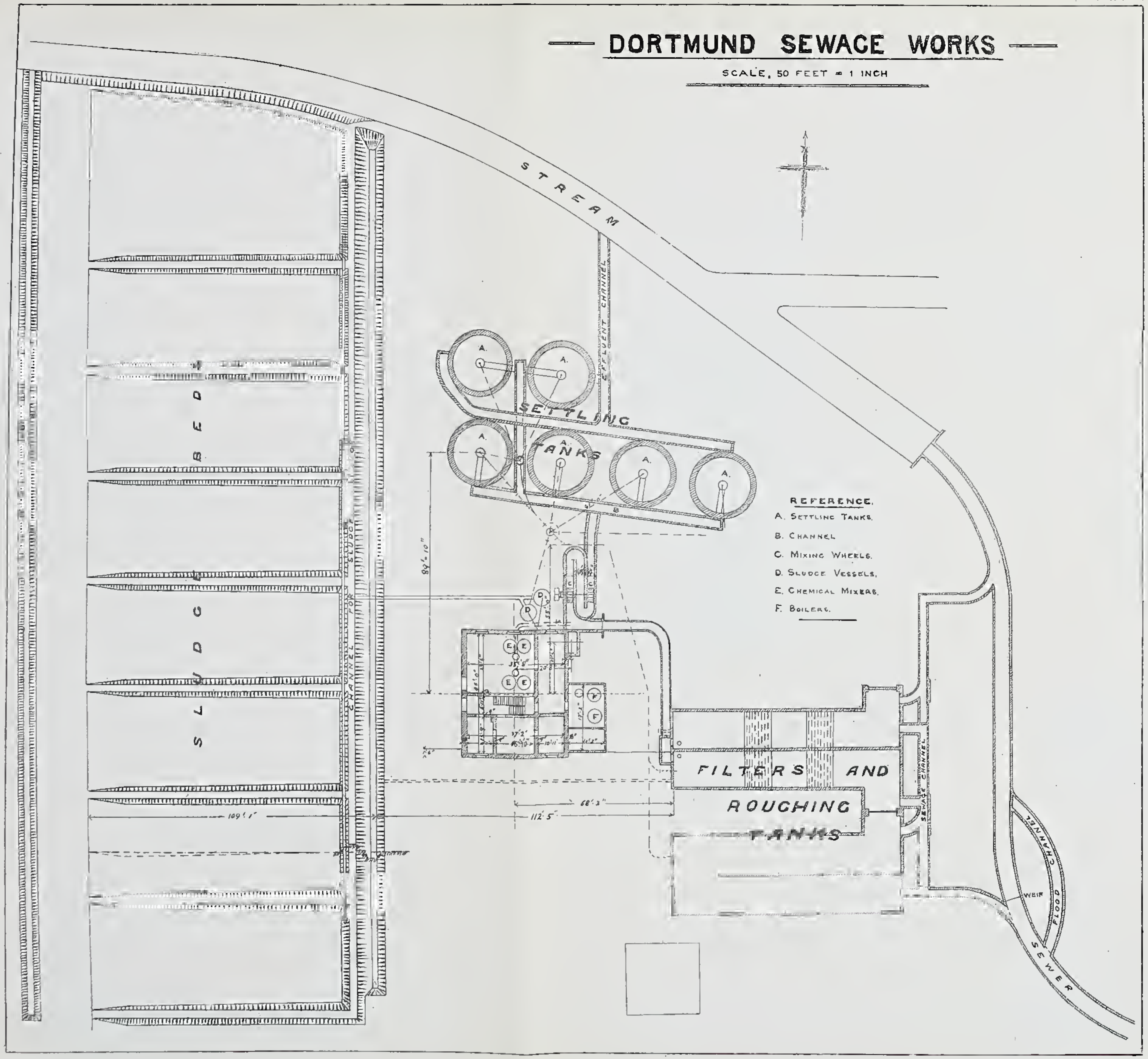
Works.—The works, as first carried out, contained two precipitation tanks, similar in design to those in use in England.

They proved, however, to be too small, and the sludge was a great source of annoyance, it putrefying within a short time, and then rising to the surface. In designing new works it was of primary importance that the remedying of this nuisance should be kept in view and that such arrangement should be made as would allow of the sludge being removed without interfering with the continuous working.

The Röckner-Rothe system seemed to solve this problem, but as its cost was extravagantly high, it was decided to adopt the plan of constructing cylinders sunk in the ground instead of vacuum cylinders. The nature of the subsoil, which consists of so-called "Flies" (sandy mud), seemed to point in this direction.

Treatment.—The old tanks are still in use and serve as preliminary depositing tanks; the sewage being in this way freed from the grosser impurities and floating matter. From the tanks the sewage flows through a winding carrier, where the chemicals are added; the mixing being performed by means of two water-wheels driven from one shaft. The floats of these wheels are made of perforated zinc. As there is very little fall to be obtained at the works, these mixing-wheels are also used to lift the water to the desired height. This arrangement allows of the chemicals used (lime and sulphate of alumina) being added at different points, the sewage, after receiving the lime, being allowed to travel some distance before the sulphate of alumina is added. This is done on the assumption that the action of the lime, from a bacteriological point of view, does its work more effectively in this way than if both were added at the same time.

After the addition of the chemicals the sewage flows through the distributing channel into the inlet pipes of the cylinders and passes down the vertical zinc cylinder to a depth of about 30 feet; it is there distributed throughout the section of the cylinder, and rises gradually to the top. In order to ensure a uniform motion of the sewage at all parts of the cylinder, *i.e.*, to obviate a rush towards the outlet, overflow channels have



DORTMUND SEWAGE WORKS

West, Newman photo-lith

been constructed at the surface into which the clear liquid flows evenly. The action is as follows:—At the lower part of the tank, flocculating matter is formed; this subsides gradually into the apex as sludge, having, however, previously served as a filter for the rising water. In this way the chemicals are, at the same time, utilised to their fullest advantage. The higher the level of the filtering medium is kept, the more complete is the action; in other words, the best results are reached, if the tank is first filled rapidly until the flocculent matter appears near the surface, and the flow is then entirely stopped until this matter has subsided. If the water is again turned on the clarified effluent overflows at the top, and subsequently a new filter is formed.

The results of this mechanical operation are very good. All that is required is to allow a sufficient sectional area and depth. It is advisable to assume a continuous stream, the velocity of which does not exceed 15 feet per hour. This will give the corresponding duration of rest. With perfect rest, as is well-known, almost complete precipitation takes place.

During the period of rest the removal of the sludge is effected, because at that time it is less liquid than during the inflow of water. The sludge is raised pneumatically through wrought-iron pipes 6 inches in diameter, which are connected with two receivers, fixed above the water level. These receivers are exhausted by means of an air-pump driven by the engine, and thus filled with sludge. The filling and emptying of these receivers is accomplished automatically by means of single-acting ball-valves closing in opposite directions. The only manual labour required is to turn the two air-cocks in the suction pipe (three-way cocks with one opening to the external air). While one receiver is being emptied of sludge, the other is exhausted; when it is filled with sludge the three-way cock is turned so as to admit air, and the sludge flows out automatically. It is then conveyed by means of wooden carriers to sludge-drying beds. Here it remains until it is sufficiently compact, and is then sold. Up to the present time the whole of the sludge has been sold to farmers at a nominal rate of about 2d. to 2½d. per ton.

The chemicals are prepared in very nearly the same manner as at other places. In the upper part of the building there are pans in which the lime is slaked, and large vats in which the sulphate of alumina is dissolved by means of steam. In the lower part of the building the mixing-vats are placed, together with a hoist for chemicals, &c., and a centrifugal pump for lifting the sewage to a projected private irrigation-farm. The engine and boiler have been designed of sufficient power for this purpose. The engine is of 14 H.P., whilst only about 5 or 6 H.P. is required for the ordinary working.

The volume of sewage having increased in consequence of the increase in the population, it has been decided to enlarge the works, and two additional cylinders are now being constructed, which will shortly be working in conjunction with the four existing ones. Each cylinder will clarify about 700,000 gallons per day.

Two points are necessary for the satisfactory working of this system—

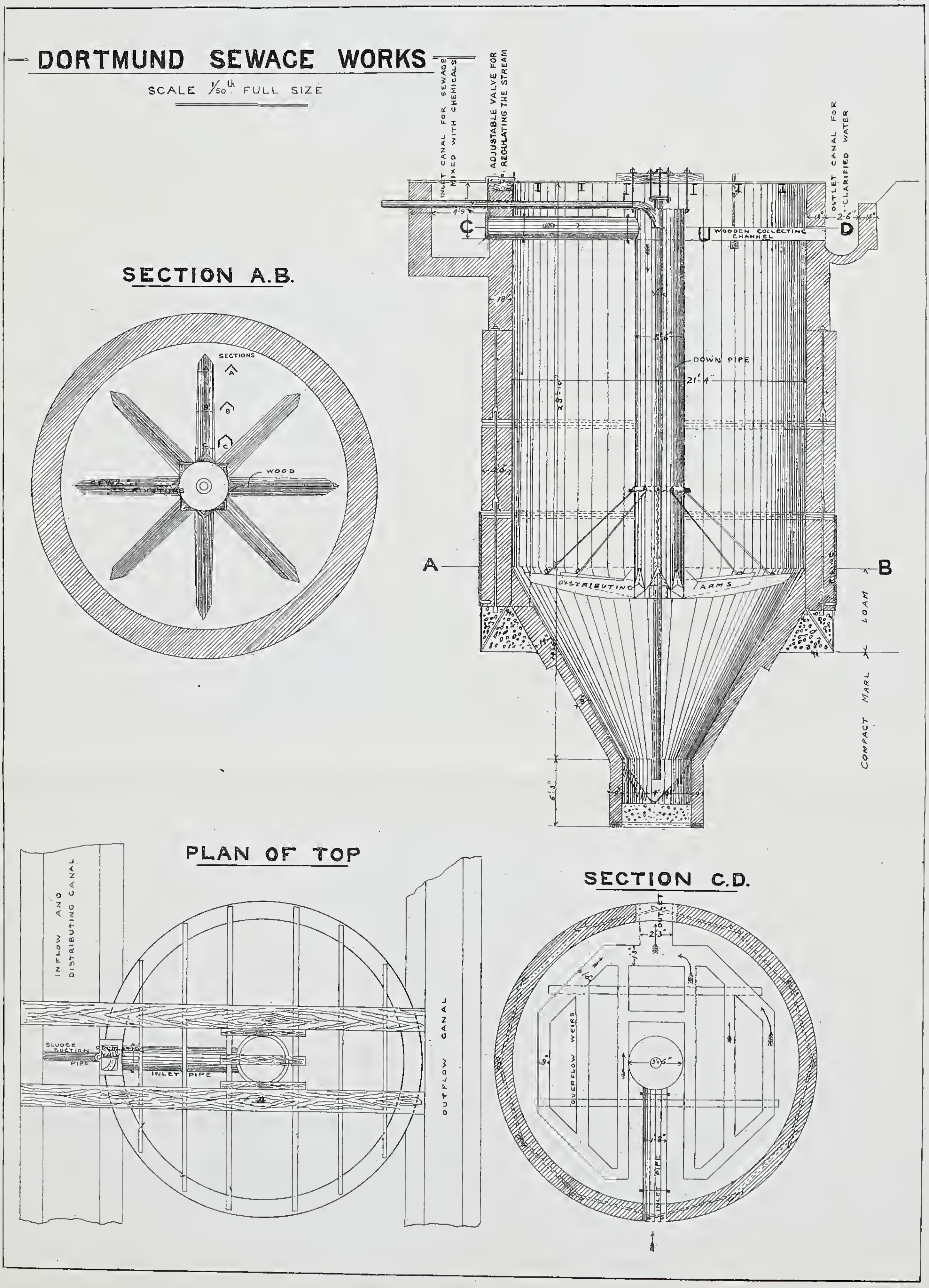
1. All floating matters and *heavy particles* must be kept out of the cylinders by means of screens or tanks.
2. The sludge must never be allowed to accumulate in the cylinders and get old.

If these points are attended to, the system is said to work smoothly and without trouble.

Cost.—The cost of the works (exclusive of the old tanks, which cost £1,250) was £5,000, the two cylinders now being constructed will cost an additional £1,500.

This special system of cylinders has been patented in the German Empire.

The author is indebted to Herr C. Kniebühler for the details of this interesting and novel system of sewage clarification. See Plates 36 and 37.



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CHAPTER XXXIII.

TREATMENT OF SEWAGE BY ELECTROLYSIS.

The Webster Process.—Of all the systems of sewage-treatment yet introduced, that by Mr. Webster may fairly be said to be one of the most promising. When it is considered that the application of electricity is almost daily extended to new objects, and that the science is, as yet, in its infancy, it must be admitted that the results achieved by Mr. Webster are of the most encouraging nature.

The time may come when our towns will be lighted with electricity by night, whilst by day the dynamos will be employed in purifying the sewage; then the loading of the sewage with chemicals, with the consequent production of large masses of sludge, will no longer be necessary.

The author is satisfied that the principle is correct; the difficulty lies in its application. But this difficulty can be overcome, and will be, as far greater ones have been in the history of modern science.

The following account of the process is by Mr. Webster, F.C.S.:—

"It may be that scientific knowledge is not sufficient at present to entirely and finally deal with this question. We should, however, aim at as high a standard of purification as possible—it is of no use to try half measures—and whatever the treatment may be, the nearer Nature's action is approached, the nearer will be the solution of the difficulty.

"**Oxidation.**—The oxidation of organic matter can only be attained by one mode—chemical action—whether it be by filtration accompanied by the action of micro-organisms, the addition of chemicals, or by mechanical force represented by the electric current.

"**Characteristics of Town Sewage.**—Sewage is a most complex compound, whose component parts depend upon the water-supply of a town; in some cases upon the rainfall and the industries of the locality. Householders and owners of factories would much assist local authorities in the end aimed at if they would disinfect their refuse before it passes into the sewers; thus, one of the most objectionable features to be noticed in London sewage is the large amount of organic matter with an obnoxious odour, floating on the surface. Its source is uncertain, but it is evidently of a nature that points to gas-works or tar-distilleries, also certain dye- and tan-refuse, which require more treatment than sewage itself. The manufacturer is at a loss where to put his waste-products, and it is an extremely difficult question for the public to solve; but it is a moral certainty that, if the sanitary authorities of our cities and towns have to purify their sewage, the taxpayer will decline to pay for the treatment of manufacturers' refuse, when it is known that sewage alone requires very much less expenditure on purification than when it is mixed with complicated waste compounds of a chemical nature.

"Most of the methods of sewage-treatment hitherto tried have not only failed to meet reasonable expectations as to their physical and sanitary characters, but they have also proved, in many cases, costly failures.

"**Iron Salts.**—It was while working with perchloride of iron as a purifier of sewage that the importance of iron salts in relation to organic matter became apparent; and it was in connection with this chemical and free chlorine gas, that the idea of electrolysis suggested itself.

"**Effect of Electrolysis.**—The chemical changes that take place in sewage when it is electrolysed, depend chiefly on the well-known fact that water as well as sodium, magnesium, and other chlorides (which are always present in sewage), are split up by the electric current into their constituent parts. Thus, we have at the positive pole chlorine and oxygen set free, and these elements are liberated in a nascent state, a condition in which they are intensely active, so that the organic matter in the sewage is rapidly oxidised into innocuous compounds. So rapidly is this action that, provided the sewage contains a sufficiency of chlorides, it is possible to produce a disinfecting fluid from it consisting of oxides of chlorine.

"The first experiments were made with platinum plates, but the experience was that the cost of platinum put its use out of the question, besides which, there was a very slight action on the positive plate, which distinctly pointed to its ultimate destruction. For the treatment of sewage it is absolutely necessary that precipitation of the matters in suspension should take place, and the more complete this is the better the ultimate result. After a long series of experiments in the laboratory, it was found that oxidisable plates produced the desired result. These plates should be of such material that they shall have no poisonous after-affects either on land or in rivers. The metal should be either aluminium or iron; the first-named is out of the question owing to cost, but iron, besides having the advantage as regards price, in the form of oxide has many valuable qualities, one of the chief being that sulphuretted hydrogen cannot exist when ferrous or ferric oxides are present. It is well known that oxide of iron, in the hydrated form, is largely used for purifying coal-gas from sulphuretted hydrogen. After many months of exhaustive experiments, carried out on a large scale at Crossness, it has been conclusively proved that cast-iron plates of the commonest quality, employed as electrodes, give the best result.

"**Electrical Action.**—The electric action is easily explained. At the positive pole the chlorine and oxygen given off combine with the iron to form a salt which is doubtless for the moment a hypochlorite of the metal, but it immediately changes into a chloride, which in its turn is deprived of chlorine to form ferrous carbonates and oxides. During the chemical action, carbonate of iron exists in solution, and its formation is due to the presence of carbonates in the sewage, chiefly carbonate of ammonia. In samples that are absolutely free from dissolved oxygen, the ferrous oxide in the white form is precipitated, and on shaking it up with air it changes to the usual pale-green colour; the carbonate of iron at the same time being oxidised, the ultimate red precipitate is known as ferric oxide, Fe_2O_3, and sometimes this changes, after a time, back again to the ferrous state, FeO, thus showing that it has acted as a carrier of oxygen to the organic matter present. On a small scale the precipitate is carried to the top, due to the bubbles of hydrogen collecting round the particles of matter in suspension, but it ultimately sinks in the usual manner. In practice the precipitate does not rise, owing to the larger evaporating area, which allows the escape of the gases produced. The current required for the action varies with the nature of the sewage. It is usually assumed that 1·5 volts are required for splitting up water into its component parts; this may possibly be true with carbon plates, but with iron plates acting on sewage the same result can be obtained with ·9 volt as with double the intensity; of course it takes a longer time, for with such a low voltage the quantity of current is small.

"**Current Required.**—An ordinary sample of sewage requires, on an average, one ampere of current for 10 minutes per gallon, but when mixed with foreign matter, such as manufacturers' waste-products, the amount required can only be ascertained by experiment.

"**Care of Plates.**—The plates themselves should always be kept under water, so as to prevent the formation of the red oxide on the surfaces, and the action should be continuous as far as possible, for if continuons, the plates seem to acquire some property which reduces the resistance to the electric current, and therefore lessens the cost. At the beginning of a month's run, which lately took place, the voltage measured across certain plates was 3, but after a few days only 1·79, when doing the same work. On examining the plates freshly taken from the liquid they were in, a thin coating of the black or magnetic oxide of iron was found, which has the property of preventing the rusting of the plate under water when the electric current is cut off.

"**Screening.**—The sewage to be treated should, of course, be screened in the usual way, and then allowed to run through the plates, so that every molecule shall come into contact with the surfaces of the metal.

"**Plant.**—For 1,000,000 gallons sewage flow in 24 hours, the complete plant necessary is:—Engine-, dynamo-, and boiler-house; two engines and boilers, each 12 horse-power nominal; two dynamos; brick shoots with culverts at side; two settling tanks; sludge-tanks; sewage culvert; treated sewage culvert; cast-iron plates, copper conductor, measuring instruments.

"**Electrodes.**—By actual experience we have been able to prove that at least 25 sections of electrodes should be in series, and across any one of these sections the potential difference need not be greater than 1·8 volts, the current being of any desired amount, according to the surface of plates used. In experiments lately carried out, a current of 370 amperes was used, which was calculated as ·23 ampere per gallon per hour; or, taking it in watts, the estimated horse-power required per million gallons in 24 hours was 26. These figures have been checked by Dr. John Hopkinson. The organic matter in solution of the particular sewage acted on upon this occasion showed a reduction of 61 per cent. after treatment. In other cases a purification of as much as 87 per cent. has been obtained. If a lesser purification be sufficient, it would mean a reduction of horse-power, as, during another run that lately took place, the measurement across the electrodes proved that 19 estimated horse-power was sufficient to treat 1,000,000 gallons in 24 hours, the resulting purification of organic matter in solution amounting to 50 per cent.; the waste of the iron plates showing an average of 2 grains per gallon of sewage treated.

A channel should be kept at the bottom of the electrodes for the collection of the silt, with a culvert at side to flush it into, so as to prevent any block occurring. The advantage of this is obvious. The plates in each section are about an inch thick, and can be of any length up to 6 feet. It may possibly be objected that a large number of plates is required. This may be so, but the larger the number of plates the less the engine-power required, and the longer they last. In each section the electrodes are in parallel, and any one section is in series with the other, the arrangement being exactly like that of a series of primary battery cells.

"In putting down plates for the above quantity of sewage, it would be as well to allow in them sufficient weight for five or ten years' consumption; what remained of this could be sold as 'old iron' at the end of that time. One of the advantages of having the plates in series is that if anything goes wrong in any particular section, it can easily be set right, the current being cut off during the repairs. The shoot containing the electrodes should be coated inside with some sort of asphalt, so as to prevent, as far as possible, any leakage of current to earth, the asphalt acting as an insulator. The highest efficiency would be obtained by using direct driving, provided that the engine is of first-rate workmanship, and the dynamo constructed to run at a comparatively low speed. This saves in transmission, and prevents any difficulty that might arise with belting. Consumption of coal under the best conditions may be taken to range from 1·8 to 2·5 lbs. per horse-power per hour; the cost of fuel and iron varies so much in different districts, the prices in London being nearly double those near mining localities, that no accurate estimate can be made of the working expenses, as these will depend upon the locality. Discounting this, it may be taken that the capital outlay necessary for complete plant, and capable of dealing with the sewage of a small town, amounting to a flow of 1,000,000 gallons daily, would be about £6,000 or £7,000, the engines and dynamos being in duplicate, as most engineers would agree they should be. The quantity of iron plates included in the above sum would be serviceable for ten years, as far as one can foresee, and it is also assumed that the town where this plant would be erected has no appliances for treatment, such as precipitating tanks, &c.; where these are already in existence the cost would naturally be less. In reference to the cost per million gallons, the same arguments hold good as to the situation of the town ruling the price. Since the first calculations were made, the rise in the markets has increased the cost of working; but it can be arrived at by the average consumption of iron, and the necessary horse-power. Thus, the daily waste of iron may be taken as 286 lbs. per million gallons, and the consumption of coal three-fifths of a ton; the labour required for working a plant of this description would be two shifts, two men to each shift.

"**Effluent.**—The effluent produced by the above process contains about 3 grains per gallon of suspended matters, which consist almost entirely of oxide of iron, which is quite innocuous. Where this is objectionable from a sentimental point of view, it can be entirely removed by filtration through a few inches of sand. Where an even higher degree of purification is required, for instance, when the effluent has to be run into a trout stream, it is possible to produce any further degree of purity required by passing it through an electric filter, which is arranged as follows:—

"**Filters.**—Alternate layers of small coke, free from sulphur, are separated, either by layers of sand or perforated tiles; by suitable connection these beds of coke form positive and negative electrodes—the first layer of material being sand, so as to mechanically separate matters in suspension. It is impossible for disease germs to propagate, owing to the nascent oxygen and chlorine produced when the filter is in action. The oxygen given off in the pores of the carbon also prevents the filter from choking.

"In this case, the sewage, after action with the iron electrodes, is allowed to flow into a settling tank, and after remaining there for an hour or longer for the precipitate to subside, the effluent is passed through the filter, any oxide of iron that may be present tending to keep the top layer of filtering medium free from any objectionable action, and in its turn forming a filtering medium.

"**Report by Sir H. Roscoe.**—Sir Henry Roscoe has investigated this process, and the following are a few extracts from his report. He states—

"'The quantity of sewage operated on in each experiment was about 20,000 gallons.

"'The reduction of organic matter in solution is the crucial test of the value of a precipitating agent, for unless the organic matter is reduced the effluent will putrefy and rapidly become offensive. I have not observed in any of the unfiltered effluents, from this process, which I have examined, any signs of putrefaction, but, on the contrary, a tendency to oxidise.

"'The absence of sulphuretted hydrogen in samples of unfiltered effluents, which have been kept in stoppered bottles for three weeks is also a fact of importance.

"'The settled sewage was not in this condition as it rapidly underwent decomposition in two or three days, even when in contact with air.

"'By this process the soluble organic matter is reduced to a condition favourable to the further precipitation by natural agencies.'

SIR HENRY ROSCOE'S ANALYSES.

No.	Percentage reduction of oxygen required to oxidise organic matter.	Albuminoid Ammonia.
1.	67·4	57·0
2.	64·3	57·3
3.	77·2	75·0
4.	72·6	50·0
5.	76·5	87·5
6.	73·0	87·5

"**Land.**—In cases where specially-prepared or suitable land of a porous nature is procurable, the treated sewage might be wholly or partially used for manuring crops, in which case the sewage should be only so far treated that the prevention of putrefaction is assured.

"The advantage of iron in the soil is one that every practical man must acknowledge. As a proof of this, some sludge (deposit after electric treatment) was pressed without the addition of lime, and it was applied to vegetables, the result being that a marked difference in favour of iron manure was shown in the crops when compared to others grown with ordinary farmyard manure.

"**Sludge.**—With regard to the question of sludge-disposal it is suggested that, where practicable, the sludge should be puddled with chalk, and run on to waste lands through wooden conduits, similar to the process of mixing clay and chalk in a washing-mill and running into backs, as carried out in cement manufacture; the only alternatives being filter-pressing, digging into land, or shipping out to sea.

"**Biology.**—The bacteria question is one which has probably still to be settled, but in order to obtain some information as to the action of the iron compound produced by electro-chemical decomposition, some experiments were carried out, with the result that after a given treatment the whole of the bacteria were killed. In the case of experiments carried out in Paris, with ordinary treatment by means of iron electrodes, the results were as follows:—

	Raw Sewage.	Effluent.
Organisms per cubic centimetre, . .	5,000,000	600

"Another experiment in which the effluent was treated still further, so that a slight odour of oxide of chlorine was perceptible, destroyed all organisms, and the liquid remained sterile.

"**Conclusion.**—In conclusion, it is submitted that the application of the electric current in the several ways described produces a precipitating and oxidising action similar to natural processes, in which the organic matter is destroyed by oxidation due to dissolved oxygen slowly absorbed from the air, assisted in many cases by matters in the soil, such as oxides of iron, acting as carriers of oxygen, and it is also stated that the question of cost will bear favourable comparison with any process which really does the work attributed to it."

Note.—The process has been tried on a large scale at Salford, and the results attained fully bear out the statement in the last paragraph.

Electricity has recently been employed for sewage treatment by M. Hermite at L'Orient, France. The *Engineer* of January 5, 1894, contains a reference to this system in the following terms :—M. Hermite's plan "consists in the employment of electrolysed sea-water. This agent, when mingled with the sewage, is said to effect complete purification, accompanied by the entire destruction of the microbes. Electricity in this case operates less directly than in Mr. Webster's method, and the latter has the advantage of not requiring sea-water, the operation taking effect at once on the sewage, without any intervening compound."

As seen by the author in operation at Worthing, sea-water was being pumped through an electrolyser, which charged it with chlorine gas derived from the chlorides in the water. The electrolysed sea-water charged with the gas to the extent of about half a gramme per litre, or about 35 grains per gallon, was then laid on to the water-closet flushing cisterns of a row of cottages, and it was then used in lieu of ordinary water.

Whatever advantages the system might possess from the sanitary point of view, and these are doubtless many, the great bar to its adoption in this country is the fact that a dual system of water mains and domestic fittings is necessary to its application. Then there are difficulties in connection with the law relating to water-supply to be surmounted, and these again are sufficiently formidable in themselves to restrict materially the adoption of the system.

The author was informed by Mr. Cooper that the method of disinfection could be applied at the outfall of a sewerage system, when the quantity of electrolysed sea-water of the strength mentioned required for treatment of the sewage would be about 10 per cent. of the daily flow; but from the commercial point of view, it would be cheaper in that case to charge the sea-water with 2 grammes of chlorine per litre, when 2½ per cent. only would be necessary.

Obviously, the system is, at the present moment, in the experimental stage only, and it is too early to give results that would be of practical value.

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THE END.

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