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REPORT

ON

THE MEANS

OF

DEODORIZING AND UTILIZING

THE

SEWAGE OF TOWNS;

ADDRESSED TO THE

RT. HON. THE PRESIDENT OF THE GENERAL BOARD OF HEALTH,

BY

HENRY AUSTIN, C.E.,

CHIEF SUPERINTENDING INSPECTOR OF THE BOARD.

Presented to both Houses of Parliament by Command of Her Majesty.

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REPORT

ON THE

MEANS OF DEODORIZING AND UTILIZING THE SEWAGE OF TOWNS.

To the Right Hon. William Monsell, M.P.,
President of the General Board of Health.

Sir,

During the past eight years, in which the sanitary improvement of populous towns has occupied the attention of Local Boards of Health, acting in execution of the Public Health Act, 1848, consideration has been almost exclusively directed to two great evils which pressed peculiarly for immediate remedy,—imperfect drainage, and the want of water.

The earliest inquiries into the causes of the great mortality of urban populations had established the fact that collections of decaying matter, within towns, were among the chief sources of disease, and that among these accumulations the contents of the cesspool were the most dangerous.

It is not surprising, therefore, that the first endeavours of local authorities should have been for the removal of this chief cause of disease from amidst habitations.

In many towns this work has been thoroughly accomplished, and there for the most part the authorities have rested, as if all sanitary improvement began and ended with it. But Nature's laws allow of no such halting. The mere removal of the decomposing mass is but a shifting of the mischief. The great cycle of life, decay, and reproduction must be completed, and so long as the elements of reproduction are not employed for good, they will work for evil.

It would argue very little acquaintance with the principles of sanitary laws, if local authorities really considered their duties complete at this point of their labours. The disposal of town refuse for the purpose of fertilization, has been so often urged that even these few remarks on the subject may seem superfluous. Reasons must be sought for the apparent apathy which has hitherto reigned on this point. Ignorance cannot be pleaded. Obviously the doubts and difficulties which have hitherto surrounded the question have stayed its practical solution.

The evil, however, of the present mode of dealing with the question—or rather of not dealing with it, by allowing the refuse of towns to poison the neighbouring streams is great beyond anticipation. Most of the refuse of houses having been hitherto chiefly stored in cesspools, the state of drainage-outfalls, nuisance as they were, served only to mislead the judgment as to the probable effect of complete drainage.

It is, perhaps, fortunate that the magnitude of the evil must lead to its cure. Independently of the detriment to life and the waste which result from the present state of things, the law courts have decided that local authorities have not the power to increase the pollution of streams, to the injury of individual rights,—to rid themselves of a nuisance by sending it on to their neighbours. Thus, the outfall of drainage becomes at this time the great and pressing difficulty of the sanitary question; and that difficulty appears to arise mainly from the fact that the sanitary and agricultural aspects of the matter are somewhat at issue.

On sanitary grounds, it has been determined that water supplied the best means for carrying off the great body of noxious refuse from the site of towns. But this very mode of removal deteriorates the value of the material as a manure; so that some persons, who ignore all the sanitary bearings of the question, are of opinion that the actual system of town drainage is wrong in principle; that the cesspool and separate collection of the manure should have been adhered to.

How far this view is correct, even upon economical grounds, it is not for me now to consider. The sanitary question is paramount; and the means of the removal of the refuse are, in this report, regarded as fixed.

The point, as I conceive, to be determined is the best practicable mode of rendering outfalls of drainage innocuous, and of realizing from sewage, diluted as it is, the highest possible value.

No practical difficulty stands in the way of complete removal of all nuisance at outfalls, except the expense. Well-known disinfectants could be successfully employed for removing, at any rate to a great extent, the noxious properties of sewage.

Some of these disinfectants, although efficacious as sanitary agents, destroy or impair the value of the sewage as manure, and their use would add largely to the already heavy expences of drainage.

Were this sacrifice necessary for the preservation of the public health, the prudent course, even on the ground of economy, would be to submit to it; but other ingredients, equally effective as disinfectants, are found not to interfere with the value of the sewage for manure.

The problem for solution is, while accomplishing the sanitary object, how best to realize the agricultural.

Water is the vehicle in which the fœcal refuse of towns is now conveyed away. If the same means of conveyance could be conveniently and beneficially used at all times, and under all circumstances, to carry the manure on to the land where required, or if, after bringing the manure to the outfall, the water could be got rid of and the excrementitious matters separated, with all their original constituents, there would be no longer any difficulty in the question; sewage would have its fixed and decided value wherever manure is wanted, which would go far to relieve the inhabitants of town districts from all the expense of sanitary improvement.

But neither of these methods of realizing the value of sewage is at all times practicable. The practicability of application by water depends on the levels and character of the surrounding country, the seasons, the nature of the soil, the water supply, the rainfall, the crops, the proportion of land available for liquid sewage, and the various interests in the property. The separation of the sewage from the water, is involved in still greater difficulty. The solid may be precipitated, but the valuable ingredients of the sewage are held in solution in the water, and no chemical process—it is said by those authorities who have given the greatest unbiassed attention to the subject—has yet been made available for their separation.

It remains to be considered what proportion of the total value it may be practicable, under ordinary conditions, to realize by either of these methods of use, or by a union of the two.

Much attention has now been given to both these divisions of the question for some years. But the subject is still too recent to admit of fixed rules being laid down. Means, however, exist for correcting both the views of the over sanguine and zealous, and those of the incredulous and the prejudiced. Having had the honour to receive the instructions of the late President to make such inquiries and collect such evidence as may serve for the guidance of Local Boards under the difficulty which so urgently presses upon them, I now congratulate myself that the duties which devolved upon me, when acting as Secretary to the first General Board of Health, prevented my taking part in the inquiries into this subject which were then conducted, as this enables me to bring an unbiassed mind to the consideration of the subject.

I have necessarily travelled over some of the same ground as previous inquirers; and where I have not been able to arrive at the same conclusions, I trust that the reasons for the disagreement will be found sufficiently explicit.

In setting forth the result of my inquiries, both chemical and agricultural questions are necessarily brought under consideration; but I wish to guard against any impression that I give any opinion of my own on either class of questions. Wherever they are involved, I have endeavoured to satisfy myself, and support my conclusions, by reference to the highest authorities.

With these preliminary remarks, I beg to lay before you the following Report, merely adding that it should be read as having especial reference to the smaller class of towns. The principles of action being admitted, it becomes an important question in what way they can be made applicable to places of the largest population. The difficulty will be in bringing them practically to bear in towns which can afford but little outlay, and to such towns, therefore, the remarks and suggestions which I have to offer are chiefly directed.

To facilitate reference, I have divided my Report under the following heads :—

1st. The constituents of sewage and their value, as far as the hitherto inadequate examinations and analyses will allow of any safe calculation of value ;

2nd. A description of the chief processes which have been adopted for deodorizing sewage, and for manufacturing therefrom a solid manure ;

3rd. A description of the means hitherto practised for the application of sewage to agriculture in the liquid form;

4th. The agricultural results of these various processes ;

and I have ventured to add recommendations of the means which appeared to me, in the present state of the question, best calculated to realize the value of sewage, while securing the removal of all danger to the PUBLIC HEALTH.

CONSTITUENTS OF SEWAGE.

The sewage of towns consists of the solid and liquid excrements of the population, the ingredients of soap, the refuse from kitchens, the drainings and washings from markets, stables, cow-houses, pigstyes, slaughter-houses, &c., the refuse drainage from many factories and trading establishments, the washings of streets and other open surfaces.

It would be difficult at present to obtain precise data for determining the value of the sewage of towns. This is a point which demands much more searching investigation than has hitherto been given to it. A long series of examinations would be necessary to arrive at an average in any one town. The quality must be tested at various times of the day, for the drainage of house refuse is much greater at one period than another, and the discharge from factories frequently takes place at particular hours. Different days again will show great variation. The house drainage will be greatest on Saturday, least on Sunday, and market day in many places will add perceptibly to the discharge at the outfall. Again, the rainfall would demand separate consideration. A moderate fall of rain after dry weather may actually increase the usual proportion of manuring ingredients, by washing down deposited matters, while a heavy discharge may so add to the dilution of the sewage after the first flush as to render the whole worth little.

Moreover, no such series of observations for any one town would form a safe general guide. Material differences would be found in towns having respectively a larger proportion of old or of new drainage works. In many of the former, much of the solid matter is deposited along the course of the drains, and the flow being sluggish, decomposition is far advanced, and gases are discharged, before the outfall is reached. In many of the latter the discharge is found to be so immediate that solid excrement is not even disintegrated.

In towns of rich and of poor population the quality of the sewage may also materially differ. Speaking of the excess of animal food consumed by the classes in easy circumstances, Professor Way says, "the nitrogen of this food is discharged in the fæces, which are probably therefore much richer in this element than that of the working community." A speculation has been cited in which a favourable result was obtained from the manufacture of manure from the refuse of a rich establishment, which failed with that of a poor one. The value of the refuse of Belgravia would, no doubt, exceed that of Bethnal Green.

The sewage of a manufacturing town would vary much also from one with a non-manufacturing population. The sewage of Manchester and Bradford would scarcely be identical in its constituents with that of Brighton and Bath.

Even times of commercial prosperity and depression must, in many towns, cause a material change in the nature of the sewage. In the manufacturing towns of Lancashire,—indeed in all towns dependent chiefly on their factories,—both the quantities and quality of the discharges must vary to a great extent in proportion to the manufacturing activity of a period.

Again, and especially, the difference of water supply, both in quantity and quality, the amount of rain-fall, the comparative completeness of drainage arrangements, and the proportion of subsoil water carried off by the sewers, would seriously affect conclusions on this point.

The value of the sewage of a town can only be determined from a series of analyses of that sewage.

Except in one particular, no general calculation can be made of the amount and value of the various refuse ingredients discharged. The exception is the solid and liquid excrements of an average of the population, which, doubtless, constitutes the most valuable portion of the sewage.

Considerable attention has for a long time been given by physiologists to the determination of the chemical constituents of human excrement, and renewed researches have more recently been made by chemists with especial reference to the utilization of sewage.

Professor Voœlcker states, in Morton's Cyclopædia of Agriculture, that the three classes of constituents on which the commercial as well as the fertilizing nature of all manuring matters chiefly depends, are, 1st, ammonia, and organic matters furnishing ammonia on decomposition; 2nd, soluble alkaline salts; 3rd, phosphates. And that "of all the natural manures obtained in this country, human excrements contain a much larger proportion of ammonia, or organic matters which furnish this valuable compound on decomposition,—more alkaline salts, especially salts of potash,—and a larger proportion of phosphoric acid, than either the excrements of the horse, cow, sheep, or pig."

Mr. Bennett Lawes, in the valuable paper read before the Society of Arts in 1855, gives an elaborate series of Tables, embodying the conclusions arrived at by various authorities from analyses of the food consumed by various classes at different ages, from direct experiments on human respiration, and from analyses of excrement. The general result deduced from these extended inquiries, is that the total dry substance of the excrements voided each day amount for the average of both sexes at all ages to 2·01 ounces, or 965 grains per head per day, or nearly 46 lbs. per annum.

There appears to be no question that of the various constituents comprised in this amount the nitrogen is the most valuable, and of the total dry solid per day ·35 of an ounce or 168 grains are nitrogen, being equal to 17·4 per cent. of the whole.

Professor Way gives the result of two examinations on the subject, in an important article on the "Use of Town Sewage as Manure," in the Journal of 1854, of the Royal Agricultural Society of England, in which the average total dry substance is estimated at 1,057 grains, and of this quantity 141·25 grains, or 13·3 per cent., are nitrogen.

Dr. Angus Smith, in a Table furnished to the first General Board of Health, gives 8,269 lbs. as the annual weight of the excretions of 100 adults, of which 2,312 lbs. are nitrogen. These quantities give 1,585 grains as the total dry substance per head per day, of which 443 grains, or 27·9 per cent. are nitrogen.

The nitrogen in this calculation is considerably in excess of the two cases previously cited; but the total solid is not so much so as at first sight appears, for on referring to the details of Mr. Lawes' table, the dry substance and the nitrogen of the excrements of children, so far as they were examined, are seen to be little more than half that of adults. And the average of dry substance from adults is 2·635 ounces, or 1,265 grains per day.

The actual value of the chemical constituents of the dry substance of the excrement of each individual, amounting to 46 lbs. per annum, Mr. Lawes estimates at 6*s*.

Beyond this, there appears to be no trustworthiness in any calculation made up to this time of the value of sewage. So far indeed as the examination of the sewage itself of different places has extended, an attempt to arrive at any conclusion seems to be followed only by contradiction and uncertainty.

The Rugby sewage in dry weather is now said to amount daily to 160,000 gallons, from a population of 7,000, or 23 gallons per head. Cesspools being now entirely abolished, the solid substance of the fæcal matter alone of the population conveyed in this quantity of water would amount to 1 in 1,669, and would contain, according to the above calculation, 7·3 grains of nitrogen per gallon. In an early sample, however, examined by Professor Way, only 2·96 grains of ammonia were found. In a sample from another completely drained town, Croydon, only 0·92 grains of ammonia per gallon were found. In this latter case, an immense waste of water and a large body of subsoil water were originally drained to the outfall, and in both cases the quantity of suspended matter was said to be insufficient for examination.

The only criterion of value which has yet, for the most part, been determined is the amount of solid matter in suspension and solution in the sewage,—of itself a most uncertain guide to its value.

Mr. Walker, who leases the sewage of Rugby, calculates that he obtains 1 ton of solid matter in 50,000 gallons, being at the rate of 1 in 223! This quantity, however, was determined by one trial only, on a small scale, by precipitation with lime, in which there would clearly be a large element of error.

A sample of the Leicester sewage (a town in which cesspools have as yet been scarcely interfered with), taken during continuous rain, gave a proportion of 1 of solid in 700 of liquid; and another sample from the imperfectly drained town of Cheltenham gave 1 in 729. These examinations were made by Mr. Lindsey Blyth. The amount of solid matter contained in the sewage of Tottenham, a completely drained district, was not determined, but the proportion in which it exceeded the above in the chief elements of value may be approximated to by the following Table, furnished by Mr. Blyth, of the relative ingredients of the dried deposit of each:—

Dried Deposit from the Sewage of	Organic Matter.		Mineral Constituents.	
	Total per-centage.	Containing Nitrogen.	Total per-centage.	Containing Phosphates.
Leicester - -	31·40	0·98	68·60	8·56
Cheltenham - -	27·61	0·91	72·39	10·28
Tottenham - -	33·86	1·52	66·14	12·66

Samples of the sewage of Ottery St. Mary and of St. Thomas's, near Exeter, were examined by Mr. Herapath. The former was taken during rain, and was found to contain only 55¼ grains in the gallon, or 1 in 1,267, only "one-sixth the strength, remarked Mr. Herapath, "of the average ordinary fluid." The sample from St. Thomas's contained 2½ cwt. in 14,333 gallons, or 1 in 512.

The ordinary flow of the refuse from the Puddle Dock sewer in the city of London, where Mr. Higgs's works were first established, was said to contain a proportion of solid of 1 in 400.

That the quantity of ammonia found in the samples from Rugby and Croydon, above referred to, does not represent the amount of fertilizing elements that may be usually expected in the sewage of *completely* drained towns, more detailed analyses of samples of sewage from *imperfectly* drained places will show.

Professor Way made complete analyses of samples from two different parts of the metropolis, one Barrett's-court, representing the more densely peopled districts; the other Dorset-square, the more open districts. The results are embodied in the valuable paper in the Journal of the Royal Agricultural Society of England, before referred to. In the Barrett-court sample 492·26 grains of solid matter were found in the imperial gallon, or 1 in 142. In the Dorset-square sample, 209·70 grains were found, or 1 in 334.

Of ammonia in a gallon, these samples contained—

—	Barrett's-court.	Dorset-square.
In the soluble state - - -	36·72 grs.	15·16 grs.
In the insoluble state - -	4·56 „	2·80 „

"It will be observed that the water from Dorset-square contains less than one half the quantity of soluble and insoluble matters found in the other specimen, and the quantities of ammonia and phosphoric acid are in the same proportion."

The following are the analyses:—

No. 1.—From Barrett's-court.

—	An imperial gallon contains (in grains and tenths)—		
	Soluble.	Insoluble.	Both.
Organic matter, and salts of ammonia -	121·50	180·32	301·82
Sand and detritus of the granite from the streets.	*1·39	19·30	20·69
Soluble silica - - - -	1·57	10·94	12·51
Phosphoric acid - - - -	7·71	2·73	10·44
Sulphuric acid - - - -	10·71	4·02	14·73
Carbonic acid - - - -	11·62	3·97	15·59
Lime - - - - -	7·50	17·03	24·53
Magnesia - - - - -	2·87	Traces.	2·87
Peroxide of iron and alumina - -	Traces.	6·20	6·20
Potash - - - - -	46·91	1·22	48·13
Soda - - - - -	—	1·51	1·51
Chloride of potassium - - -	—	—	—
Chloride of sodium - - - -	31·52	1·72	33·24
	243·30	248·96	492·26

No. 2.—From Dorset-square.

—	An imperial gallon contains (in grains and tenths)—		
	Soluble.	Insoluble.	Both.
Organic matter and salts of ammonia -	57·32	23·00	80·32
Sand and detritus of the granite from the streets	0·78	44·50	45·28
Soluble silica - - - -	1·16	12·09	13·25
Phosphoric acid - - - -	2·53	1·64	4·17
Sulphuric acid - - - -	0·28	3·63	3·91
Carbonic acid - - - -	10·58	1·99	12·57
Lime - - - - -	7·40	8·37	15·77
Magnesia - - - - -	0·07	Trace.	·07
Peroxide of iron and alumina - -	Trace.	2·66	2·66
Potash - - - - -	2·60	0·72	3·32
Soda - - - - -	—	—	—
Chloride of potassium - - -	—	—	—
Chloride of sodium - - - -	27·27	2·10	29·37
	109·00	100·70	209·70

* "This is some small proportion of insoluble matter escaping the linen filter, and properly belonging to the other column."

The examinations, under the direction of Dr. Anderson, of the Edinburgh sewage and of a sample from the tank of the Morningside Lunatic Asylum, bear the same conclusion. The proportion of solid found in the sample from the Lochend sewer, Edinburgh, was 1 in 665; that from the Morningside sewer contained 1 in 527.

The following analyses of these samples are from the Journal of the Agricultural Society of Scotland:—

Sample from Lochend sewer.

	Grains per gallon.
Organic matter soluble in water -	21·90
Organic matter insoluble in water	21·70
Peroxide of iron and alumina -	2·01
Lime - - - -	10·50
Magnesia - - -	2·00
Sulphuric acid - - -	6·09
Phosphoric acid - - -	6·14
Chlorine - - -	12·20
Potash - - - -	2·89
Soda - - - -	13·27
Silica - - - -	6·50
	105·20

Dr. Anderson states, "What is here called organic matter is the whole amount of volatile matter expelled by a red heat. It contains, however, a very large quantity of ammonia, amounting to not less than 7·7 grains in the gallon; in addition to which the organic matter contained 5·93 grains of nitrogen in the form of nitrogenous compounds, so that altogether the quantity of nitrogen present must be considered remarkably large."

In the tank from which the Morningside sample was taken, the whole sewage from the lunatic asylum was collected. The following is the analysis:—

	Grains per gallon.
Organic matter - - -	51·77
Alumina - - -	4·93
Protoxide of iron - -	10·34
Lime - - - -	11·99
Magnesia - - -	2·85
Chloride of sodium - -	4·49
Soda - - - -	3·00
Potash - - - -	2·66
Carbonic acid - - -	11·22
Sulphuric acid - - -	3·12
Phosphoric acid - - -	1·32
Silica - - - -	25·02
	132·71
Ammonia - - -	3·18

It will be observed that this sample does not contain one-fourth of the nitrogen of that from the Lochend sewer, although it contains a much larger amount of solid matter. With referenee to this point, however, I find that whereas this sample from the Lochend sewer was found to contain 1 of solid in 665 of liquid, a sample from the same sewer, examined by the late Mr. Phillips, of the Museum of Economic Geology, contained the large proportion of 1 in 214.

Dr. Anderson eonsiders that so large a quantity of nitrogen as was found in the Edinburgh sample of sewage, examined under his direetions, would not be found at all times, and that the Morningside sample, in all probability, gives a *better general idea* of the value of sewage; and yet the Edinburgh sample contained but little more than a third of what was found in the specimen from Barrett's-court.

I have put together the above cases, and have quoted these examinations rather with the idea of showing how inadequate are the present means for arriving at any general conclusion of the actual value of sewage waters as manure, than of presenting any precise data for the calculation. Many other analyses, no doubt, exist, which have not fallen in my way; but looking at the varying nature of the subject, I do not apprehend that they would serve for guidance any more than the above examinations.

The only conclusions deducible from the scattered investigations hitherto conducted are, that there does exist in the ordinary sewage water, from the houses of a town, a large body of solid matter in suspension and solution, to the extent at least of two or three times what is due solely to the fæcal refuse of the population;—that this additional matter varies much in different places;—that though it bears a certain value in all, this is not for the most part a great value, and that in the present state of knowledge upon the subject it would not be safe to attempt any general calculation of that value.

The amount and value of refuse carried to the sewers from open surfaces of a town by rain, is a branch of the inquiry which has received still less attention, and which, equally varying with the different characters of towns, demands extended investigation.

The only examinations of this kind with which I am acquainted are those conducted by Professor Way, with such remarkable results. The following particulars are extracted from his paper:—

His examinations were made on "ten samples of rainwater which, having fallen in the streets, had been intercepted in their passage to the sewers. They were collected from streets of different kinds, some being paved with granite, and others macadamized. In some cases also the traffic in the streets was considerable, in others very limited.

"All these circumstances had, as the analyses show, a perceptible influence on the quality of the waters. The mechanically abraded matters of the street were collected as well as the waters themselves.

"The following Table shows the quantity of matter, both in solution and in the solid state, in an imperial gallon of the different samples:—

STREET WATER.

Number of Bottle.	Name of Street.	Quality of Paving.	Quality of Traffic.	Residue in an Imperial Gallon.		
				Soluble.	Insoluble.	Both.
				Grains.	Grains.	Grains.
1	Duke-street, Manchester-square	Macadamized	Middling	92·80	105·95	198·75
7	Foley-street (upper part)	do.	Little	95·30	116·30	211·43
5	Gower-street	Granite	Middling	126·00	168·30	294·30
12	Norton-street	do.	Little	123·87	3·00	126·87
3	Hampstead-road (above the Canal)	Ballasted	Great	96·00	84·00	180·00
4	Ferdinand-street	do.	Middling	44·00	48·30	92·30
2	Ferdinand-place	do.	Little	50·80	34·30	85·10
10	Oxford-street	Granite	Great	276·23	537·10	813·33
6	Do.	Macadamized	do.	194·62	390·30	584·92
11	Do.	Wood	do.	34·00	5·00	39·00

"Four samples of these waters were further analysed, and the results are very interesting.

"Two samples were from granite, and the other two from macadamized roads.

"ANALYSIS of the SOLUBLE MATTER in DIFFERENT SPECIMENS of STREET DRAINAGE WATER."

	Grains in an Imperial Gallon.			
	Great Traffic.		Little Traffic.	
	Granite. No. 10.	Macadam. No. 6.	Granite. No. 12.	Macadam. No. 7.
Water of combination and some soluble organic matter.	77·56	29·07	22·72	13·73
Silica - - - -	0·51	2·81	—	—
Carbonic acid - - -	15·84	12·23	None.	None.
Sulphuric acid - - -	36·49	38·23	46·48	34·08
Lime - - - -	6·65	13·38	25·90	16·10
Magnesia - - - -	None.	23·51	Trace.	3·50
Oxide of iron and alumina, with a little phosphate of lime	2·58	1·25	—	—
Chloride of potassium. - -	Non e.	10·99	None.	2·79
" sodium - - -	53·84	44·88	18·44	19·70
Potash - - - -	82·76	18·27	8·75	5·23
Soda - - - -	—	—	1·58	—
	276·23	194·62	123·87	95·13

I instance these cases to show that this part of the subject is most worthy of attention also. Professor Way adds, that "so far as London is concerned, and considering only the composition of the liquid which reaches the sewers in the time of rain from the streets, it seems pretty certain that it would be as valuable in a manuring point of view as the ordinary contents of the sewers. There would seem no reason, therefore, to exclude such waters on the ground of the dilution and deterioration of the sewage to which they might be supposed to lead." It is clear, however, that nothing like these results are to be expected under usual circumstances. And such liquids are still less capable of any general estimate than the miscellaneous matters of house sewage; but I shall have to return to the subject of the separation of drainage upon other considerations.

Such being the uncertain position of the question, I refrain from attaching any positive value to these adidtions to the sewage, either from ordinary household operations or from the washings of external surfaces. I am content for the present purpose to admit that the *minimum* value of sewage is comprised in the excrementitious refuse of the population, and is represented by six shillings per head per annum.

This looks a small sum in itself; let us see what it means in reality. It means 3,000*l.* per annum for every 10,000 of the population. *It means an average annual rate of upwards of eighteen pence in the pound!** And the difference between this sum and the actual cost of getting this manure on the land means the amount of the *direct* money loss from permitting this matter to pollute our rivers and injure our health.

I shall endeavour to arrive at a reliable calculation of the cost of its more profitable employment for agricultural purposes.

The Deodorization of Sewage and its Manufacture into Solid Manure.

The chief plans for treating the sewage of towns, and applying it to the fertilization of land, may be designated the solid and the liquid methods.

I shall proceed, in the first place, with a description of the solid methods, which aim at obtaining from the sewage a dry, portable manure. These may be subdivided into three classes of operations:—

1st. The precipitation of the solid matters held in mechanical suspension and partial solution in the water, by the addition to the sewage of various chemical ingredients.

2nd. The separation of the solid matters in suspension by straining or filtration, and their admixture with various solid deodorizing materials.

3rd. Simple deposition and draining off of the liquid from the solid mass.

1. *Chemical Processes for separating the Solid Matter of Sewage.*

Judging from the number of patents which have been granted for the chemical treatment of night-soil and

* The total of the rateable value of property assessed to the poor's rate in England and Wales, contained in the return of 1854 relating to poor law unions, amounts to 67,730,299*l.*; the total of the population included in the same return being 17,718,605.

other town refuse for the manufacture of solid manure, the subject appears to have engaged considerable attention for the last twenty years. Indeed, the first patent was granted in 1802, to Lewis James Armand Estienne, for converting "human exerement into a powder divested of all smell, preserving at the same time its fertilizing properties;" but no other patent for similar purposes seems to have been obtained until 1835.

From that period to the end of last year, patents were granted for dealing in some way with town refuse, the first patent for treating sewage matter at the outfalls of drainage being that of Mr. Higgs, in 1846.

The majority of these patents appear never to have come into operation, and I do not propose, therefore, to enter into any general description of them; but, as it may probably possess some interest, I have added a list of them in the Appendix (A.). I shall submit only here a brief account of those operations which have chiefly commanded public attention, and of those which I have had an opportunity of examining.

The principal process hitherto adopted for the preparation of a solid sewage manure consists of the admixture of a certain proportion of lime, of the consistency of cream, with the sewage as it flows to the outfall, whereby the solid matters in suspension are rapidly precipitated, and some of those in solution disengaged, and the supernatant water allowed to flow off in a comparatively pure state.

The lime process is chiefly represented by the patents of Mr. Higgs and Mr. Wicksteed. In 1849 works were established at the outfall of one of the main sewers in the City of London, for the purpose of carrying out Mr. Higgs' patent process. These not having proved commercially successful, were subsequently abandoned, but works have since been established on Mr. Higgs' plan at Cardiff gaol, and recently on a more extended and perfect scale at Tottenham.

This town, which now comprises about 10,000 inhabitants, has been completely drained under the

Public Health Act. The outfall was led into the nearest stream, where of course the pollution from refuse, before retained amidst the habitations of the people, soon became a considerable, although less dangerous nuisance. It was the subject of great complaint, and the next step was to seek for some means of avoiding the evil consequences of this noxious discharge.

Sewage works have been erected by a company at great expense for carrying out the lime process under Mr. Higgs' superintendence.

These works comprise a reservoir capable of holding 44,000 gallons, into which the sewage is first received, and then raised consecutively into 4 iron tanks (each capable of holding 5,000 gallons) by an engine of 10-inch cylinder, 16-inch stroke, working up to 8-horse power. The engine in ordinary work makes 110 strokes per minute, and the pumps 900 strokes per minute.

Cream of lime is poured into and mixed with the sewage as it passes into the iron tanks. The proportion of lime used is estimated to be one fourth of the solid matter of the sewage and the solid of the sewage is calculated by Mr. Higgs to be on the average 1 in 500 of the liquid.

Only $1\frac{1}{2}$ per cent. of this solid matter at Tottenham is stated to be grit.

When each tank is charged, from half an hour to an hour is allowed for settlement before the liquid is passed off to the outfall, and 7 or 8 deposits are made before the solid is removed.

The great difficulty which has been experienced in the lime process both here and at Leicester has been the drying of the sewage, so as to render it portable.

Various expedients have been tried at both places, and successively abandoned. At Tottenham a quantity of the manure had been dried by various means, but the difficulty of accomplishing this economically had not been overcome at the time of my visit. The new plan then proposed, but not in operation, was to pass the sewage, in the semi-fluid state in which it is withdrawn from the tanks, round a drum in a thin layer, from which it would continuously fall on to a series of heated plates.

A great discharge of foul gases takes place on disturbance of the deposit in the tanks. At Tottenham these gases are not allowed to escape, but are conducted to a purifying air chamber, and there treated with hydrochloric acid and oxide of manganese. The whole establishment was perfectly free from noxious or unpleasant odour.

The price of the manure was fixed at 4*l.* per ton.

A circumstance remarked at Tottenham is so illustrative of the rapidity with which, in a properly graduated system of drainage with a smooth channel, the refuse flows from the houses to the outfall, before decomposition or disintegration of the solids has to any extent taken place, that it is worth recording. A small recess or pit is formed at the mouth of the sewer, guarded by a wire screen, for the purpose of intercepting any foreign substances that might otherwise reach the pumps, and it is the duty of a boy to attend at this pit to clear away rags, paper, &c., that would otherwise choke the screen. A sufficient quantity of soap in cake or lump is daily found here to pay for this labour.

The largest works, however, for carrying out the lime process have been established by a company at Leicester under Mr. Wicksteed's patents. The principle is precisely the same as that adopted at the works just described. It differs only in the modes of operation, and in the adoption of various improvements which experience has from time to time pointed out.

Leicester contains about 65,000 inhabitants. The Local Board being compelled by their Act of Parliament to raise and deodorize the whole of the sewage of the town, in order to prevent pollution of the river, entered into an agreement with the Solid Sewage Manure Company, whereby a lease of the sewage was granted by the Local Board, on the condition that the Company should erect works for the continuous pumping of the sewage, and for its complete deodorization, at their own cost. A complete system of public sewers has been constructed in the town, and a large number of manufactories are drained into them; but a considerable proportion of the houses has not yet been properly drained. Cesspools still prevail in the town for the most part. The outfall, where the sewage works are established, is about a mile below the town, and here the whole liquid drainage, except in times of flood, is dealt with by the lime process.

The sewage flows into a pump well, whence duplicate engines, with 25-inch cylinders, 7 feet 6 inches stroke, and 28-inch pumps, raise it to the level of the reservoirs.

Quicklime, mixed in water to the consistency of cream, is raised at the same time by the same engine, and discharged in certain proportions, varying from 2 to 16 grains per gallon, into the pipe which conveys the sewage. The two are intimately mixed by a series of agitators, and afterwards pass through a perforated chamber into the first reservoir, where the greater part of the solid matter is precipitated.

The bottom of this reservoir is sloped from 5 feet depth at the sides to 15 feet in the middle to a centre channel or trench, along which an Archimedean screw of 3 feet in diameter continuously works, drawing the precipitated matter into a covered well at the upper end. From this it is lifted by a Jacob's ladder of dredging buckets alternately to one of two tanks twenty feet above on an upper floor.

At this stage of the process the material raised from the reservoir is in a state of "slush," and the chief difficulty until recently appears to have been, as stated with regard to the works at Tottenham, to get rid of the remaining fluid. At Leicester this difficulty has now been ingeniously overcome by Mr. Wicksteed, by means much more perfect and far less costly than those hitherto employed.

A portion of the semi-fluid sewage in the tank descends through a pipe into a portable apparatus below, consisting of a pile of filtering trays secured together, from which the water is discharged by the pressure of the remaining sewage above. The solid matter comes from the trays of this press in firm slabs, and it is then cut by strings into ordinary sized bricks, and put out to dry.

The agitators, screw, and Jacob's ladder are worked by a separate engine.

The first reservoir is about 60 feet in length and 45 feet wide, and the liquid sewage travels from it, at the rate of about a quarter of an inch per second, to a second reservoir, 130 feet long, where further settlement takes place; seven-eighths, however, of the precipitation take place in the first reservoir.

An offensive odour pervaded the buildings at the time of my visit, which evidently escaped from the sewage deposit as it was raised from the bottom of the reservoir. On opening the chamber in which the Jacob's ladder works the effluvium was intolerable, but this might be very readily dealt with, and all nuisance obviated.

The water which flowed off to the river after treatment with the lime possessed still a perceptible smell and taste, although the sewage was in a very diluted state on that day from continuous rain; but as proof of the great improvement which these works have occasioned in the condition of the river, it must be stated that fish have recently returned to old haunts at a short distance below, where they have not been seen for many years.

It is said that upwards of 30,000*l.* have been expended upon these works. This amount, however, must not be taken as the necessary cost of establishing similar works elsewhere, a considerable sum having, no doubt, been sunk in the various trials and experiments necessary to bring the process to its present practical condition. Mr. Wicksteed calculates that works sufficient for a population of 500,000 could be established for the sum of 40,000*l.*

From this population it is estimated that 60,000 tons of manure would be produced per annum prepared in a plastic state, like clay ready for brickmaking, at a cost of 2*s.* 4*d.* per ton, including the discharge into carts or barges lying alongside the works.

The price of the dried manure of the Company was a few months ago fixed at 40*s.* per ton. There having been little or no demand for it, and a large and increasing accumulation at the Company's works, it has been more recently offered at 25*s*. per ton.

While treating of the lime process, I must not omit mention of the important trials recently carried out by Dr. Angus Smith, Mr. Crace Calvert and Mr. McDougall, on the foul water of the River Medlock at Manchester.

In the account of these experiments published by the Manchester and Salford Sanitary Association, the effect of the admixture of lime with the river water is thus described:—"When lime is thrown into the River Medlock it produces what may be familiarly called 'curdling,' which results from the formation of a very flocculent precipitate. This precipitate is formed by the combination of the lime with the carbonic acid, organic matter, and other substances held in solution and suspension in the water. It separates into large and distinct portions, which subside very rapidly. Careful observations repeatedly made show that the precipitate falls at the rate of about 1 foot in 8 minutes, or about $1\frac{1}{2}$ inches per minute."

It was found that about 2 grains of lime per gallon added to the water of the Medlock which had the most repulsive odour almost totally deprived it of unpleasant smell.

This proportion of lime appears to have been confirmed also as sufficient on a large scale, if time enough could be given for the operation of the lime before the precipitate was allowed to take place.

In the early experiments it was found that 17 cwt. of lime mixed with 1,000,000 gallons of water produced instant precipitation without excess or causticity. "The precipitate so made contained no caustic lime: the water also ran free from caustic lime." Further trials, however, determined that under more favourable circumstances 10 cwt. of lime would be sufficient for immediate precipitation from 800,000 to 1,000,000 gallons of water.

Considering it an important thing to devise some means of reducing still further the quantity of lime, it was tried whether the lime which had once been used had really done all the duty that it was capable of performing. It was found by using the precipitated matter over again to repeated fresh charges of the same quantity of impure water, a fourth charge was acted upon with nearly equal advantage. So that where a large subsiding area could be obtained, and the water could be kept sufficiently long in suspension, it was concluded that somewhat more than a fourth of the above quantity of lime, or about 3 cwt. per million gallons, would effect the complete precipitation.

Mr. Calvert states that "to appreciate fully the value of lime, it is necessary to draw attention to the following important fact, namely, that if we take the average amount of organic matter in suspension and solution as 12·11 grains per gallon, there remains after treatment by lime only 3·5 grains per gallon *in solution*, or, in fact, a quantity less than exists in many river waters which are used for domestic purposes"

The full effect of the application of lime, as regards the smell of the water, was not sufficiently ascertained, owing to the imperfection of the apparatus and arrangements.

On this subject Dr. Smith and Mr. McDougall remark:—"We found the smell of the water of the Medlock was not entirely removed by precipitation with lime, or if removed, that it soon returned; we therefore used a disinfecting agent to the amount of $2\frac{1}{4}$ per cent. of the lime used. We used for this purpose our own powder."

As to the value of the precipitate, Dr. Smith and Mr. McDougall state that it "has a certain value as a manure, although not a great one. It may be advantageously used near the banks of the canal, but at the distance of even a few miles, it could not be used economically by farmers, as it would not bear the cost of transport."

"At any rate, the value of our precipitate cannot be reckoned higher than 7s. 6*d*. per ton." And Mr. Calvert also remarks "*that no great commercial value* can be attributed to this deposit."

With reference to the proportion of lime, namely, 3 cwt. per million gallons, which was found to be sufficient for deodorizing the waters of the River Medlock, it must be borne in mind that these experiments will form no criterion of the quantity required for effecting this object with ordinary sewage water.

The chairman of the Leicester company estimates a consumption of lime of 100 tons per week for a population of 500,000, which, with an ordinary water supply of 200 gallons per head per week, would be equivalent to 1 ton per million gallons of sewage.

In Mr. Stothert's patent process, the sewage is treated with sulphate of alumina in addition to the lime, which causes a rapid subsidence of the solid matters, and to these, charcoal, made from solid sewage, is added. These ingredients cost 30*s.* per ton and they are stated to make 2 tons of manure.

A small model establishment was put up by Mr. Stothert at Northumberland Wharf, Strand, where the sewage from one of the main outfalls of the Metropolis was operated upon for a considerable period, with apparently complete success so far as deodorization was concerned, but I am not aware that any other works have yet been erected under this patent.

Mr. Herapath's process consists of the admixture of sulphate of iron and burnt magnesian limestone with the sewage. This process was put in operation for a short time at St. Thomas's, Exeter, by a person to whom a lease of the sewage and of certain tanks erected at the outfall was granted by the Local Board. The contractor, however, having no capital, soon failed in his undertaking.

The proportion of materials used is 1 of sulphate of iron to 4 of magnesian limestone. Founded on the experience obtained at St. Thomas's, Mr. Herapath estimates the cost of the materials, including labour and fuel for the manufacture of the manure, at 17*s.* per ton. One ton of the ingredients will produce 2 tons of dry manure.

I must add that the operation was conducted at St. Thomas's in a very slovenly manner, and at the time of my inspection was, by no means, calculated to improve the sanitary condition of the neighbourhood.

The method proposed in Mr. Richard Dover's patent, consists in "treating sewage with an acid or acids, either alone, or together with a salt or salts or other chemical agents, for the purpose of depriving it of its putrescent qualities, and also obtaining certain products therefrom." Hydrochloric acid is named, with chloride of sodium and protosulphate of iron. The sewage is then to be filtered through charcoal, gypsum, or clay, and mixed with these are various other materials to form compound manures.

Two other patents of more recent date must not be passed over, as they have already claimed much favourable notice in the North, namely, the disinfecting powder of Dr. Angus Smith and Mr. McDougall, of Manchester, and the process of Mr. Manning, of Leith, for treating sewage.

The agent prepared by Dr. Angus Smith and Mr. McDougall "is a compound of two acids and two bases. The acids are sulphurous acid and carbolic acid, and the bases magnesia and lime. These four exist in it as two salts, viz., sulphite of magnesia and lime, and carbolate of lime." These ingredients are said to remove entirely the noxious emanations, the sulphuretted and phosphoretted hydrogen, from fæcal and other organic matters, and at the same time to preserve the fertilizing elements, the phosphoric acid and ammonia.

Of the deodorizing power of this agent under various circumstances, and of its convenient form for use, there appears to be abundant testimony. The Borough Engineer of Liverpool has used it in cesspools with great success, and it seems admirably adapted for use in stables, and for preventing noxious emanations from cesspools and from solid manure or other decomposing substances; and it is said that it could be *economically* applied at the outfalls of town drainage for the deodorization of the sewage and its preparation as manure, although this does not appear to have been actually determined yet by trial on the large scale. The price of the material is 10*l.* per ton.

Mr. Manning's material is prepared from alum shale, containing sulphate of iron, and animal charcoal in equal quantities. Its use has been adopted at Edinburgh and at the new gaol near Liverpool with considerable success as a deodorizing agent.

These ingredients are stated to cost 7*s.* 6*d.* per ton, and including carriage, the cost of deodorizing 1,000 gallons of sewage will be a penny, or say 1*s.* per head per annum, and according to the analyses of Dr. Penny, a valuable manure is the result.

The actual working expenses at the new gaol near Liverpool were 50*l.* per annum for the deodorization of 12,000 gallons per day, including the digging out of the solid and carting away.

The process originally conducted at the outfall of the new drainage works of Croydon was that of mechanical separation of the solid matter from the liquid by passing the sewage through perforated plates or strainers. The liquid was then allowed to flow off, and the solid was mixed with peat charcoal. Various causes led to the failure and abandonment of these operations, and an action having been brought against the Local Board for pollution of the river Wandle, various endeavours have, I believe, since been made by them to arrive at more satisfactory results.

I visited the outfall again last year, when it was still by no means free from nuisance; but the works were then in a transition state. They had recently been let for the carrying out of a new process.

It was proposed to treat the sewage with lime in alternate reservoirs within the building at the outfall, in which the chief precipitation would take place, the effluent water being made to travel afterwards through a long course of open brick channel, constructed in parallel lines, the water flowing along it backwards and forwards before discharge into the river. The solid matter was to be mixed with various other materials, to form manure of different qualities and description.

An action in the Court of Queen's Bench having been a few months ago decided against the Guardians of the Clifton Union near Bristol, for an alleged nuisance arising from the drainage of their Workhouse, Mr. Blackwell, the engineer, was called in to advise on the means to be taken for deodorizing the sewage, and the following process was adopted.

The inmates of the workhouse number 608 on the average, and the actual liquid sewage from the establishment appears to be only about three gallons per head.

Mr. Blackwell's examinations led him to consider that lime and sulphate of iron would be the best deodorizing ingredients, but that a larger quantity of water would be required to obtain the desired effect.

At the outfall of the sewage from the house a well was sunk and a small steam engine about two-horse power erected for raising the additional supply of water, of about four times the previous quantity, into the cisterns in which the sewage is received. When these cisterns are full, the lime is first thrown in and agitated with the sewage by a kind of churn apparatus worked by the engine, then the sulphate of iron is added and treated in the same way. The contents are afterwards run off alternately into one of two adjoining tanks, whence after some hours settlement the water is allowed to flow off to an open stream which runs into the river Froome.

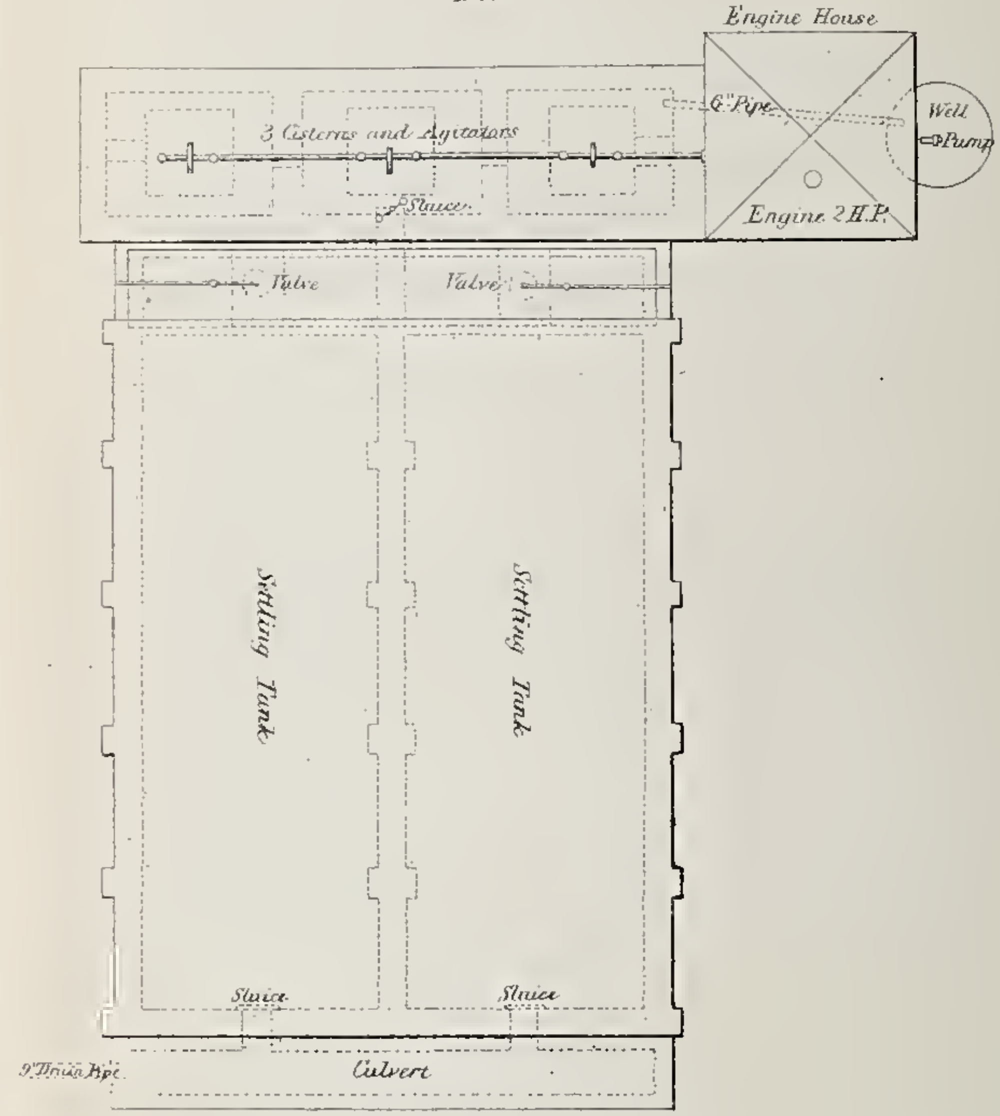
The operation of mixing takes place twice each day, each of the two tanks (together containing about 10,000 gallons) being filled and discharged every 24 hours. The cost of the works was about 600*l.*

Six bushels of lime are used per week, and $2\frac{1}{4}$ cwt. of sulphate of iron. One man's time is occupied in the operation. The total working expenses, including coals and all materials and labour, may be calculated at about 94*l.* per annum, and if the interest and wear and tear be assumed to be 45*l.*, the total cost of the

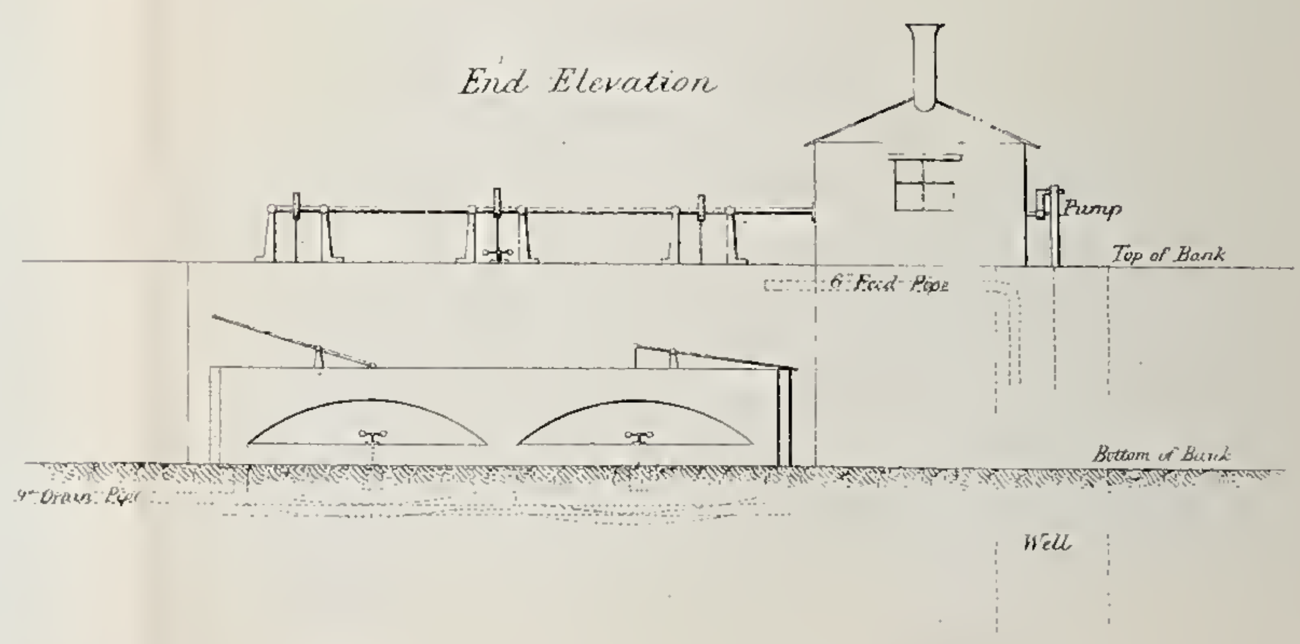
No. 1.

Longitudinal Section

Plan



End Elevation



CLIFTON UNION.

SKETCH SHEWING
DEODORIZING APPARATUS.

16 feet to the inch.

Day & Son, Lithrs to the Queen.

operation would be about three shillings per head per annum; but with a more copious supply of water, for which arrangements are now being made, it is expected that the cost will be less. The solid deposit is removed from the reservoirs about once per month, but it has scarcely yet been applied as a manure. I apprehend that it would be of little service for that purpose.

I give a plan of these works (No. 1) as an instance of the compactness with which deodorizing arrangements may be established for small populations.

I found a perceptible smell from the sewage in the reservoirs after the operation was performed, arising probably from the disengagement of the ammonia by the lime, but the works may be said to have accomplished their object, as no complaint whatever has been heard since their establishment from the parties residing near the open stream below, who indicted the Guardians for the previous nuisance.

The sulphate of iron, I presume, would not be a beneficial addition to the manure, and other substances equally efficacious as deodorizers, to which that objection does not apply, being at command, its use is not to be recommended.

For this reason, also, I do not propose to enter upon any account of other chemical agents long used for deodorizing, such as chloride of zinc and nitrate of lead; for however valuable their properties for dealing with specific cases of decomposition, they would render the sewage unfit for use as a manure, and would involve therefore perpetual waste and additional expense.

2. *Mechanical Processes for separating the Solid Matter of Sewage.*

Among the works which have been established for the mechanical separation of the solid matter of the sewage from the liquid by straining or filtration, and applying it as manure, those of Cheltenham appear to be the most extensive, and at the same time most successful.

There are two outfalls of the sewage at Cheltenham, and works have been established at each of them.

For the more ready comprehension of the following description, I append a plan (No. 2) of the construction at the principal outfall.

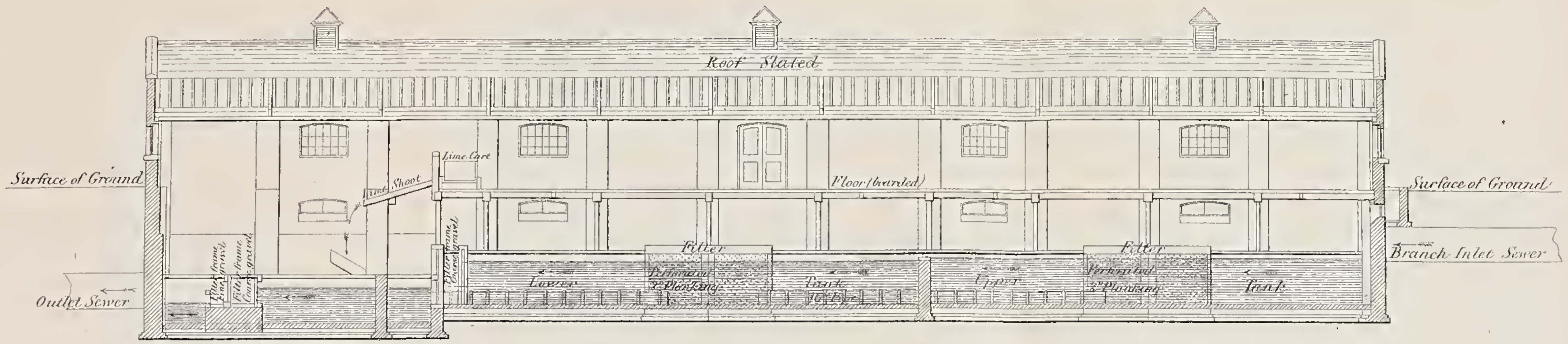
The building is divided longitudinally, forming below ground two sets of reservoirs or tanks, which are employed alternately. The sewage passes through vertical filters in the upper and lower tanks, whereby the great bulk of the matters in suspension is separated and retained. These filters are 5 feet deep and 2 feet thick, and consist of coarse gravel inclosed within 2-inch perforated boards, these being protected with basket work to prevent clogging.

The heavier matters of the sewage deposit themselves at the bottom of the tanks, but a large proportion of the solid forms itself into a floating body, and accumulates to about 18 inches thick on the surface. The liquid is conveyed from the angular filters in the upper tanks by a line of pipes in each division.

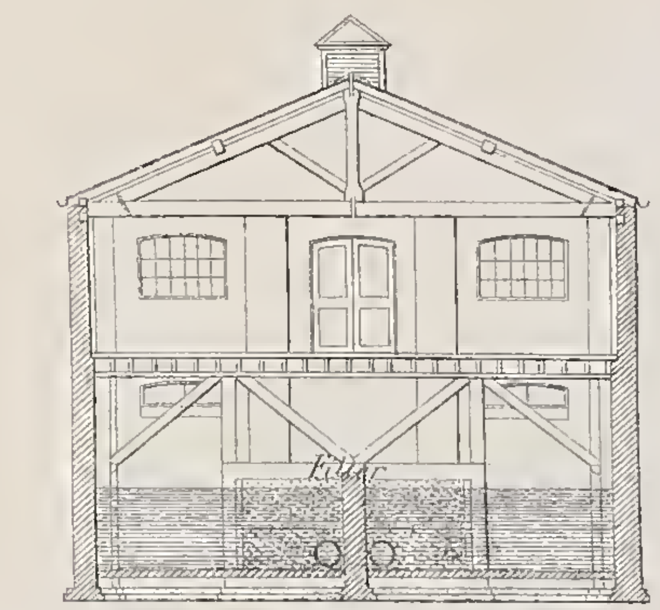
A weir, or rather division in the third or liming tank causes the water, then partially clear, to flow through a channel at each end, during its passage through which a certain proportion of cream of lime mixed on the floor above falls into it, and occasions a further precipitation to take place. The effluent water then passes through another filter of gravel finer than before, and then through a third, finer still, to the outfall.

When either reservoir contains a certain amount of solid matter, the flow of sewage is cut off and turned into the other. This takes place about every eight weeks, and the filtering medium of gravel is removed at the same time and washed. The contents of the tanks which are in a state of "slush" are then hoisted in buckets through the trap lids on to the floor above, and wheeled out and mixed with the scavenger's refuse of the town, the ashes, street sweepings, &c. These are brought to the yard, and a kind of embanked reservoir is formed of them immediately outside the building, and as the semi-solid sewage is wheeled into the midst, the dry refuse outside is turned on to it.

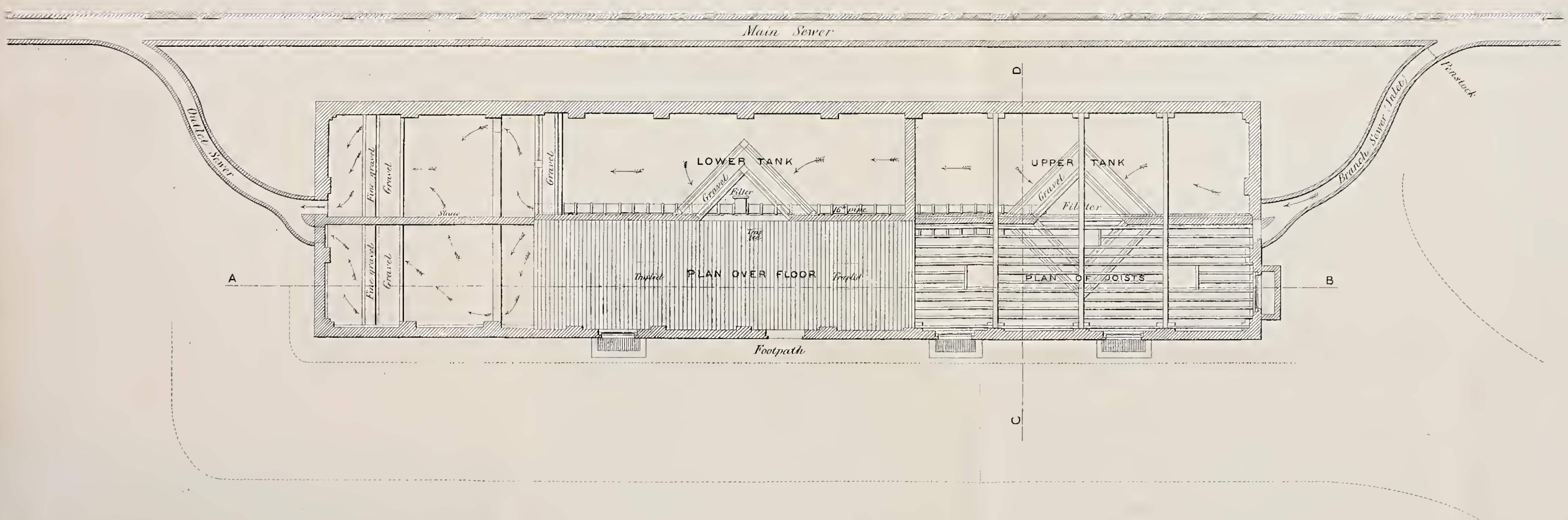
CHELTENHAM SEWAGE WORKS.



LONGITUDINAL SECTION THROUGH TANK ON LINE A TO B.



TRANSVERSE SECTION ON LINE C TO D.



Scale 16 feet to an inch.

The liquid is at once absorbed, and after being turned over and thoroughly intermixed, the solid mass is fit for immediate removal and use.

The ashes and dry refuse of the town are said to be just about sufficient for the purpose. They absorb about two-thirds of their bulk of sewage; that is to say, that one cubic yard of the ashes, &c. and two-thirds of a cubic yard of the semi-fluid sewage, make only 1 cubic yard of solid manure.

This operation was commenced in the spring of 1855. The drainage of Cheltenham is not yet by any means complete, but already the manure is manufactured at the rate of about 2,000 cubic yards per annum.

None of the lime deposit had been removed at the time of my visit. This addition to the process had only recently been adopted. The cost of it is about 14*s*. or 15*s*. per week.

The outlay upon this building was about 1,250*l*. The houses draining to it number about 3,200, discharging about 300,000 gallons in 12 hours of daytime. The cost of the operation at the outfall is found to be 2*s*. 2*d*. per cubic yard of manure, and the ashes are worth 8*d*. per yard. The Local Board wisely put a very low value on the manure in the first instance. Up to the time of my visit it had been sold at 2*s*. 6*d*. per yard, but as the demand exceeded by two or three times the supply, it was intended immediately to raise the price. Three and sixpence per yard would pay the working expenses and interest on the outlay.

As the first attempt of the kind, I must observe that Mr. Dangerfield, the local Surveyor, has carried out this work very satisfactorily, but further consideration dictates some improvements in a sanitary point of view, and in economy of construction and saving of labour, to some of which I shall beg to draw attention in another part of my Report, as they may be useful for future guidance, more especially to small towns.

The operation did not appear to give rise to any nuisance, and the effluent water and solid sewage were nearly free from unpleasant odour; but the process may, in my opinion, be conducted in so complete a manner as to obviate the slightest offensiveness even in the hottest weather.

Similar works to those at Cheltenham have just been adopted by the Local Board of Health of Coventry.

The Local Board of Health of Uxbridge being much pressed by an injunction prohibiting the discharge of the sewage of that town into the River Colne without its being deodorized, constructed works for this purpose.

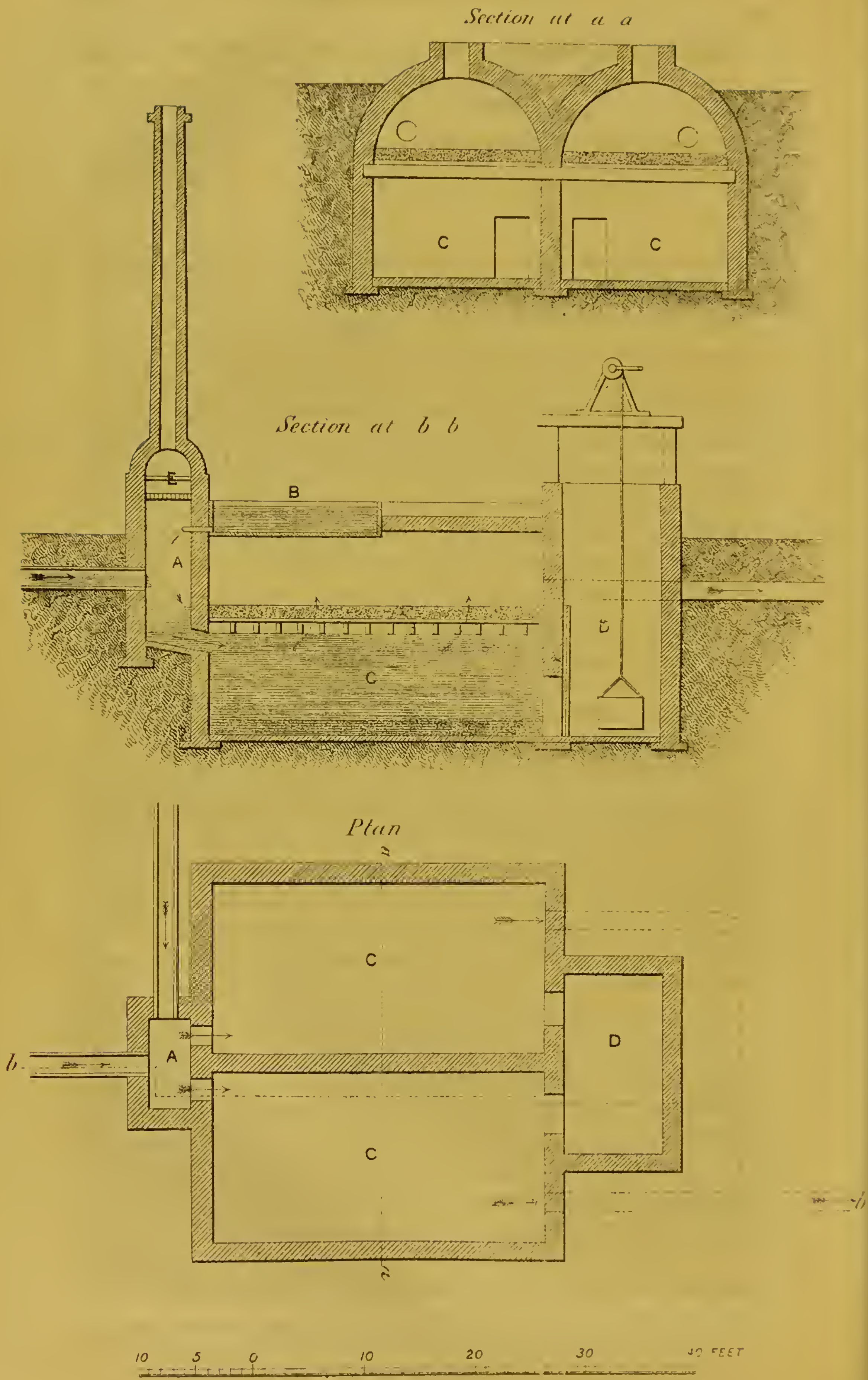
The sewage is received into a large tank arched over. As much of the solid matter as can be collected is dragged by a rake out at a door at the end of the tank. This refuse is here spread on the ground and covered with a thin layer of charcoal or earth, and is then conveyed away in carts by the farmers. The liquid refuse flows from the tank through boxes filled with peat charcoal in lumps of 3 or 4 inches. It simply passes through these boxes and runs direct to the river.

I refer to this case more as an example not to be followed than as one possessing any merit. Although considerable expense has been incurred in constructive arrangements, which are sufficient for complete deodorization, care has not been taken to collect information as to processes which have been found effective, and it is not surprising, therefore, that the Local Board should still be in legal difficulties on the subject. Endeavours are now being made, however, to rectify the errors into which they have been led.

There are about 1,500 houses in the town of Uxbridge. An examination of these works took place when about 500 only of the houses were connected with the drainage, and it was then found that the liquid refuse running into the River Colne was much discoloured, and the appearance of the ground showed evident symptoms of deposit of an unpleasant character.

The Local Board are restrained by the injunction from turning lime water into the river, on the plea

SEWAGE WORKS—ELY.



that it would destroy the fish; but the experience at Leicester shows that this is not a necessary consequence of treating the sewage with lime. There, however, the lime water does not enter the river; sufficient reservoir space is allowed for its precipitation before the effluent water is discharged.

Mr. Burns, the local Surveyor of Ely, having, as early as 1834, made some successful experiments in treating gas water with clay, was induced recently to apply it, in conjunction with lime, for deodorizing the sewage, on completion of the drainage works of Ely. Sewage works have been erected at the outfall in which the experiment has been in operation for some time, and it is stated with complete success. At the time of my visit the place was certainly quite free from offensive smell; but the collecting tank has not yet been opened to try the effect of the manure.

It is found that one ton of clay is sufficient to deodorize 600 tons of sewage as at present discharged at Ely; but, as only a portion of the houses have waterclosets as yet, the liquid is comparatively weak. It is expected that every house will in the course of the present year be connected with the sewers, when it is supposed that about double the weight of clay will be required for the same quantity of sewage.

As the sewage discharges into the mixing tank A (Drawing No. 3.), a stream of clay water falls from a cistern B above, and passes with the sewage alternately into one of two reservoirs C below, whence the water filters upwards through a layer of charcoal and sand, and discharges by the outfall drain to the river.

It is proposed to pass the solid matter daily into the emptying chamber D, and to mix it with dry clay powder and peat charcoal, or with fine dry ashes, when it will be fit for removal and use as manure.

The furnace E shewn in the section is intended for consuming the foul gases from the sewers, and for heating an oven for drying clay and peat for mixing with the wet manure. When the drainage works will be complete it is proposed to add a series of open tanks, with other filters of charcoal and sand, through which the effluent water will pass before discharge.

An attempt has been made for some time at Hitchin to intercept the solid matter of the sewage in a series of reservoirs and open pits at the outfall of the new drainage works, without any means of deodorizing, or arrangements for precipitating, straining, or filtering. As might be expected, the process has not been successful. An action has been decided against the Local Board for pollution of the river, which will necessitate the adoption of more complete arrangements.

The gas for lighting the Dartmoor Prison has been manufactured for the last five years from the peat with which that neighbourhood abounds, and some very interesting results are being elicited in the process by Mr. Watts, the Resident Engineer, by whom the system was introduced.

The peat charcoal and the ammoniacal liquor, two of the products of the manufacture, are mixed with the solid night-soil of the establishment, and with bone-dust, to form a solid manure, which is used on the neighbouring lands.

The liquid refuse of the premises is pumped up and applied for irrigation, as will be described further on.

It may be useful to mention, with reference to the manufacture of peat charcoal, that one cubic yard of the dug peat makes about 4½ cwt. of the dried material, and that 5 cwt. of charcoal are produced from 1 ton of the dried peat.

As so much disagreement prevails with respect to the deodorizing power of peat charcoal, Mr. Blyth was instructed to make some experiments on the subject, and to determine the comparative value of peat charcoal and the ground Boghead coke for this purpose. I append Mr. Blyth's report (App.B.) on this examination. The results obtained are of considerable interest.

It appears that neither of these substances has much deodorizing power when mixed with liquid. When heated after saturation they both gave off offensive effluvia in abundance, but, when spread over the surface of offensive matter, the escape of all odour was prevented. The experiments show that they have no power to separate matters from solution, and thus confirm the previous statements of Professor Way and Dr. Henderson that the power of charcoal to absorb ammonia from the atmosphere does not extend to the separation of that gas, or of anything worthy of notice, from solution.

In condensing gases, or as a deodorizer of atmosphere, the peat charcoal appears to have about four times the power of the Boghead coke; but, on the other hand, it must be borne in mind that, whereas the peat charcoal has latterly cost in London between 4*l.* and 5*l.* per ton, the ground Boghead coke is to be had for 12*s.*

In the course of these experiments a valuable property of the Boghead coke was discovered. It is only with great difficulty that this material can be made to mix with water; it remains a floating mass on the surface, and it was found that in that position it has considerable power of promoting evaporation of the liquid below, while effectually condensing the odorous gases that would otherwise escape. It thus becomes of value in promoting the drying up of offensive deposits. The sample of the Boghead coke was obtained from the Chartered Gas Company's works, Horseferry Road, a certain portion of this coal or bituminous shale being now very generally used in the manufacture of the London gas.

3. *Deposition of the Solid Matter of Cesspools; and the Separate System of Drainage.*

The simple deposition of the excremental refuse of towns, and the draining off of the liquid from the solid mass, as the means of manufacture of a portable manure, is carried out on the largest scale in Paris. A full and able report upon these works was prepared by

Mr. Rammell, C.E., and is comprised in the Appendices of the Water Report (1851) of the first General Board of Health. It would be needless, therefore, under any circumstances, to enter into any detailed description of that operation here; but it is, in truth, so utterly inapplicable to the mode of drainage which I assume to be indispensable for the health of town populations, and constitutes so great a nuisance in itself, that I should scarcely have considered it necessary to allude at all to this method of dealing with the matter, had it not still been doubted by many whether that system of drainage can itself be right which leads to considerable difficulties in realizing the full value of the refuse of town populations.

I fear that all such objectors who would revert to the cesspool system view the subject with agricultural or commercial sympathies, rather than with an anxious regard for the public health as the primary consideration. At least they must be ignorant of the overwhelming evidence which a long course of inquiry has brought to light of the evils sustained by the retention of town refuse about habitations.

Some will admit these evils, but maintain that they arise from carelessness and defective arrangements both for the retention and removal. So far as this country is concerned, these defects, whether of construction or transport, must be admitted; but the Paris arrangements are the very perfection of the system. No care or expense has there been spared, and yet it is proverbial that the great source of the noxious atmosphere in Parisian houses is the cesspool.

Admitting this danger, even with the best arrangements, some will ask, is not chemistry equal to the control of these substances,—either to prevent their passing into a dangerous state or to convert them into innocuous and valuable fertilizers?

Granting this power to chemistry, we must bear in mind that any arrangement made with this view, must receive daily proper attention in every separate household; and, supposing this to be given, cost of the necessary arrangements and collection would exceed the difference of value between the refuse in this more solid form and that in which it is presented at the outfall, diffused in a large body of water.

The middensteads of Liverpool and Manchester are an example of this kind of treatment. These places receive daily the ashes and the privy refuse; they have of late years been drained, and have received constant attention in other respects, with the view to make the best of them. The ashes themselves form an excellent deodorizer when properly used, and yet the rate of mortality in both of these towns seems to me to support the conclusion of those who contend that a high standard of health is not to be expected until the water-closet has been generally substituted for the middenstead.

Sharing in this conviction, I shall not consider the cesspool system further. The deposition of the refuse and draining off of the liquid practised in the neighbourhood of Paris, whereby the portable manure "poudrette" is obtained, is practicable only as part of that system, and is itself, at best, a most offensive operation.

With the method of town drainage now established in this country, arrangements for deposition of the solid matter of the sewage at the outfall would be insufficient as a sanitary operation, as the attempt at Hitchin has shown; nor, if this could be admitted, would the solid possess anything like the value of the Paris deposit, the chief value of the matter in our case being in solution in the water. Here, indeed, we may invoke the aid of chemistry, to render that value again available in all towns and places in which the liquid itself cannot be applied to the lands; and we may reasonably hope that the great attention which the importance of the subject has for some time secured to it from scientific men, will, ere long, be crowned with greater success than has hitherto been attained.

From the foregoing observations,—first, as to the constituents of the sewage of towns, and, second, as to the state of dilution in which alone it is available either for solid manufacture or for direct application to the land in the liquid form,—we may judge of the difficulties which present themselves in realizing the value of this manure, however well determined that value may be.

Having alluded to the opinions of those whose remedy for the difficulty would consist in reverting to the cesspool system,—modified and improved of course, but in any case a system, in my opinion, incompatible with a due regard to the public health, even if preferable in the interests of agriculture,—I come to a further difficulty in the question, namely, the additional dilution of the sewage by rain. For the remedy of this, what is called "the separate system of drainage" has long been strenuously advocated.

The difficulty of this increased dilution is at first sight so great in practice, and the remedy so obvious and simple in theory, that I purpose to offer a few observations on the subject, feeling satisfied that the proposition of two separate systems of drainage, one for surface waters and another for house refuse is founded on a mistaken view of the question.

First, as to the extent of dilution by rain water, which has to be considered.

Because a certain amount of rain falls in the course of the year at a given spot, it is not to be assumed that this represents the daily addition of water to be applied to the land, or from which the sewage constituents have to be disengaged.

An annual rainfall of 24 inches, equally distributed, would amount to about the same quantity per head as the usual water supply of the population of a town, namely, 25 gallons per day. Whatever the amount of rainfall, however, considerable deduction must be made from it for evaporation. On examination of the registers of rainfall, it will be found, moreover, that a very large proportion of the whole quantity of rain usually falls in a small number of days of the year, which of course may be discarded from calculation altogether; for on those occasions of flood, or storm, there would be no attempt, after the first flushing of the sewers, to make use of their contents. Conveyed in such an enormous bulk of water on those few days, the sewage would be innocuous and of no service for manure, and therefore might safely be allowed to pass off direct to the outfall.

Taking some years' registers of rainfall in the metropolis at hazard, I find that about *one-half* * of the total rain fell in from twenty to thirty days of the year, and such days will naturally be eliminated from calculation, with reference to the distribution of the sewage. On half the remaining number of days in which rain fell, the quantity would not have exceeded the usual daily water supply, and the maximum fall upon other days was only such as should, with proper arrangements, be usually under command for distribution.

Mr. Walker, at Rugby, has scarcely been deterred at all by rain from pumping all the sewage that he could on to his land, for, except during one period of frost, he has worked on regularly for 300 days of the year; stopping, therefore, (Sundays of course being excluded,) for only thirteen days on all accounts. So far as the quantity of water thus distributed over the land is concerned, even if the whole of the usual rainfall on the site of Rugby, in addition to the town water supply, were applied to Mr. Walker's land, *it would not be above one sixth of the bulk of water which is regularly applied to the Craigentinny Meadows in ordinary working.*

It is obviously desirable, on agricultural grounds, to avoid as much as possible any dilution by rain of the already greatly diluted sewage; and all land water, drainage of suburban roads—in short, all waters free from pollution—should *as far as practicable*, be excluded from town sewage. Allow me, however,

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* I find this fact more completely confirmed by Mr. Beardmore in his hydraulic tables. In the register of 17 years' rainfall at Boston, the average annual fall is seen to be 22·30 inches, and 11·03 inches fell within 24 days. In the register of 16 years' rainfall at Glencorse, where the much heavier quantity of 37·38 inches fell in the year, 25·61 inches, or more than two-thirds of the whole, fell within 42 days.

briefly to consider what advantage would really be obtained by the separate system of drainage applied to a town.

To what area is the separation to extend? What will it amount to? If it is to be a separation of the drainage of all public streets, and other public areas of all kinds, from that of private properties, I have been at some pains to discover what proportion these bear to each other, and I find, from the admeasurement of these areas in eleven separate towns of various population, that the average extent of the public surface is not one-fifth of the area of the private property, or rather of that portion of private property to which the drains would extend. By separation to this extent, therefore, four-fifths of the rainfall would flow to the original sewers with the house drainage, and one-fifth to the new or rain-water sewers.

But if the system is to extend, in addition, to private properties, where is the separation to take place? A complete double system of house drainage would be necessary. Will the interior of the house be drained to the refuse sewers, and the exterior to the rain-water sewers? the stable yard with its dung-pit to the one, the stable itself to the other? Or will the waste from the wash-house sink, and that from the accumulations in house-yards of the lowest class, where the scavenger rarely enters, drain their several ways?

It is manifest that the separate system, if by it we mean the division of a clear water drainage and a foul water drainage, is simply impossible; but were it not so, it would simply be, in the agricultural view, a question whether it would be cheaper to construct this costly system of complicated works, than to apply the useless rain-water to the land, or to waste the sewage on wet days. But it will be observed that the distribution of the additional quantity is not all profitless expenditure. Large quantities of manure are at all times brought down from town surfaces by rain, although the street washings will not often be found anything like so rich in fertilizing elements as were those of the metropolis examined by Professor Way.*

There is no sufficient evidence of the precise value of these elements; but there seems reason to suppose that at all ordinary times a very large addition of manure is thus washed down with the house sewage. This fact is the more obvious to those who have given much attention to the subject, from the evidence which is constanly presented to them of the rapidity with which stagnant water from street surfaces becomes extremely offensive, although kept perfectly distinct from other drainage. During repeated examinations, some of the foulest emanations I have experienced were from places with which no house drainage whatever was connected; the noxious smell came from the surface refuse only, washed by the rain into gullies and catch pits.

And this consideration leads me to the main objection to this proposed separate drainage, namely, that we should have two foul systems of sewers and house drains instead of one; at the best, two sources of foul atmosphere ramified over every town, and each the more dangerous for that very separation. So that even if the interests of agriculture loudly demanded this treatment of the case, and the enormous cost were not an object, REGARD FOR THE PUBLIC HEALTH WOULD FORBID IT.

In short, the public would be called upon to incur double expense for a source of great and decided danger to their health, and a very questionable advantage to agriculture.

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* The objections to the separate system are far stronger in the metropolis than in provincial towns, both on agricultural and sanitary grounds. In the first place the rainfall does not bear so large a proportion to the water supply, and in the next, it becomes much richer in manurial elements, or in other words, much more foul and noxious than in less crowded places.

The Utilization of Sewage in the Liquid Form.

I shall now proceed to a description of the methods employed for utilizing liquid sewage as it flows to the outfall.

The methods of application of liquid sewage to agriculture fall under two divisions:—

1st. the system of open irrigation, which has been practised in some places for many years; and,

2nd, the system of underground pipes, and distribution by moveable hose and jet, which has been brought into practice only within the last few years.

1. *The System of Open Irrigation.*

Of the application of sewage by open irrigation the Craigentinny meadows at Edinburgh certainly form the most striking and successful example.

The area of land in question consists in all of about 260 Scotch acres, the Scotch acre being rather more than an acre and a quarter English. They are irrigated with the waters of the "Foul Burn," into which about half the City of Edinburgh is imperfectly drained.

Over the "Old Meadows," which comprise about 180 acres, the sewage is said to have been so applied for these sixty years. This land lies somewhat on a gentle slope. It was partly drained some time ago. I was informed by the Superintendent that these drains were, in his opinion, rather an injury than a benefit, as they carried the liquid too rapidly from the land. Mr. Oliver, however, under whom the drainage was carried out, believed that he derived great advantage from it, as it permitted the water to percolate the soil to a greater depth than it otherwise would have done. Another informant states, no doubt with much truth, that if, on the one hand, the sewer water is allowed to form pools on the land, the crop is destroyed, or the yield is small in quantity and bad in quality; but, on the other hand, in very dry seasons, the exits of the drains require to be plugged up in order to retain a sufficient degree of moisture in the land.

The soil of another portion of the meadows which was laid out about thirty years ago consists of sea sand, which, before the irrigation was commenced, was very nearly barren and worthless. The whole of this land is irrigated by gravitation from the Foul Burn, but another portion, consisting of about fifty acres, lies above that level, and to this the sewage is raised by a steam engine of about eight-horse power.

The sewage water is conducted to the Old Meadows by open channels or ditches, following the levels of the ground; but the level lands more recently irrigated are divided into panes of about half an acre each, over which the water is successively conducted.

The irrigation goes on incessantly, except on Sundays, all the year round, winter and summer. Two men complete the irrigation of all the lands supplied by gravitation in about three weeks or a month, and then work through it again. The operation is conducted night and day, and a weekly return made of the work done.

No other manure is ever applied to the irrigated lands.

Each irrigation of the 50 acres of high level land is completed in about ten days.

The quantity of water discharged over the low lying lands in the course of the year must be enormous. I had no opportunity myself of testing the ordinary flow of the Foul Burn, as there was incessant rain during the whole period of my visit; but it has been estimated at 220 cubic feet per minute. The Superintendent informed me that it is never allowed to run to waste except in times of excessive floods. There are not many days in the year in which a greater amount of rain would fall than during my visit, and the irrigation was then proceeding as usual. If it be only assumed, however, that the quantity which comes down in dry weather is applied during nine months of the year, deducting the Sundays as well, there will, on the above calculation, be passed over the meadows annually a depth of water between six and seven feet; and yet the Superintendent states, that the fertility is invariably in proportion to the quantity of sewage employed.

"The more water each portion receives the larger is the crop raised on it, and the higher the price got for that crop in the market."

The higher level lands do not get nearly the same quantity, because of the expense of pumping, and the results are proportionally less.

I could perceive no trace of effluvium from any part of the *land* under irrigation at the time; but although it was cold weather, sufficient smell arose from the *ditches* to indicate that in summer time they must become highly offensive. I agree in the conclusion arrived at by several previous observers, that the solid deposit in these channels has been the cause of all the complaints that have been made of these works of irrigation, and I believe that the evil, under a better system and with greater care, may certainly be obviated. I shall have to allude further to this point in another part of my Report.

The solid deposit is at times cleared out from the ditches at Edinburgh, and is used with other manure on other parts of the farm.

The laying out of these meadows for irrigation is said to have cost from 6*l.* to 30*l.* per acre; the chief portion of the work, that of the old meadows, having cost 15*l.* per acre.

The drainage of the town of Tavistock was undertaken at the cost of the Duke of Bedford, and completed about six years ago. During its construction about 90 acres of meadow land were prepared in catch meadows and beds for the purpose of irrigation with the sewage of the town. About 10 acres only of this land were drained.

Mr. Benson, the Duke's steward, in a communication to the first General Board of Health, in September 1851, says:—

"There are only 50 waterclosets in Tavistock which are supplied by water, and which communicate with the sewers. There are, however, a considerable number of privies, the drainage of which goes more or less into the sewers; as does also the drainage from various stables, pig-houses, slaughter-houses, and other premises. It would, however, be impossible to estimate the proportion of fertilizing matter which the occupiers secure to themselves, and how much is allowed to escape into the sewers. It is, however, supposed that the greatest portion of the privy-soil, and the whole of the housewash of about 500 dwellings, is carried into the sewers; a great portion of the houses having drains from the premises direct to sewers, while others are merely drained on the surface, and the waste arrives at the sewers with the wash of the streets."

At the time of my visit to Tavistock, in December 1855, about 70 additional waterclosets had been admitted to the sewers, and about 30 new houses.

There is nothing particular in the formation of these meadows; they are irrigated by two main open lines of gutter, an upper and a lower level, from which the subsidiary channels lead. These carriers vary from 1 foot to 3 feet in width, and seemed to me considerably wider than necessary I could not help remarking, also, the considerable slope at which the beds are formed, which I should think must carry off the water much more rapidly than desirable.

An ample supply of water has been provided for Tavistock at the Duke of Bedford's expense, and the sewage appeared to be in the usual state of dilution for dry weather; but the solid matter is entirely disintegrated before reaching the outfall, owing, no doubt, to the amount of friction to which it is subject in the angular-shaped inverts which have been adopted in the sewers here.

The sewage is applied to the meadows throughout the year, winter as well as summer, but not in the continuous mode adopted at Edinburgh. At certain seasons, therefore, and when the grass is high, much of the sewage is allowed to run to waste in the river.

It was cold weather at the time of my visit, but there was a perceptible, although not a strong smell of sewage in the meadows. The little offensiveness there was seemed attributable to a considerable amount of deposit at the outfall and along the course of the channels.

The Duke of Bedford formerly held 25 acres of this irrigated land himself, but the whole 90 acres are now in the hands of two tenant farmers.

The cost of these irrigation works appears to have been a little over 13*l.* per acre, and the working expenses about 15*s.* per acre per annum.

At the town of Harrow, which has been drained under the Public Health Act within the last few years, the sewage has for some time been applied to neighbouring grass lands by surface irrigation; but very little has been done by way of works for this purpose, nor is the sewage yet employed with anything like system for the production of the utmost effects, although the favourable position of the lands offers an admirable opportunity for doing so at very small cost.

Harrow stands on an eminence, with a rapid fall in all directions, and when the new works were first executed there were nine outlets for the drainage. The sewage at the mouths of the two main outfalls was originally stored in pits and ponds somewhat too near to the town, and complaints of nuisance arose. The pits have now been abandoned and filled up, and the two outfalls have been connected and extended in one main line of eighteen inches diameter to a point where no nuisance can be caused to the town.

All cesspools at Harrow have been removed, and soil pans and six-inch house drains have been substituted; but although waterworks have been established by a company, water has not been laid on to most of the poorer class of houses. These obtain their supply from pumps and wells as before, and there being a rapid fall, the drains are kept clean by throwing the house slops into the soil pans.

Taking into consideration, also, that a large part of the population of Harrow consists of the school establishment, the consumption of water per head must be considerably less than in other towns of which the drainage is complete, and its sewage in dry weather must be far less diluted than usual.

The sewage has been hitherto applied only on Mr. Chapman's farm in a rude manner through the spring and summer months, but with admittedly good results. It is stated to be the intention to make better and more extended provisions for its use.

Dr. Bucknill, of the Exminster lunatic asylum, Devon, has for some time applied the sewage from that establishment to some neighbouring grass land by open irrigation on a small scale, and also for promoting the growth of vegetable produce.

The sewage derived from the imperfectly drained town of Crediton has been for many years employed for the irrigation of some neighbouring flat low lying lands called "Lord's Meadows," consisting of about 32 acres.

An offensive open sewer conveys the sewage from the town, and the only discharge for it is by means of the irrigating channels through these meadows, whence it passes into certain ditches which have their outfall into the river Creedy.

Other land also, higher up, called the "Palace Meadow," and very near to some of the houses of the town, is irrigated from the same open sewer.

The irrigation goes on winter and summer, producing luxuriant growth. There is nothing particular in this case to distinguish it from the ordinary method of irrigation practised in Devonshire, except the fact of sewage being used instead of simple water.

There are many similar cases to be found throughout the country. I call attention to this one among them, more for the purpose of offering a few observations as to such modes of dealing with the sewage, when treating of the results of its application in another part of my Report.

On some other land near Crediton, which this same open sewer traverses, pits were formerly used for intercepting the solid matter of the sewage for manure, but these being found a nuisance, an action was brought by the Poor Law Guardians, and the proprietor was compelled to abandon them.

For the same reason which leads me to refer to the Crediton meadows, I will allude also to two important cases of irrigated lands, of which particulars are given in the Report of the first General Board of Health, the catch meadows at Pusey, and the Clipstone water meadows, although I have not had an opportunity of examining them.

The Pusey meadows consist of about 100 acres of flat land, which before the irrigation was commenced, was said to be worth a rental of about 5*s*. per acre.

The expense of forming the gutters, &c., varied from 4*l*. 10*s*. to 2*l*. per acre; the cost of earthwork and labour having been much diminished in the portion more recently executed. The amount of cost was equal to an average of 3*l*. 4*s*. per acre, exclusive of sluices. These were of oak, and cost 2*s*. 6*d*. each, and ten of them were reckoned as necessary to the acre, making altogether 4*l*. 9*s*. per acre. In some parts, however, clods were used instead of sluices; but taking the expenses of diverting the stream into account, Mr. Pusey stated that this estimate could not be far wrong.

The irrigation of the Clipstone water meadows, which consist of about 400 acres, is effected by a considerable work. The River Maun, which in passing through Mansfield receives the drainage of that town, is diverted from its natural channel by a flood dike 4 yards in width, extending a distance of 5½ miles on a perfect level. At the extremity of this line a new dike commences, extending for a further distance of 1½ miles, in the course of which it receives other drainage.

The formation of the channels for irrigation is thus described:—

"The centre carriers are at right angles with the flood-dike and the river, and have a quick descent. They supply a great number of cross carriers, branching off on each side, so as to form figures, like what is known by the term 'herring-bone.' The cross carriers are level, and shed the stream over the surface from one to the next carrier successively, until it has done its work, and reaches the river.

"The carrying gutters at Clipstone are not cut out by vertical spits below the level of the ground, but are hollow dished channels, two or three feet wide, upon which the grass grows almost as freely as upon the other parts of the meadows. This has two important advantages; there is no loss of producing surface, and the cost of cleaning gutters is almost saved."

The average cost of formation is said to be at least 120*l.* per acre, which, taken at 7½ per cent., with 10*s.* per annum added for superintendence, &c., makes a total annual charge of 9*l.* 10*s.* per acre.

The whole area of what is now water meadow would have been well let, it is stated, at from 3*s.* to 5*s.* per acre, before these works were executed. Such of the land as is now let irrigated produces a rental of 4*l.* 10*s.* per acre, but Mr. Denison, in his account of these lands, gives statistics of the produce, showing the average annual value to be not less than 12*l.* 4*s.* per acre.

It may be useful also to refer to an example of irrigation in Lombardy with the sewer water of Milan, upon which some important considerations arise. A description of these works by the Count Arrivabene, one of the Surveyors, is appended to the Report of the first General Board, and the following is extracted therefrom:—

"The city of Milan consists in three concentric circles, two of which are formed by canals constantly provided with flowing water, and the other by the town walls.

"The inner canal, or Sevese, which is the most ancient, encloses the first nucleus of the city under the Romans, is all covered, and serves only for drainage. The other canal, or Naviglio, which forms the second circle, encloses the city as it was during the middle ages, is open, and serves for navigation as well as drainage. The Sevese carries off the drainage of the two inner circles, and the Naviglio that of the external.

"All the streets of the city have along the centre a subterranean sewer in brickwork, and proportionate in its dimensions to the body of rain water it is intended to receive, considering the length of the street and the depth of the houses on its sides. The rain from the front roofs is collected in vertical pipes fixed to the walls of the houses, and runs through subterranean gutters into the longitudinal sewers of the street. The rain from the back roofs and courts, as also the waste water from offices, provided it be absolutely liquid, flows in the same manner into the street sewer. But the houses along the two canals discharge at once into these, not only their liquid drainage, but every sort of half-liquid material proceeding from water-closets and laboratories.

"The drainage of the city being thus carried to the Sevese and the Naviglio, either by the street sewers, or direct by the gutters of the neighbouring houses, the street sewers are levelled according to the depth of the canal into which they discharge their contents."

The Sevese is cleaned twice a year, in April and September, periods at which the water of the canal is turned off.

"The Sevese derives its water from the Naviglio by means of three inlets, one of 17 inches, the other of 10, and the third of 6, in three separate spots These waters are then collected by another canal, called Vetra, which, after receiving another contribution from the Naviglio, assumes the name of Vettabbia.

"The Vettabbia flows out of the southern part of the city, and, after a course of 10 miles, discharges itself into the river Lambro, fertilizing prodigiously a considerable extent of meadow land. It can be easily conceived what must be the fertilizing quality of the Vettabbia, as it carries off all the filth of a city of 150,000 inhabitants, and the quantity of fertilizing matter borne along by its waters raises in such a manner the surface of the meadows it irrigates, as to render it necessary that from time to time the deposit should be removed from the meadow in order to preserve the level of irrigation. The deposit is by itself an excellent manure, and is bought by the neighbouring agriculturists as a fertilizer. The Vettabbia possesses also the valuable peculiarity of protecting from frost the meadows it irrigates, owing to the high temperature it receives in its passage under the town.

"The Cistercian monks were the first who turned to a profitable use the slimy waters of the Vettabbia, and introduced the system of irrigation, which forms a most important branch of the agriculture of Lombardy.

"The waters of the Naviglio, after receiving the drainage of the remainder of the city, are also applied to the irrigation of an extensive surface of land.

"It may, perhaps, not be useless to add a short description of the water meadows, which in Lombardy are called *marcite*. These meadows are divided into various rectangular zones, about 22 feet wide, by means of rectilineal channels, which serve alternately, one for irrigation, and the other for draining. These zones are arranged so as to have a slope of about six inches from the channel of irrigation to the draining channel. The waters of the feeder, which is placed on one of the sides of the meadow, at a right angle with the channels of irrigation, flow into these, and through the whole of their length spread over the zones on both sides, covering them, as it were, with a watery veil, which preserves the life of the plants and promotes their vegetation. The water of the draining channels is then collected again into another channel, which conducts it to irrigate another meadow in a similar manner. The *marcite* are irrigated in summer during a certain number of hours about once a week; and from the end of September to the end of March they are irrigated permanently, the water being only turned off when the grass is cut. During winter the irrigation of the meadows is also carried on with spring water, which landowners are authorized by law to conduct to their lands through the lands of their neighbours. To this very ancient law a great portion of the agricultural wealth of Lombardy is to be ascribed.

"Some of the meadows irrigated by the sewerage water of Milan yield a net rent of 21*l.* per *tornatura* (a measure of 10,000 square metres, equal to about two acres and a half), besides a land tax of 61 francs 10 cents, the expenses of administration, repairs of buildings, &c. These meadows are mowed in November, January, March, and April, for stable-feeding; in June, July, and August they yield three crops of hay for the winter, and in September they furnish an abundant pasture for the cattle till the beginning of the winter irrigation."

The two cases of the Pusey and the Clipstone Meadows are cited as examples respectively of the cheapest and of the most expensive mode of laying out land for the purposes of irrigation; the formation of the Pusey Meadows having cost 4*l.* 9*s.* per acre on the average, the Clipstone Meadows, 120*l.* per acre; but in even stronger contrast to the heavy cost of the Clipstone works, I will here briefly notice the system of laying out land for irrigation introduced by Mr. Bickford, of Crediton, who has had some 20 years' experience of water meadows.

My attention was drawn by Sir Stafford Northcote to this simple yet efficient method of conducting water over lands whether of even or of undulating surface; and I beg to append to this report (App. C.) the account given of it by Sir Stafford in the Journal of the Agricultural Society of England.

I allude to this system, not because it is applicable for the irrigation of land with the sewage of towns as at present conducted; but because I desire to offer some suggestions herein-after in relation to it, having much reason to believe that with certain modifications this method may be made a most valuable adjunct.

The principle of Mr. Bickford's plan consists in so disposing of his irrigating lines, that whatever the levels, or whatever the inequalities of the surface, an equalized distribution of the flow is secured over the whole area, without any artificial formation of the ground.

This is accomplished by tracing over the land a series of very small contoured (or nearly contoured) lines of gutter, subsidiary to the main carrier, so that as each level line is filled, the water sheds equably over its edge, to irrigate the next area in succession.

It has the effect, in short, to use Mr. Bickford's own words, "of continuing (and even causing) a smooth and uniform surface to the meadow, allowing of the operations of mowing and carting over the meadow, without any sensible perception of the existence of the gutters used for irrigation."

These gutters are about 4 inches wide and 1 to nearly 4 inches deep, and obviate the necessity for the usual large and frequent level gutters. They are cut with a die fixed in a sort of plough of simple construction.

Any series of the gutters may be reached by cross feeders, without necessarily first irrigating those above, so that lower portions of ground may, whenever desired, be irrigated before the upper levels.

Sir Stafford Northcote estimates, from experience on his own land, that water meadows similarly situated might be completely laid out at an expense not exceeding 1*l.* per acre; and that the annual expense of cleaning the gutters, or of cutting fresh gutters by the side of the old ones, may be taken at 1*s.* per acre.

2. *The System of Underground Pipes.*

Distribution of Liquid Farm Manures.—Before entering upon a description of the works which have been recently laid down for the application of the liquid sewage of towns to agriculture by a system of under-ground pipes, it will be well to refer to some instances of the farms upon which works are in use for distributing artificial and farm manures in a liquid form, as these have been in operation for several years, and the arrangements since adopted for the distribution of sewage have been founded upon them, and are of very similar character.

The cases of this class comprised in the appended list (App. D.) have been brought to my notice, but other instances no doubt now exist, so much attention having of late been given by agriculturists to the advantages obtainable by such works.

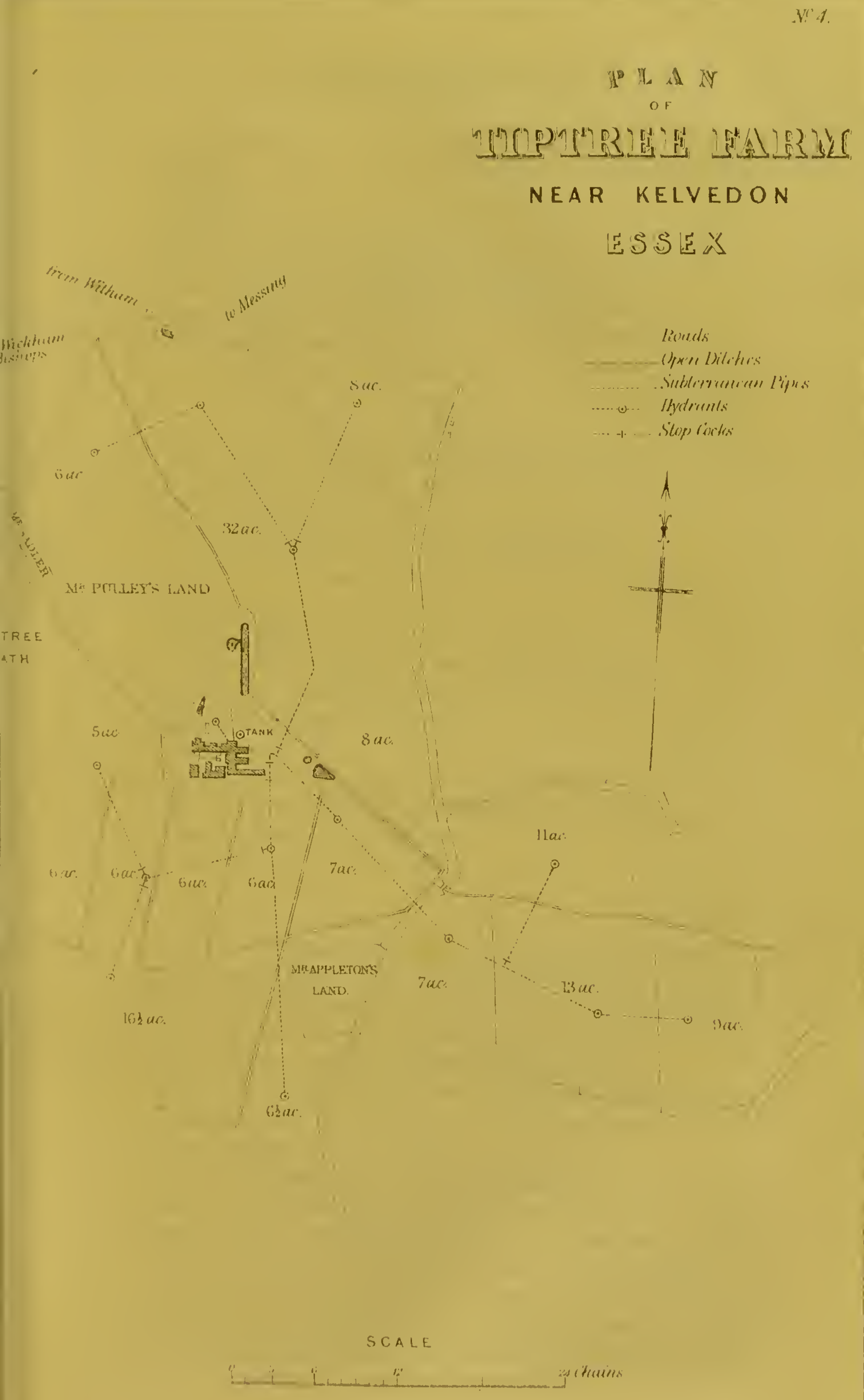
It would not have been necessary for the purposes of this report, even if it had been practicable for me, to visit the whole of these establishments. Some of those which had already been described in the report of the first General Board (made in 1851), it seemed desirable to visit, in order to observe any further points of experience which might have been gained. I shall confine myself, for the most part, with regard to these places and to others I have also had the opportunity of inspecting, to such points as may seem to bear upon the immediate object of this report, namely, to afford useful information for guidance in the laying out or management of similar works for the application of the sewage of towns.

The principle of the plan is soon described. It consists simply of a system of under-ground pipes laid over the farm, into which the liquid manure is forced from a tank either by gravitation, or by pressure from pumps worked by steam or water power; and upon these pipes, at convenient distances, certain valves, hydrants, or junction pieces are fixed, to which a length of flexible hose pipe, with a nozzle, is attached when required for distribution of the liquid over any part of the land.

Such a system of pipes has been for some time laid over Tiptree Farm, and Mr. Mechi has furnished to the public from time to time the valuable results of his experience on this subject. The accompanying plan (No. 4.) of Tiptree Farm is copied from one furnished by Mr. Mechi to Morton's Cyclopædia of Agriculture.

The farm comprises 170 acres, chiefly of arable land, and the pipes are laid so as to command the whole area. A covered circular brick tank capable of holding 80,000 gallons receives all the solid and liquid farm refuse, and it is there diluted by water, in part derived from the drainage of the land, and the whole is kept in agitation by the spare steam from the engine playing through an arrangement of perforated pipes at the bottom of the tank. The engine is of four-horse power. The pipes are all of 3 inches diameter, 50 tons weight in all, and in length 2,550 yards, or 15 yards to the acre.

The following is Mr. Mechi's statement of the cost of the works:—


No. 4.
PLAN
OF
TIPTREE FARM
NEAR KELVEDON
ESSEX
from Witham
to Messing
Wickham Bishops
Roads
Open Ditches
Subterranean Pipes
Hydrants
Stop Cocks
8 ac.
6 ac.
32 ac.
Mr. PULLEY'S LAND
TREE
ATH
5 ac.
TANK
8 ac.
11 ac.
6 ac.
6 ac.
6 ac.
6 ac.
7 ac.
Mr. APPLETON'S
LAND.
7 ac.
13 ac.
9 ac.
16½ ac.
6½ ac.
SCALE
Chains

	£
Tank - - - - -	100
Engine - - - - -	100
Pumps - - - - -	60
Pipes, laying, and hydrants - -	350
Gutta-percha distributing pipes - -	50
Extra taps, air vessels, and sundry minor arrangements - - - -	60
	£720

or about 4*l.* 5*s.* per imperial acre. The price of iron, however, at the time these works were executed was as low as 5*l.* per ton.

The daily working cost is stated to be—

	s.	*d.*
Coals, at 1*s.* per cwt. - - -	6	0
Man at engine - - - -	1	8
3 boys } working two jets, and moving the pipes - - -	1	6
1 lad }	1	0
Wear and tear, and repairs - -	2	6
	12	8
7½ per cent. interest on first cost 54*l.* per annum or for 300 days - -	3	7
	16	3

The quantity delivered daily, in ten working hours, would be 130 tons of water, but Mr. Mechi estimates that the cost of delivery may be fairly placed at from 1½*d.* to 2*d.* per ton, "the specific gravity of liquid manure being so much greater than water."

There will be distributed over the whole farm on the average from 45,000 to 50,000 gallons of liquid manure per acre per annum.

Of course, if at any time desirable, the liquid manure of the farm may be applied in a concentrated state, but Mr. Mechi's practice is to dilute it sufficiently to avoid any offensiveness, and certainly on the occasion of my visit, in warm weather, although there was a perceptible smell from the jet, it was by no means powerful, and the land was perfectly free from any odour of manure within a minute of its application.

At Myer Mill Farm, in Ayrshire, which until recently was rented by Mr. James Kennedy, works for the application of liquid manure have been established for some years, and have been previously described in the Report of the first General Board. The arrangements differ somewhat from those at Tiptree, and especially in the fact that water has to be raised about 70 feet for the purpose of diluting the liquid manure.

The pipes are laid over about 400 imperial acres of very variable soil. The liquid refuse of the farm drains into four separate covered tanks, of a total internal capacity of nearly 45,000 cubic feet, and capable of holding three months' liquid produce of the farm. An agitating apparatus was fixed in each of these, but it has never worked efficiently. A fifth tank, of 20 feet diameter and 15 feet deep, is situated on the high ground at a distance, to which the liquid manure is raised and thence applied to a part of the farm by gravitation.

The pipes are of iron, of 5, 3, and 2 inches in diameter, and upon these, hydrants are placed at intervals for attaching gutta-percha distributing hose. The engine is of 12-horse power, but it is not wholly employed in pumping; all the usual farm machinery is worked by it as well. From 3,000 to 4,000 gallons are pumped from the tanks per hour. The liquid manure had not been applied to the land for three months before my visit, Mr. Kennedy having just vacated the farm; but the agent informed me that it had been the practice to apply from four to six dressings in the course of the year, and about 6,000 gallons per acre at each dressing after cutting. The smell was said to be perceptible for a day or two after application.

Besides the liquid manure produced from about 130 cows and from 1,600 to 1,800 sheep, large quantities of other manure—farm-yard, guano, and ammoniacal liquor,—were applied on the farm. It was the practice to sow the guano, and then wash it in with the hose. The liquid manure was applied winter and summer.

One man attended to the engine, and a man and a boy to the distribution; their wages were under 2*l.* per week.

I could not obtain any reliable information as to the complete cost of these works, but as there is nothing special in their character the outlay may be presumed to be somewhat similar to that of other ordinary cases, which appears to be on the average about 5*l.* 10*s.* per acre; the range having been hitherto from about 4*l.* 10*s.* to 6*l.* 10*s.* per acre.

The tanks are unusually large, but they were cheaply constructed of stone obtained in the neighbourhood. Iron would be cheaper here than in many other localities, but additional outlay was necessary for raising a supply of water for dilution.

The arrangements at Mr. Robert Harvey's dairy farm, near Glasgow, differ again in some degree from those previously described.

The pipes are here laid to command the distribution of liquid manure over 400 acres of heavy clay land of a hilly character, immediately above the city of Glasgow.

Mr. Harvey possesses an extensive distillery here, and the dairy of about 700 cows appears to have been established with the view to the profitable disposal of the grains, and the farm arrangements are subservient to this establishment.

The works for the application of the liquid manure on the farm were established some years ago in consequence of the complaints of nuisance from its previous discharge into the adjoining canal.

The whole of the liquid refuse from the cow byres, and the waste fluid from the distillery, drain into a tank capable of holding 30,000 or 40,000 gallons, whence it is raised by an engine of 12-horse power, fitted with two 5-inch pumps, into nine circular wooden cisterns or brewer's vats erected above ground on the different high points of the land.

The rising and connecting main to these vats is 4 inches in diameter, and the different systems of pipes laid over the land from the vats are supplied by gravitation from these centres.

Hydrants are fixed at certain intervals along the pipes, to which, instead of the considerable lengths of flexible hose now more commonly used, moveable iron pipes in three-feet lengths, and of one and a half inches diameter are attached, being joined on to each other as they are successively required for the irrigation of the more distant parts around. The distribution is effected either by shedding from the end of these pipes as they lie on the ground, or by a short length of gutta percha and canvas hose joined to the end of them, and fitted with a nozzle.

The liquid manure appears to be used in a very concentrated form; in fact, at the time of my visit, it was being shed on the land in about the consistency of pea soup, but there was then only a small supply in the tank from which it was delivered. There was an offensive smell from the distribution, as might be expected, and the irrigated land remained in an unpleasant state, the refuse being too thick to be absorbed.

I failed in obtaining any particulars as to expenses of the works or as to produce on this farm. Mr. Harvey was unwilling to afford any information, and he assured me, indeed, that he had kept no records whatever that would enable him at any time to make a correct estimate either of the cost or of the results of this work, distinguished from the other operations of his establishment.

The cows are in great part fed from the distillery.

Mr. Telfer's dairy farm, near the town of Ayr, over which pipes are laid for the application of liquid manure, consists of about 50 imperial acres on a low level, close to the sea, the subsoil being in great part beach gravel. Forty-eight cows are here kept, and the dairy arrangements are a perfect model of neatness and of ingenious contrivances for the health and comfort of the cattle.

The cows lie on cocoa-nut fibre mats. No litter is used, and the solid and liquid excrement of the animals drain together from the byre into a tank outside, which is capable of containing about six weeks or two months' supply. The liquid from this tank is applied by the hose and jet over the farm; the solid is allowed to deposit and is mixed with the farm yard manure, and employed in the usual way.

Another liquid manure tank adjoins the one for the reeeption of the refuse from the byre, from whieh ammoniacal liquor, phosphates, &e. are also applied by the hose and jet. Both tanks are open.

The liquid is raised from these tanks, and the requisite pressure for distribution given in the pipes by a three-horse engine working two 4-ineh pumps. The pipes are of iron, 3 inehes diameter, and a length of 150 yards of gutta pereha pipe 1½ inehes diameter is fixed to the hydrants for distribution. Eaeh hydrant eommands about 3 acres.

In addition to its use for irrigation the engine is employed in churning, pumping water, and other farm purposes.

From four to six cuttings of Italian rye grass are obtained, and after each cutting the land is dressed with about one inch depth of liquid manure, say 23,000 gallons per imperial aere. Guano is sown on the land and washed in with the hose.

The system of liquid manuring is considered a most useful auxiliary on the farm, but it does not supersede the employment of manure in the usual way. Large quantities of solid manure are used.

John Daw, Esq., of Exeter, farms about 100 aeres of heavy elay land at St. George's Clist, about five miles from that city, and he has had 3-inch pipes laid over 35 acres of drained land, for irrigation with the liquid manure from the eattle sheds and homestead.

The requisite pressure for distribution is given by a water-wheel 17 feet in diameter. The irrigation goes on only for about eight hours, one day in the week on the average, but it is employed most frequently in the winter and in times of rain, for there being no water to spare for dilution, the liquid manure is used in the concentrated form as it drains into the tank.

The tank is capable of holding 100 hogsheads, or 5,400 gallons, whieh quantity is applied at each working to an acre and a half of land.

There are eight hydrants or junction pieces on the pipes for attaching the distributing hose. The cost of the works, exclusive of the power, which is employed for all other farm purposes, was about 5*l.* per acre.

Distribution of Liquid Sewage.—Although for some years past works of the nature already described have been established on several farms in this country for the application of manure to the lands in the liquid form, it is only recently that works have been established for the application of town sewage in the state in which it drains to the outfall.

From this statement, however, the abandoned works of the Metropolitan Sewage Manure Company, established some eight or nine years ago, must be excepted; and as these works, notwithstanding their abandonment, afford an instructive lesson, it will be useful briefly to refer to them.

The pipes were laid over the market gardens of Fulham, the steam-engine, and stand pipe 75 feet high, being situated at Stanley Bridge, adjoining the Kensington Canal. About 15 miles of pipes were laid down, ranging from 14 to 2 inches in diameter. The sewage was taken from the Walham Green sewer. Hydrants were fixed at convenient points on the pipes, and the tenants of the lands over which they were laid paid a rent to the Company of 3*l.* 10*s.* per acre per annum for the privilege of distributing the sewage themselves whenever they pleased.

Such are the particulars of these works given in the report of the first General Board of Health. I shall have to show, further on, how impossible was a successful commercial result from such an undertaking.

The most important and complete example of works for the distribution of town sewage is that in the neighbourhood of Rugby, where G. H. Walker, Esq., of Newbold Grange, has established the necessary means for applying the sewage of Rugby to his land.

PLAN OF GROUND
UNDER
Irrigation
FROM THE
SEWAGE WORKS
OF
G. H. WALKER, ESQ^R
In the Neighbourhood of
RUGBY.

Complete works for the drainage and water supply of Rugby have been carried out within the last few years under the Publie Health Aet. The sewage is estimated to proceed from a population of about 7,000, and in quantity it is ealculated at about 160,000 gallons per day. All eesspools have been abolished in the town, and even the humblest dwellings have been provided with water-elosets, so that the whole of the fœeal refuse is at once removed from the site of the houses, and diseharged at the outfall before time has been allowed for its deeomposition.

The outfall for the drainage was originally eonstrueted for diseharge into the River Avon, and this line still forms the overflow during flood, or when the applieation of the sewage to the land may from any eause be interrupted; but the outfall for ordinary diseharge is now into an open briek reservoir of 50 feet diameter and 12 feet depth, on Mr. Walker's land.

From this reservoir the sewage is foreed into the system of east-iron pipes laid over the farm by a high-pressure steam engine of 12-horse power, fitted with an ordinary 12-ineh pump usually worked with a 2-feet stroke. The greatest elevation to whieh the sewage is pumped is about 60 feet above the reservoir, but a eonsiderable portion of the land is only 20 feet above that level, and some of it is 20 feet below.

The engine works at the same time a small air-pump for the purpose of agitating the sewage in the reservoir, and preventing deposit of the solid matters. An ineh and a half gutta-pereha pipe extends from the air-pump to the reservoir, where the diseharge of air from it keeps up a constant ebullition in any part required.

The pipes are laid over 470 aeres of ehiefly grass land (plan No. 5), and eomprise a length of about 5½ miles, or about 20 yards per aere. They have not been properly graduated in size; the rising main is 6 inehes in diameter; and all the branehes are of 3 inehes.

Upon these pipes, at distanees varying aeeording to the requirements of the land, 66 hydrants or junetion pieces are fixed, to which the moveable gutta percha piping is attached from time to time as it is required to distribute the sewage in the neighbourhood of each.

Until recently there were but thirty-nine of these junction pieces, but they were found inconveniently distant. There is even now only one hydrant to about $7\frac{1}{2}$ acres on the average.

Mr. Walker originally employed the usual ball valve hydrants used in waterworks, but he did not find them successful, as the solid matters constantly prevented the close contact of the valve. The hydrant, properly so called, is not now used here at all, but a common flanged junction piece is fitted on the line of pipe, turned up vertically, capped with a simple flat cover, secured with a couple of nuts, with a gutta-percha ring between. The hose is provided with a mouth-piece which is fitted on for use in the place of the cover, when the engine is not at work or when the sewage is shut off.

About 140 yards of $2\frac{3}{4}$-inch gutta-percha hose is used, to the end of which two lengths, each of 100 yards, of $1\frac{1}{2}$ inch pipe are attached for distribution. The $2\frac{3}{4}$ pipes are in 20-yard lengths, as many being secured together as are required, by a screw clip. Five or six of these $1\frac{1}{2}$-inch distributing pipes are in constant work. Trial was made of the flexible canvas hose for distribution, but it rotted in a very short time. The gutta-percha pipe remains sound, except where damaged by heat, or by clinking in the cold weather.

The hose is apt to get choked at the junction of the smaller pipes with the $2\frac{3}{4}$ main length, which occasions some trouble, but this would be corrected by better means for preventing solid substances from reaching the pumps.

These works have cost very nearly 3,000*l.*, or about 6*l.* 7*s.* 0*d.* per acre. With the experience now gained, Mr. Walker considers that complete works might be executed for 5*l.* per acre, and, moreover, looking at the quantity of sewage at command, he would not, in laying down the work de novo, extend the system over so large an area.

About 100,000 gallons, or 446 tons per annum are now on the average distributed on each acre of land at a cost of 20*s.*; that is to say, that the interest on outlay, rent of sewage, coals, labour, and all expenses amount to 1*l.* per acre per annum.

Mr. Walker pays to the Local Board of Health of Rugby, 50*l.* per annum for his lease of the sewage.

The land is not drained. This is proposed to be done very shortly; the soil is, for the most part, of a marly character.

I could perceive no smell whatever, either at the reservoir, or on the land even where thoroughly saturated; scarcely was any discernible even when walking close round by the jets. It was cold weather at the time of my visit; but Mr. Walker assured me that no offensive odour has been at any time perceived on the land, although the irrigation is constantly going on immediately around his own house and that of a neighbour.

No distribution, of course, takes place on the Sunday, and smell at the reservoir is said to be very perceptible on Mondays, the sewage having had so many hours time for decomposition before it is received into the soil.

The distribution has gone on through winter and summer for about 300 days in the year, since the works have been established, with only one interruption during the six weeks frost of 1854, when an action was brought against the Local Board for pollution of the river by discharge of the sewage.

During last winter, 1855, the works were stopped only for two days.

The sewage derived from the very partial drainage of the town of Rusholme, near Manchester, has been applied for the last four years upon the land of Mr. Worsley.

These works were examined by Mr. Dickens, Superintending Inspector, in November 1855.

The quantity delivered at the time of the examination appears to have been about 15,000 gallons per day. It discharged into a tank capable of holding about 24,000 gallons.

The area of land irrigated is about 80 acres.

The sewage is forced into the system of pipes laid in the land by a high pressure engine of 3-horse power, fitted with two pumps of 3½ inches diameter, with 9-inch stroke.

The pipes are partly of iron and partly of wood. The iron pipes are 3 inches in diameter, and the wooden pipes are 2 inches. Between 500 and 600 yards of each kind have been laid. The greatest elevation to which the sewage is forced is only 30 feet; but the wooden pipes, which are mostly of poplar, will not stand the pressure, and they constantly require repair and renewal.

Hydrants are placed at intervals on the pipes, to which the distributing hose of gutta percha, 2 inches in diameter, is attached.

The daily quantity of sewage (15,000 gallons) is distributed over 2 acres in the space of 10 hours.

Reckoning 300 days' distribution this quantity furnishes annually to the land irrigated 56,250 gallons per acre, or little more than half the quantity applied at Rugby.

There was very little smell perceived from the sewage issuing from the pipes, but it was stated by Mr. Worsley's agent, Mr. Taylor, that at times when irrigating the field *in front of the house*, they have been ordered to desist, in consequence of the smell being very apparent there.

These works have cost about 500*l.*, being at the rate of 6*l.* 5*s.* per acre.

Two men and a boy are employed with the engine and the distribution of the sewage, at the respective wages of 15*s.*, 10*s.*, and 6*s.* per week. About a ton and a half of coal, costing on the average 7*s.* per ton, is consumed weekly.

The cost of the application of the sewage, therefore, is said to stand thus:—

Wages and coals per annum - - - -	£107	18	0
Interest and depreciation on 500*l.* at 7½ per cent -	37	10	0
	£145	8	8

or about 1*l.* 16*s.* 4*d.* per acre per annum.

Mr. Taylor appears to have expressed himself well satisfied with the effects of this sewage irrigation, and obligingly promised to furnish the result of some careful experiments he was about to undertake as to the relative productiveness of land manured with the sewage and of that manured in the ordinary way, and as to the quality of the produce of each in reference to the fattening of stock.

These works are interesting as an example of how small a place it may be worth while, as a profitable investment, to lay down pipes upon, and even to erect engine-power for the purpose of getting this manure on to the land. The quantity of sewage delivered at the outfall was equal only to the ordinary discharge from 150 houses.

About ten acres of land near the Craigentinny meadows at Edinburgh, but closer to the city, have had pipes laid down for about three years, for the distribution of sewage from the Foul Burn, which is raised for the purpose by a small water-wheel.

I was not able to obtain any detailed particulars of this case, and it is scarcely worth mentioning, except for its smallness and for the enormous produce of Italian rye grass which is said to have been obtained from it.

The town of Watford having been drained and supplied with water under the Public Health Act, the Earl of Essex has entered into a contract with the Local Board of Health to take the sewage upon lease, with the view to its application to the neighbouring lands in the liquid state.

His Lordship has agreed to pay 15*l.* per annum for the use of the sewage for a term of fourteen years, and he conveys to the Local Board the freehold of the site of the reservoirs erected by them, and pays 5 per cent. on the cost of construction of these works.

They have been completed for some time. An engine has been erected, and cast-iron pipes of 5, 4, and 3 inches diameter have been laid over 200 acres of land; but various causes appear to have delayed the regular application of the sewage to the land.

Pipes have also been laid by the Earl of Essex over about 40 acres of the Home Park of Cashiobury, by which the liquid manure of the farm has been distributed for the last three years.

In addition to the arrangements for the manufacture of solid sewage manure at Dartmoor Prison already described, the liquid drainage from the establishment is raised by hydraulic engine, (with a pressure on the cylinder of from 20 to 25 lbs. on the inch,) for application to the land.

The buildings are drained by 6-inch earthenware pipes, into an arched cesspool, whence the liquid portion of the sewage is pumped through 2-inch cast-iron pipes into a tank, 13 feet by 7 feet 6 inches and 5 feet 6 inches deep. This tank is situated at the highest point of the fields, about 280 feet above the level of the cesspool, and at a distance of 34 chains.

From this tank two others of the same size are supplied by 2-inch connecting pipes, the quantities being regulated from one to the other by sluice valves. Each of these tanks is furnished with a 2-inch cast-iron outlet with sluice valve, to which 2-inch canvas hose, in 40-yard lengths, with brass couplings, was formerly connected for the distribution of the sewage to the surrounding land; but as the hose was found to decay very soon, the liquid has for some time been conveyed to the different parts required by small channels cut in the land, regulated merely by stopping, where necessary, with a sod.

The liquid is applied to grass lands and green crops with remarkable results; but the dry manure is principally used here, being considered more suitable to the land, which is naturally of a damp nature.

The level of Dartmoor Prison is 1,400 or 1,500 feet above the sea.

Works have been constructed at the Colney Hatch Lunatic Asylum, and pipes laid on the neighbouring land for the distribution of the sewage of the establishment by hose and jet, but the works not being complete, I have not yet had an opportunity of inspecting the operations at this place.

Agricultural Results from the Use of Sewage Manure.

When we look at the enormous value, in the aggregate, of the sewage refuse of our towns,—the metropolis alone producing 140 tons daily of dry manure, of which upwards of 20 per cent is said to be ammonia,—it appears strange at first sight that at a time of great excitement and anxiety as to foreign supplies, so little attention should be given to this great store of fertilizing matter at home; but I believe that little examination is necessary to show that this is a very natural consequence of the present state of the question.

So many contradictions and discrepancies are encountered in the experience of the use of sewage as manure, that I should hesitate to offer any observations on the results of its application, were there not the strongest evidence offered to common sense of the causes of those contradictions.

It would be beyond the province of this report, even if I felt competent to the task, to enter into any comparison of sewage with other manures, or of the advantages of its application in the liquid, over those of its application in the solid form. Unless some standard be used, I am at a loss to know how these comparisons can be made. Nothing has impressed me more strongly, during my inquiries, than the loose but decided manner in which sewage and other liquid manures are frequently spoken of as one and the same thing, of a fixed value, from which the same results may be expected, whatever fertilizing elements they may contain or whatever their amount of dilution.

The analyses conducted by chemical authorities have satisfied them that all the elements required for the food of plants are contained in the sewage of towns, and therefore that, like farmyard manure, it is of value for general application. It is most important to see by what means that value has been hitherto best realized, or what promise there is of attaining better general results, and of removing objections to its use by the employment of improved methods of application.

Chemical examinations of some of the patent solid sewage manures show that they contain certain elements of value as fertilizers; but although some of these have been in use for several years, there appears to be no distinct evidence yet of decided agricultural results. True, large quantities have been sold, even at high prices; but I am afraid that this cannot be admitted as evidence of value.

The slowness of the agricultural mind to depart from old practices, or to receive new doctrines, is often alluded to in explanation of the little progress that has been made in the utilization of sewage. My short experience on the question by no means supports this conclusion. Whether or not the old school of farmers may be open to the allegation, a race of men are now found taking the lead in the agricultural affairs of the country, anxious above all things for progress and improvement, and the very fact that manures will constantly find buyers for the purposes of trial, at 3*l.*, 5*l.*, and even 10*l.* per ton, without satisfactory guarantee that they are worth as many shillings, would suggest rather too great eagerness than any slowness in the trial of new things.

Various analyses of solid manure, manufactured by the lime process from sewage of very different quality in the liquid state, are so far similar as apparently to confirm the statement that very little of the more valuable ingredients is arrested by that method; nor, although this manure has now been in the market for at least eight years, does there appear to be any authentic record of decided increase of fertilization from its use.

Among the analyses of solid sewage manure which show a greater value, Mr. Herapath's, of sewage manure made under his patent, and Dr. Penny's, of manure obtained by Mr. Manning's process are entltied to consideration. Mr. Herapath fixes a price of 3*l.* per ton for manure manufactured by his process; Mr. Manning estimates the value of his manure, according to Dr. Penny's analysis, at upwards of 2*l.* per ton. I do not presume to offer an opinion upon these prices, but no results are yet known from the use of these manures. Mr. Manning states that he has taken measures to ensure trial on a large scale, by dressing land with quantities varying from one to three tons per acre.

The examination of the solid sewage manure of Cheltenham shows a low value, as might be expected, but one sufficiently near the value of manures obtained by the lime process, as apparently not to justify the adoption of the expensive apparatus involved in the latter manufacture.

The agricultural results obtained at Cheltenham warrant the conclusion that, sold at a price which will cover the cost of manufacture, this manure will always be in demand for local use—but for *local use only*, as the expense of transport to a distance would soon run away with its entire value, and even render it costly at a gift.

In the absence of repeated and watchful trial, it is, for obvious reasons, impossible to determine the precise value of a manure. One manure may show good results immediately, but may have an exhausting tendency; another may produce but little result on a first crop, reserving its effects, as it were, for a second, when its value may be ascribed to some subsequent, and perhaps worthless addition; but, so far as can be judged from a single trial, the results from the use of the Cheltenham sewage were very satisfactory.

Two tons of hay were obtained where previously not one ton had grown; the grass much finer than before, and clover abundantly springing up. Mangel wurzel was grown of 35 and 36 lbs. weight, where previously it had attained only from 16 lbs. to 18 lbs. Immense quantities of the manure, however, were applied—too much for economy; and probably good effects may be traced from this first application in subsequent produce; but being a manure of low value, large results could not reasonably be expected from small quantities. On grass lands 20 and 25 cubic yards per acre were applied,—the latter admittedly an overdose; but quantities may be lavishly used at 3*s.* or 4*s.* per ton, that would be utterly ruinous at 2*l.* or 3*l.* for manure of little additional value. All the evidence leads me to doubt whether marked benefit will be found from the use of one, or even three, tons per acre of any solid sewage manure yet made, so far as its value has been derived from sewage.

The Cheltenham manure was used upon heavy land, and the ashes themselves would, in such case, be of lasting benefit. For use upon light land, it may be preferable to prepare the solid manure with clay as the deodorizer, as at Ely, when it can be obtained immediately on the spot; and, in some cases, no doubt, charcoal, lime, gypsum, and other ingredients will recommend themselves.

With respect to results derived from the application of liquid farm manures, although much evidence has been offered on the subject, I have scarcely found in any case that those results could be considered as wholly due to such mode of application, both solid and liquid manures having been, for the most part, used more or less on the same land.

But even where liquid alone has been applied, it proves absolutely nothing in favour of the application of liquid *sewage* to show that certain remarkable results were obtained from the use of liquid *farm manure* of any desirable quality and strength.

Upon one point, however, the evidence as to the application of liquid manures on farms is most satisfactory; as showing, namely, that the laying down of distributing apparatus for the purpose is of itself an excellent investment, from the facility thereby afforded for conveying manures cheaply to the land whenever or wherever required, or for washing in solid manures. This experience is wholly irrespective of the advantage of the application of sewage; but it has an important relation to it as lessening the risk which might otherwise be run, of providing expensive apparatus usefully applicable to this purpose alone.

With respect to the advantages to be derived from the application of liquid town-sewage to agriculture, there is no subject, probably, as to which a greater difference of opinion prevails,—a difference which seems to be accounted for by the very various results of its application.

On the one hand it is stated, that the use of sewage encourages the growth of weeds and of rank and inferior grasses; makes coarse hay; renders the land unsuitable for cattle, dangerous for sheep; and kills the grass in winter.

On the other hand it is alleged, that where liquid town-sewage is applied, fine grasses and white clover, never seen before, spring up; that animals do not suffer, and much prefer the grass last irrigated; that luxuriance of growth is much encouraged by the previous winter's application.

These opposite experiences may all be verified, and appear to be solely due to difference of treatment.

Similar variety will be found in the actual amount of produce obtained, and in the increase of the value of land from the use of liquid sewage.

The land at Crediton, irrigated with the sewage of that town for years, lets in small parcels at about 7*l.* per acre, while good grass land in the neighbourhood, not capable of irrigation, is said to be worth 5*l.* or 6*l.* per acre. The grass of these irrigated fields is both rank and coarse, and the hay of inferior description. The land is very wet and swampy, and cannot be stocked with sheep or cattle so early in the spring or so late in the autumn as other meadows.

The rental of the meadows of Tavistock referred to, varied from 15*s.* to 2*l.* per acre before the sewage irrigation; they are said to be now worth from 2*l.* to 5*l.* per acre. This difference Mr. Benson, the Duke of Bedford's steward, conceives to be due to the irrigation, but considers that were it well attended to, the value would be "vastly increased." The grass was very eoarse here at the time of my visit, and the meadows were looking in very ill condition.

At Harrow the value of the land is admittedly increased by the sewage irrigation, but this inerease is not stated as of any amount, and the hay is said to be of eoarse quality.

Of the instanees in whieh underground pipes have been established for the application of sewage, that of the Metropolitan Sewage Manure Company was, commereially, a eomplete failure. No other result was possible. Considerable works, of the most expensive kind, were constructed for distributing liquid very nearly worthless as manure over a distriet already in possession of the greatest facilities for obtaining the valuable stable manure of the Metropolis at the most eeonomieal rate, by means of the return carts whieh eonvey to London the produee of the market gardens, and whieh would otherwise return empty. In faet, praetically, this was little more than a company for supplying the market gardens of Fulham with water during periods of drought; and, although, no doubt, a beneficial serviee, it will readily be imagined that the saving of labour of hand-watering over a limited district of garden ground would produce no adequate return for so eostly an establishment.

The Rugby works, although sueeessful, ean only be pronouneed so in a limited degree as an investment. The results of the applieation of the sewage, as there eondueted, appear to warrant an estimate that the value of the land is permanently increased by the works to the extent of 1*l*. per aere.

I have reason to believe that these aecounts and statements represent the *usual* increase of value of land from the applieation of the sewage of towns, and the agricultural objections to its use as ordinarily applied.

Let us now turn to the Craigentinny meadows. Part of this land, formerly almost worthless, is now let at from 9*l*. to 11*l*. per Scoteh acre; the average rental of the meadows is said to be 20*l*. per aere; the last highest letting before my visit was very nearly 40*l*. per acre.

From what cause does this enormous difference of value arise? Simply from the fact, that in the latter case, the continuous application of the sewage is reduced to a system, by which immense quantities of manure are judiciously put upon the land; while in the other cases, very inadequate quantities are injudiciously given, by intermittent application without system.

There is nothing special in the Edinburgh case beyond this, and the mode of disposal of the produce. The ordinary sewage of a mixed population is there distributed in enormous bodies of water over land of various quality, light and heavy; and that portion of the land which was naturally not well suited for the reception of such large quantities of liquid, was rendered so by artificial drainage.

There can be no reason why, by similar methods, judiciously applied, similar results may not in most cases be produced, wherever liquid sewage is at command.

It should be borne in mind, that it is from grass only, cut for stall-feeding, that this extraordinary value is obtained. The meadows are let in small lots every season (extending from April to October), to the cowkeepers of Edinburgh, who obtain four and five cuttings during that period, amounting in weight, in some instances, it is said, to eighty tons per acre.

The whole area is laid out in divisions for watering, which proceeds successively throughout the year; so that when the whole of the divisions have been served, the irrigation is commenced again with the first. The same course of irrigation goes on through the winter, and if any portion of the land has not done so well the previous season, it is treated in the winter time with a larger quantity of the sewage than usual, invariably with marked improvement. The limit of production has not yet been reached; *the more water each portion of the land receives, the larger is the crop produced.*

Such being the extraordinary results of a system practised for so many years, does it not naturally suggest itself in seeking the means of disposing of town-sewage generally to the best advantage, that they should be such as to allow of the application of the whole quantity upon a minimum space on which the vegetation can assimilate it without waste, rather than upon a wider area, at an increase of cost and with a decrease of fertility?

Evidence is afforded, in other places, of remarkable effects of sewage applied to cereal, and especially to root crops. Mr. Walker has grown wheat for three years in succession on the same ground with no other manure than the liquid sewage, with perceptibly increased results; but I regard all such evidence as unimportant, for at the best there can be but a very small consumption of sewage in this way.

Let me add a few words as to the agricultural objections to sewage irrigation to which I have already alluded.

"It produces coarse inferior hay." If so, why make it? No hay is made on the Edinburgh meadows. Opportunities exist in that case for disposing of the produce in a green state. Similar opportunities exist more or less in every town.

"It encourages the growth of weeds and the ranker grasses." But may not this arise from the very fact of extending the period of growth for the purposes of hay, when the ranker vegetation usurps the ground and overpowers the finer and sweeter grasses? Such has been my impression from observing, where hay has been made, the land covered with dandelions and the coarsest grasses, while in other cases, where the crop has been kept close by frequent cutting, the grosser vegetation seems to have been kept under, and the finer grasses to have had fair play. I find no complaints of the coarseness of hay made on the lands irrigated with the sewage of Milan; but there the climate admits of three crops of hay being made in as many months, June, July, and August; and they are fed off once, and mown four times in the year besides. But again, has the selection of the grasses, for which such irrigation is especially applicable, yet received that attention which the importance of the subject demands? With the exception of Italian ryegrass, I apprehend not. Benefit may probably arise from consideration of this point.

With respect to hay-making from grass thus grown, I will venture to intrude a suggestion, even at the risk of its being considered beyond my province. In the *Agricultural Gazette* of last year, an account was given of some successful trials in the artificial drying of grass. The proposition there made was to provide a large barn, on the floor of which the grass would be strewn and turned, in a warmed atmosphere. The calculations founded on the trials showed a promising return, but I apprehend that the main objection to the general adoption of the plan would be the first cost of the building for conducting the operation. Might not an apparatus for this purpose be added to the many ingenious machines that have of late years come to the aid of the agriculturist? A wooden or other enclosure, through which a current of dry and heated air should continuously pass, as already employed for the desiccation of other materials; to which current, revolving hay rakes would continuously expose the grass in its passage? The spare heat from the steam-engine furnace might be made partly available.

It would be a great boon to agriculture if some means could be adopted for making hay, whether the sun would shine or not, whenever grass would grow. Not only would much larger quantities be produced, but from the very frequency of cutting would it not consist of finer and sweeter grass? And might not the same or similar apparatus, be made available for artificially drying grain in unfavourable harvest time?

To return to the objections to sewage irrigation. "Cattle will poach the land; sheep will be exposed to disease." If so, why place them upon such land? None are ever seen on the Craigentinny meadows. Keep them on higher and safer ground. Devote the lower levels to the work for which they are most suitable. "Few water meadows," Mr. Pusey says, "are safe to feed sheep upon in autumn."

"Irrigation with sewage in winter time injures or destroys the grass." It may certainly happen with sewage as with other manures, that plants which have been stimulated during mild winter weather, and are looking luxuriant and well, may be more liable to be subsequently cut off and destroyed by severe frost; and yet the irrigation goes on with sewage and with liquid farm manures alike throughout the winter in all the places recited, with nothing but good result, as far as I could learn; and it was a very general opinion that even in the most exposed positions the vegetation would always be preserved from this danger by keeping a good head to it as protection to the roots.

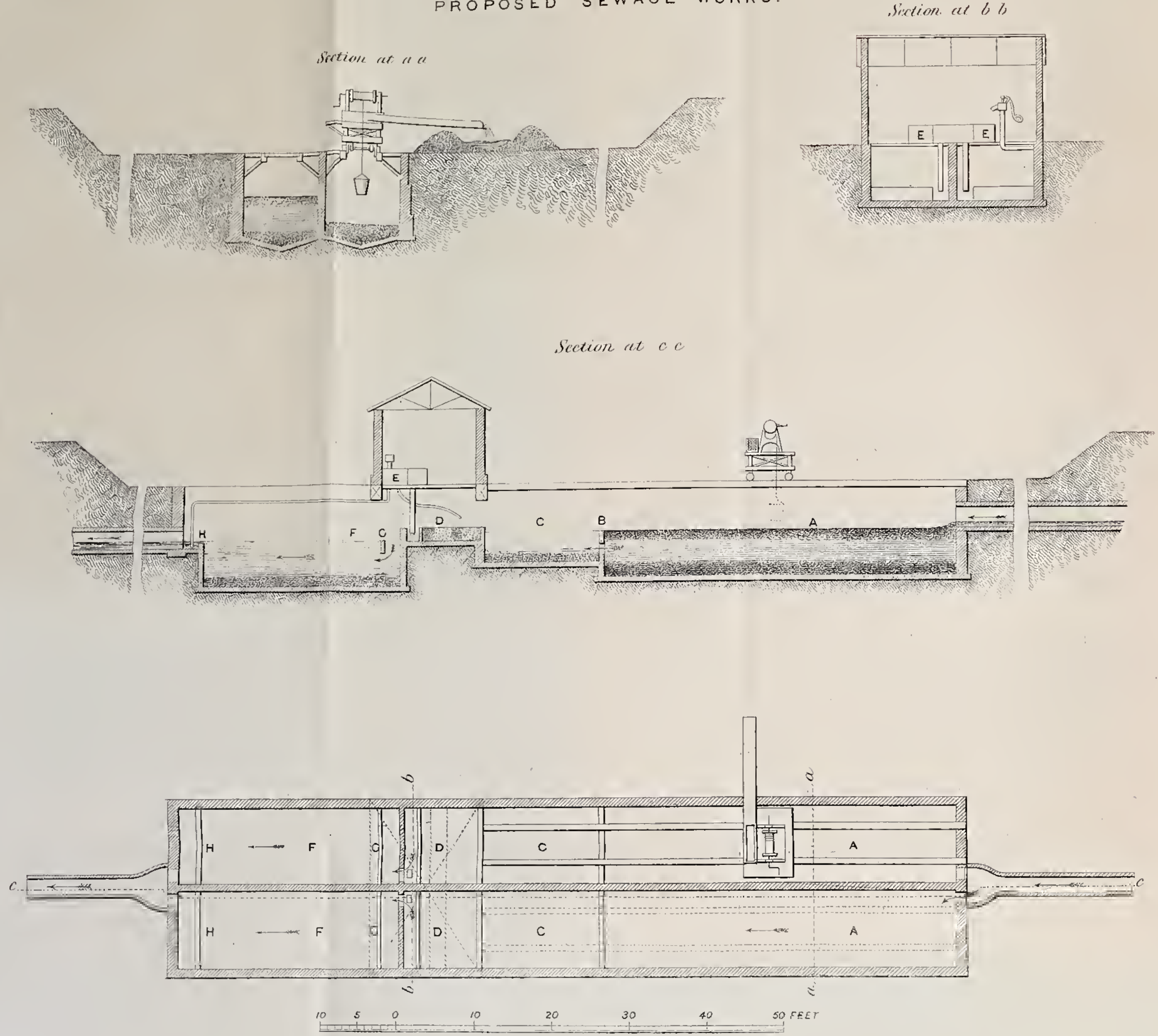
The agricultural objections to sewage irrigation, properly conducted, do not seem to be formidable. The more serious and valid objections, made on sanitary grounds, to the system as practised at Edinburgh, will, I trust, be entirely obviated by the modifications of practice which I presume to recommend.

Recommendations.

Upon consideration of the facts which I have now been enabled to submit, it will at once be evident that the best means of deodorizing and dealing with the sewage of towns demands much further investigation than has yet been made of the subject; but it will probably at the same time be gathered from the experience so far obtained that by certain processes and admixtures the main object of this inquiry may be in great part at once secured; that is to say, that much of the offensiveness of the sewage of towns may be removed, and therefore much pollution of the rivers and streams of the country avoided; that a solid manure of a certain low value may be obtained by these processes, which under certain conditions will probably pay for the outlay; and that on sanitary grounds, therefore, the adoption of some such process by Local Boards, wherever the Public Health Act is applied, or by the local authorities of the towns where it is not, ought to be insisted upon, wherever an offensive outfall exists, whether arising from new works of drainage or from old.

It would appear that various patent processes are adequate to this partial dealing with the subject; but while the arrangements or materials adopted in those

PROPOSED SEWAGE WORKS.



Day & Son, Lithrs to the Queen

which have been brought into practical operation are for the most part expensive, there is no evidence of their having realized any better results than have been obtained by the simple and economical method adopted with the same object in the town of Cheltenham. Such methods, unfettered by patents or other difficulties, appear to come strictly within the duty of the local body charged with the disposal of the refuse of a town, being, in fact, little more than a transference to the outfall, of duties which they are already bound to perform, namely, the removal from the separate houses of the contents of the midden or cesspool and dustbin.

In proposing, however, for general adoption, some such arrangement for separating the solid portion of sewage from the water in which it is conveyed,—as the first step towards the removal of that pressing evil, the poisoning of the rivers and streams throughout the country,— I desire to submit for consideration certain modifications in the plan, with a view to the more efficient and economical working of the process. These may perhaps be of service for the guidance of local bodies, more especially in towns of the smaller class, where any saving in the cost of works, or in current working expenses, is a material object.

The great bulk of the solid matter, when the sewage comes to comparative rest in the reservoir, divides itself into two bodies; the heavier particles at once deposit themselves at the bottom, and the lighter portions collect, in a solid floating mass, on the surface. It appears to me that the chief proportion of these matters may be intercepted in the first tank A, (Drawing No. 6) both above and below, without a filter, by a simple division, B, with basket-work and perforated boards in the middle, allowing the water to pass through only at a certain depth beneath the surface.

The second tank or reservoir, C, need not then be so deep or so large as the first. At the end of it, filtering materials of different kinds should be arranged, through which the sewage would pass laterally; 1st, coarse screened gravel, beach, or broken stones; 2nd, gravel of medium coarseness; and, 3rd, some finer material. And there would be much advantage in having this filter, D, shallow and broad, rather than deep and narrow; the surface-water only would pass away, and thus allow of further deposit from the main body before filtration; it would be subject to greater friction and disengagement of the solid matter and foul gases; and the filtering medium itself would be less readily clogged, and would be more accessible for cleansing without removal, as it could be turned over in its place and subjected to complete washing, from a water tank, E, above, as often as desired. A very small area of filter so placed would be found sufficient for all practical purposes.

By some such arrangement also as is shown in the accompanying general plan (No. 7), the work may be brought more compactly together, and the scavengers' carts may deposit the ashes on the spot where they are wanted, and where they may be at once formed into continuous banks for the reception of the sewage deposit, which would be hoisted in the buckets and discharged by a shoot into the midst. Much labour in filling, wheeling, and mixing would be thus saved, and much exposure also of the sewage, which at certain times must be as offensive to the smell as it will always be to the sight, where such an operation is openly conducted.

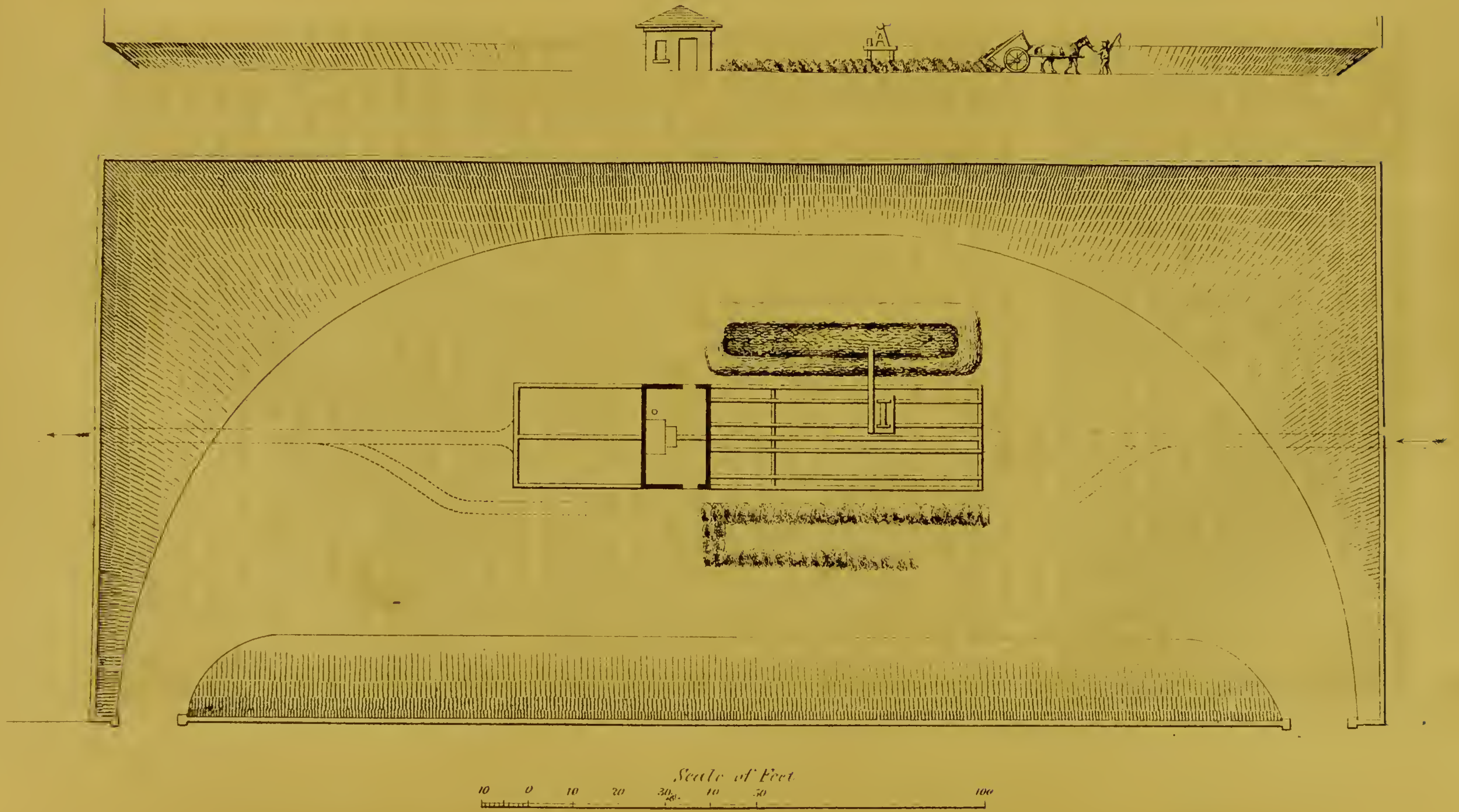
The same necessity for a covering shed over the filters will then no longer exist, and it may safely be dispensed with, provided that the premises are enclosed with a boundary fence, or wall. A small shed only will be required for the liming process, and for housing apparatus and tools.

The reservoir for deposition after the addition of the lime should be considerably larger than that at Cheltenham. There is not time, in that case, for the precipitation to take place. The lime and remaining sewage flow off in suspension to the stream, and have an unsightly effect, if no other inconvenience.

It is stated as one of the results of the Manchester experiments, that the lime falls at the rate of an inch and a half per minute. The admixture being made as the sewage flows into the reservoir at each side, I propose that it should be intercepted by a fender,

PROPOSED SEWAGE WORKS.

General Plan.



that it may not disturb the main body of water, and that the discharge to the outfall should take place over a weir, allowing only a surface film of the water, from which the lime has descended, to pass over.

The depth of this surface water passing over, and the length of the reservoir, must be of course determined by the quantity which has to be discharged.

The construction shown on the plans would be sufficient for a town of about 3,000 inhabitants, and would probably cost from 250*l*. to 300*l*., exclusive of the excavation of the site and the fencing shown, which would depend upon locality.

The problem, however, of the proper dealing with the sewage of towns is but partially solved by any such process.

If it be granted that the *sanitary* requirements of the question are thus practically satisfied, and that the further decomposition of the remaining elements in solution in the effluent water would be too slight for mischief (a question that demands strict chemical investigation,) all the evidence goes to show that the *agricultural* problem would still be far from settled. The water is robbed but of little fertilizing power by the removal of the solid matter. It will still contain in solution all the most valuable properties, and these, in the present state of knowledge on the subject, can practically only be made available by the application of the water itself to the land.

In some towns, the circumstances of the surrounding district forbid this application, and it will be a subject for further inquiry, whether in such cases the water flowing off should be subject to more complete deodorization than can be accomplished by the above process. But in the majority of cases there is no insurmountable impediment to this application of the liquid sewage, and the evidence clearly points out *that if only proper means be adopted for this application, and for disposal of the produce*, very great advantages may be expected from its use.

True, those results are in some degree speculative, and it is not meet for local governing bodies to engage in speculations, however promising their nature; but if general facilities are only granted by the Legislature for carrying out the necessary works, the speculation will as certainly recommend itself to proprietors or to local companies or contractors as the more ordinary local investments, such as gas and water works. In the present state of agriculture in this country, the means of realizing this object are assuredly most worthy of the attention of Parliament.

The best consideration, however, which I have been enabled to give to the subject, satisfies me that the *large* results promised are not to be obtained by the process employed for the application of liquid farm manures, and for that of the sewage of Rugby and other places; namely, the hose and jet. A certain result will, no doubt, be attained by this method of distributing sewage, which, under favourable circumstances, as at Rugby, will give an excellent return for the outlay; but there will be many exceptions to these favourable conditions. In a great number of places, and for a large portion of the year, the sewage itself will be presented in a far greater state of dilution than it is at Rugby; and were it not so, in no places, and under no circumstances, will the *great* results for years obtained at Edinburgh from the application of liquid sewage, be realized by use of the hose and jet. *The immense quantity required for success cannot by such means be economically got on to the land.*

This expensive and limited mode of pipe distribution answers admirably, no doubt, for the application of the comparatively valuable liquid farm manures, and for the application of sewage to root and grain crops,—or in its least diluted form, in comparatively small quantities, to higher levels of land,—the hose and jet may be usefully employed; but it is not in this way that the greatest benefits from the application of sewage can be realized.

One comparison of present experience will suffice to show how inadequate such modes must be to deal with the enormous quantity in which sewage, to be valuable, must be applied.

Mr. Mechi considers that the cost of delivery of his liquid manure may be fairly estimated at from

$1\frac{1}{2}d.$ to $2d.$ per ton, and he is very well satisfied with his results at this cost. But $1\frac{3}{4}d.$ represents just about the value of the excrements in a ton of sewage, allowing 30 gallons of water per head per day, so that at this cost of distribution every particle of value of the manure which it is at present safe to calculate upon, would be absorbed in getting it on to the land.

According to Mr. Walker's figures, the cost of delivery of the sewage of Rugby on to his land is little more than $\frac{1}{2}d.$ per ton, exclusive of the portion of the rainfall applied. Even this cost, however, must be very materially reduced, for there would otherwise be little value left in the sewage of some places. I shall hope to show that this may be accomplished by the modifications proposed.

The quantity of sewage which may be most profitably applied to land, can only be determined by experience under the many conditions which will modify the practice; but judging from the experience at Edin burgh, I arrive at the conclusion that the sewage of Rugby might have been most advantageously applied to one-fourth or one-fifth of the land over which it is now distributed. Fully that proportion of the area lies conveniently on the low level, so that little or no pumping power would have been required. The saving in original outlay and in the annual working expenses would be the first advantage gained. Without framing any estimate of this reduced work for comparison with the actual expenses incurred by Mr. Walker, which from various circumstances were greater than necessary, the large economy that would be obtained in the main items of outlay,—engine power, pipage, distributing hose, current expenses and superintendence,—is obvious. The next, and far greater consideration, however,—if the produce now obtained from the 470 acres can be grown on so much less an area,—is the saving of that quantity of the land for other cultivation, and of all usual annual expenses attaching to such land.

As to the necessary works for getting the required quantity of manure on to the land, the plan which appears to me best adapted for accomplishing this, and at the same time for avoiding the sanitary objections to a system of open irrigation as practised at Edinburgh, is to apply the liquid sewage, *after separation of the solid matters*, by a combination of underground mains with Bickford's system of contour gutters.

The quantity which could by this method be delivered at a certain spot, and distributed over a given area, would be limited only by the size of the pipes and the pressure applied therein by gravitation or by engine power. By opening valves placed at convenient points, the pipes would deliver into small troughs, whence the sewage would discharge into the top gutters, and thence into cross feeders as required; and with the same sized mains, one lad would superintend the distribution of many times the quantity that it is practicable to get on to the land by means of the usual small subsidiary pipes and the hose and jet.

In reply to any objections that may be raised, on sanitary grounds, to irrigation with these large quantities of sewage water, it must premised that all land so irrigated ought, as a matter of course, to be sufficiently drained, unless the soil be of a very absorbent nature, so that no stagnant or superfluous water can remain. Unless this can be secured, malaria can hardly fail to follow; but I must repeat that the well-founded complaints at Edinburgh arise from the great extent of evaporating surface in the ditches. In the plan proposed, there will be no ditches; no land either wastefully or mischievously occupied; no stagnant surface of water; no foul deposit.

The main pipes will be the substitutes for the large Edinburgh ditches; the solid matter will be separated before irrigation, and the liquid will be absorbed by the earth, Nature's great deodorizer, as fast as it is exposed.

As an example of the laying out of a farm for the application of the liquid sewage of a town (of, say, 20,000 inhabitants,) upon this principle, I submit the accompanying plan (No. 8.) and estimate.

The land selected for the illustration is an unfavourable example with respect to cost, as the whole of the sewage would have to be pumped and dis-

No. 5.

PLAN OF GROUND UNDER *Irrigation* FROM THE SEWAGE WORKS OF G. H. WALKER, ESQ.[r] In the Neighbourhood of RUGBY.

tributed all in one direction from the outfall. In order to make it an extreme case also in other respects, I have preferred to confine the area to be irrigated with the sewage from this amount of population to about 260 acres, although at a very trifling increase of cost, a considerable additional space westward might be irrigated from the same main.

I have estimated that the total quantity of sewage to be applied will be equal to 50 gallons per head per day, although the works proposed would be adequate to the delivery of much larger quantities during the time of the heavier rainfall, which, as I have previously stated, ought to be provided for.

The pressure will be maintained by iron mains, rising to the highest point of the land, but the carriers leading off from the mains, if properly laid out and worked, would not for the most part have to resist any pressure, and might consequently consist of stoneware or strong earthenware socketed pipes with cemented joints.

The works would comprise a reservoir at the lowest and the highest points for regulating the discharge and delivery and for receiving the ordinary sewage of Sunday, a pair of 12-horse high-pressure engines with pumps, &c. complete, 12 and 9 inch iron mains, and stoneware carriers varying from 12 to 4 inches diameter. The carriers would deliver into shallow troughs placed at the highest point of each division for irrigation, and from these the open contour gutters and cross-feeders would extend in each desired direction.

I estimate that these works would cost from 3,000*l.* to 4,000*l.* according to the locality in which they might be constructed, the average being 13*l.* 10*s.* per acre. Interest on this amount and working expenses I estimate at 600*l.* per annum, being 2*l.* 6*s.* 2*d.* per acre.

Calculating upon 280 working days in the year, (and including the sewage of Sunday, which would be distributed on Monday, but omitting the increase of quantity on days of heavy rainfall,) between 5,000 and 6,000 tons per day would be delivered on to the land, or about 12 tons for one penny.

In a case, however, in which the whole quantity could be delivered by gravitation, and in which the outfall would be favourably placed for sending the sewage in different directions, the cost of the works would be about one third less, and the annual expenses including interest on the less outlay, about 300*l.* per annum, or one half of the above, in which case 24 tons of sewage would be delivered on to the land for 1*d.* Taking the mean of these two extremes, the interest and working expenses of the system will amount to 6*d.* per head of the population per annum.

True, that reckoning the cost of this work per acre, it amounts to more than double that which has hitherto been incurred for the underground pipe system; but the only correct criterion of the economy of the work is the cost at which a certain quantity of manure in the sewage can be put on to the land; and it will be seen that that economy is upwards of 4 to 1 in favour of the examples given when compared with the Rugby case.

The quantity of manure proposed to be applied per acre in this example would, no doubt, by many persons be considered excessive, although the quantity of liquid in which it would be conveyed to the land, falls short of the ordinary amount distributed over the Craigentinny meadows. I presume it would be wasteful to apply such an amount of fertilising matter upon some lands, but on others again, even larger quantities might probably be advantageously distributed. As before stated, the proper rule would appear to be in each case, the maximum quantity which the vegetation can assimilate without waste.

Conclusions.

As the result of my inquiries, and of the best attention which I have been enabled to afford to this important subject, I beg to submit the following conclusions:—

1. That although from the earliest agitation of the question of sanitary reform and of the complete drainage of towns, the mischief from pollution of

rivers on the one hand, and the waste of valuable manure on the other, by the direct discharge of the sewage, was insisted upon, no conception was at any time formed of the *extent* of the evil which now so imperatively calls for remedy.

2. That although the means of remedy by deodorization appear to be as yet but imperfectly understood, and demand further investigation, various processes have for a long time been in more or less successful use for this purpose. That the employment of some of these, known to be destructive of the fertilizing power of sewage, would involve expense without any return; and although such expense, if unavoidable, should unhesitatingly be incurred to avoid any permanent danger to the population, it appears that other deodorizing materials are not destructive of that fertilizing power. That it is most important, therefore, to determine whether the fertilizing elements in the refuse are presented in such form as to be practically available for agriculture, either in the solid state or in the liquid form, so as to avoid the injurious consequences, and enormous waste of throwing away the sewage.

3. That the nature and value of the chemical constituents of the fæcal matter in sewage having long been known to physiologists and chemists, and admitted to contain all the elements necessary for the food of plants, the recent discussions as to its practical value for agriculture have not arisen from any doubts on that point; but from the uncertainty whether, being diluted in the large bodies of water employed for the drainage of towns, that value is realizable.

4. That chemical research has not yet arrived at any satisfactory method of economically arresting from solution the fertilizing ingredients in sewage, while the analyses of solid sewage manures, manufactured under various patents, show, that although for the most part possessing a certain low value, they do not justify the high prices at which they have been offered to the public; nor does there appear to be evidence of any agricultural results derived from their use, which will support such a view of their value.

5. That the manufacture from excrement of a dry portable manure, as practised at Paris, although realizing results of greater value, is applicable only where the cesspool system prevails, and leads to an aggravation of the nuisance of that system, which due regard for the public health would not tolerate.

6. That the separate system of drainage, frequently proposed as a solution of the sanitary and agricultural difficulties of the sewage question, would increase immensely the cost of drainage works ; would add to the sources of danger to the public health ; and would tend to a waste of fertilizing power.

7. That the practical experience obtained during many years at Edinburgh and Milan, has shown the great value of sewer water on grass lands, although applied in a state of great dilution ; while valuable experiments have shown the power of soils to remove from solution, and retain for vegetation, the fertilizing elements.

8. That notwithstanding the enormous quantities of sewage water which have been applied to the land at Edinburgh, the produce is said to be always in corresponding ratio to such quantity, and that the limits of quantity to be applied, and of produce to be realized, have not yet been ascertained.

9. That the precise value of the manure in a given quantity of sewer water, may be readily determined, and, therefore, that the corresponding quantity of water which must be applied to convey a certain required quantity of such manuring elements on to the land, may be at any time known.

10. That although such immense agricultural results have been obtained from irrigation with sewage water at Edinburgh, the method employed has given rise to much complaint of nuisance. That this arises for the most part from foul deposits in wide ditches, and from the large evaporating surfaces of the sewage constantly exposed in the channels of irrigation.

11. That all such sources of nuisance and danger are preventible, and should not be tolerated. That no ditches should be used, and that the sewage should be exposed only during the act of irrigation of each

portion of the land, when it would be immediately absorbed and deodorized by the soil.

12. That in order to avoid all further risk of injury to health, whether from discharge of the sewage into the rivers and streams, or from its application to the land, it appears desirable that the solid matter should in every case be separated from the liquid sewage at the outfall, and that a cheap portable manure should be manufactured therefrom for use in the immediate neighbourhood, as practised at Cheltenham. That it should be mixed with the ashes of the town, or such other deodorizing material as may be most suitable for application to the surrounding land, and prepared, if desirable, with other manuring ingredients for particular crops.

13. That it appears probable that such operation will in most places pay its own expenses, but that as some such measure is absolutely necessary for the public health, even though involving some expense, it should be the duty of Local Boards and other governing bodies to carry it out, just as much as arrangements devolving upon them for removal of dust or other refuse from the town. It should form, in fact, part of such service, and might be combined in the same contract.

14. That the liquid portion of the sewage, thus cleared of its solid matter, but still retaining its chief value as manure, might then be applied with benefit to the neighbouring lands in any quantity; but that all land upon which this method of application of the sewage is practised should, if not naturally porous, be artificially drained; as the liquid, if allowed to become stagnant, would, as in common irrigation, be likely to engender disease in the neighbouring inhabitants, or in cattle exposed to its influence.

15. That the distribution of manures in the liquid state by the hose and jet, from a system of underground pipes on the land, has been found, by the experience of several years upon farms in England and Scotland, most advantageous, and that the outlay for such works is considered by eminent agriculturists, who have had experience of their benefits, as a very

profitable outlay, irrespective altogether of the question of *sewage* distribution.

16. That although the adoption of the same system at Rugby, and other places, for the distribution of liquid sewage, has been found decidedly successful, the great Edinburgh results are not attainable by this method, unless conjoined with more ample and ready means for getting much larger quantities of sewage on a given area, in less time and with less labour and expense than can be done with the hose.

17. That upon grass lands, for which the application is best adapted, these larger quantities of the liquid sewage, deprived of its grosser particles, may be economically distributed, especially upon the lower levels, by a combination of the underground pipe system with the subsidiary open irrigation by small contour gutters, practised by Mr. Bickford.

18. That this work, being of a commercial or speculative nature, and not so much required for the safety of the public health, would fall rather within the province of local companies or proprietors than of the local authorities, and to those parties all facilities should be granted for carrying it out.

19. That the solid sewage manure, prepared and deodorized as above proposed, may be anywhere used, and any quantity of the liquid applied on absorbent or properly drained land, without any risk of injury to health, and without any of the offensiveness constantly experienced from farmyard and other solid manures applied as top-dressings.

20. That in any neighbourhoods, however, where no opportunity exists for this beneficial irrigation, the liquid sewage, before being discharged into rivers or streams, should, after separation of the solid matter, be treated with lime or other deodorizing and precipitating agents; a duty which should devolve upon the Local Board or other governing body, as a precaution in which the public health is materially concerned.

Lastly—That it is an object of immense public concern that the poisonous accumulations of our towns, now fast becoming the sources of pollution of our rivers and streams, should without delay be rendered powerless for further mischief, and applied, as Nature's law demands, for reproductive uses. That by this means the greatest sanitary problem will be solved, and the greatest advancement of agricultural prosperity secured.

In drawing this Report to a close, I venture to express a hope that the attention I have been enabled to give to the subject may have added some little to our information ; but impressed with its great importance and its difficulties—extending as it does into so many branches of inquiry—I feel strongly my own inability to do justice to it. It is a subject of study not for engineers alone, but for agriculturists, physiologists, and chemists of the highest attainments and experience.

I have the honor to be,
Sir,
Your very obedient servant,
HENRY AUSTIN,
Chief Superintending Inspector.

Whitehall, March 1857.

Postscript.—The examinations were made for this Report, and the particulars embodied therein were noted down, many months ago. The subject, however, having become daily more pressing and important, especially in relation to the metropolitan drainage, the Sewage Commission was appointed before my ordinary duties would permit of the entire Report being put into shape. The want of further investigation upon many points, which I have so strongly felt, will, I trust, now be supplied ; and the bearings of the whole question upon the case of the metropolis, which, of course, have not come under my consideration, will now, I hope, be thoroughly investigated.

APPENDIX A.

LIST of PATENTS granted for DEODORIZING and PREPARING MANURE from FÆCAL MATTERS and SEWAGE.

ESTIENNE, Lewis James Armand; 1802, January 9. —Converting or reducing human excrement into a powder divested of all nauseous smell, preserving at the same time its fertilizing properties in rendering land infinitely more productive and vegetative than any other manure hitherto discovered.

POITTEVIN, Joseph Henri Jerome; 1835, July 17.—Powder which is applicable to the purposes of disinfecting night soil and certain other matters, and facilitating the producing of manure.

ALBERT, Dominic Frick; 1842, August 10.—A new combination of materials for the purpose of manufacturing a manuring powder.

BUISSON, Michel Antoine Bertin Burin du; 1845, June 23.—New and improved methods for the distillation of bituminous schistus and other bituminous substances, as well as for the purification, rectification, and preparation necessary for the employment of the productions obtained by such distillation for various useful purposes.

HIGGS, William; 1846, April 28.—The means of collecting the contents of sewers and drains in cities, towns, and villages, and for treating chemically the same, and for applying such contents, when so treated, to agricultural and other useful purposes.

BROWN, Edward; 1847, February 20.—Certain carbonic compounds formed of earth, vegetable, animal, and mineral rubbish, fæcal substances, the waste of manufactories, and certain acids and alkalies, which compounds are applicable as manures.

ADAMS, William Bridges, and RICHARDSON, Robert; 1847, May 24.—Certain improvements in the construction of railways, and of engines and carriages used thereon; and also in transport and storage arrangements for the conveyance, management, and preservation of perishable articles.

ELLERMAN, Charles Frederick; 1847, October 7.—Certain processes or methods of rendering fæculent, excremental, and other matters inodorous and disinfecting, and also of retarding the putrefaction of animal and vegetable substances, and certain chemical re-agents employed in the said processes or methods. (There is no Specification of this Patent enrolled).

BARKER, Edward; 1847, October 26.—Certain improvements in the preparation of manure.

MITCHELL, Benjamin; 1848, January 13.—Improvements in the manufacture of manure.

ROGERS, Jasper Wheeler; 1848, June 1.—Certain improved methods and machinery for the preparation of peat as a fuel, and in combination with certain substances as a compost or manure.

LEGRAS, Louis Napoleon; 1849, Nov. 30.—Improvements in the separation and disinfection of fæcal matters in the manufacture of manure, and in the apparatus employed therein.

TARLING, Henry James; 1850, March 7.—Improvements in the manufacture of fuel and manure, and deodorizing and disinfecting materials.

ANGELY, Paul d'; 1850, June 4.—Certain improvements in the construction of privies and urinals, and in apparatus and machinery for cleansing privies, cesspools, and other places, and in deodorizing the matter extracted therefrom, and rendering it available for agricultural purposes.

BROWNE, James Hamilton; 1850, October 10.—Improvements in the separation and disinfection of fæcal matters, and in the apparatus employed therein.

WICKSTEED, Thomas; 1851, February 24.—Improvements in the manufacture of manure, and in machinery to be used therein.

DOVER, Richard 851, October 16.—Improvements in treating sewage, in obtaining products therefrom, and combining such products with other matters.

STOTHERT, Henry; 1852, April 17.—Improvements in the manufacture of manure.

PETTITT, Edwin; 1852, October 1.—Improvements in the manufacture of ammoniacal salts and manures.

GILBEE, William Armand; 1852, October 6.—An improved mode of disinfecting putrified and fæcal matters, and converting fæcal matters into manure; also applicable to the disinfection of cesspools, drains, sewers, and other similar receptacles.

PERKES, Samuel; 1852, October 12.—Certain improvements in mines, buildings, and sewerage, for effecting sanitary purposes, and treating the produce therefrom.

BARDWELL, William; 1853, January 5.—Improvements in treating sewage waters and matters.

PINEL, Jacques Francisque; 1853, March 8.—Improvements in deodorizing sewage water and cesspools, and in manufacturing manures.

HERAPATH, Thornton John; 1853, March 15.—Improvements in treating sewage and in manufacturing manure therefrom.

DERING, George Edward; 1853, March 28.—Improvements in preserving or preventing decomposition in vegetable and animal substances and matters.

DIMSDALE, Thomas Isaac; 1853, May 20.—Improvements in disinfecting sewage or other fœtid matters, and in absorbing noxious gaseous exhalations.

MACPHERSON, Allan; 1853, June 20.—Improvements in disinfecting sewers or other drains, and in converting the contents thereof to useful purposes. (This invention did not proceed to the Great Seal.)

NEEDHAM, William, and KITE, James; 1853, July 14.—Improvements in machinery and apparatus for expressing liquid or moisture from substancćs.

SHAW, John, and STEINTHAL, Joseph; 1853, August 25.—An improved manufacture of artificial manure.

MANNING, James Alexander; 1853, November 29.—Improvements in the treatment of sewerage and other polluted liquids, and the products thereof.

MACPHERSON, Allan, 1853; December 10.—Improvements in disinfecting sewers or other drains, or depositories of fœtid matters or gases, and in converting the contents thereof to useful purposes.

SMITH, Robert Angus, and McDOUGALL, Alexander; 1854, January 20.—Improvements in treating, deodorizing, and disinfecting sewage and other offensive matter, which said improvements are also applicable to deodorizing and disinfecting in general.

WICKSTEED, Thomas; 1854, January 26.—Improvements in the manufacture of sewage manure.

WICKSTEED, Thomas; 1854, January 26.—Improvements in the manufacture of sewage manure.

WICKSTEED, Thomas; 1854, January 26.—Improvements in the manufacture of sewage manure, and in apparatus for that purpose.

HERAPATH, Thornton John; 1854, March 17.—Improvements in the manufacture of manure from sewage, which are also applicable to the preparation of other artificial manures.

MANNING, James Alexander; 1854, March 27.—Improvements in the treatment of sewerage.

KITE, James (Secundus); 1854, June 15.—Improvements in machinery and apparatus for expressing moisture from substances.

WHITE, William; 1854, October 12.—Improvements in the manufacture of manures.

LITTLETON, Thomas; 1854, December 1.—Improvements in separating gases from sewage and other waters for the manufacture of manure, and for supplying of steam engines.

ANDERSON, George; 1854, December 23.—Improvements in purifying sewers, and buildings or other places, from noxious vapours.

THEROULDE, François Alphonse; 1855, May 12.—Improvements in preserving animal substances.

MANNING, James Alexander; 1855, August 7.—Improvements in the treatment of sewerage.

COCHRANE, Alexander; 1856, January 1.—Improvements in collecting and distributing water, and alluvial deposits contained in sewage and other waters.

MANNING, James Alexander; 1856, July 5.—Improvements in the manufacture or production of manure.

WICKSTEED, Thomas; 1856, July 31.—Improvements in separating sewage and other matters, from water or fluid mixed therewith.

WARRINER, George, 1856, August 25.—Improvements in compounds for preserving, deodorizing, and fertilizing.

CHODZKO, Stanislas; 1856, September 15.—Improvements in the manufacture of manure, and the apparatus employed therein.

APPENDIX B.

EXAMINATION of the COMPARATIVE DEODORIZING powers of PEAT CHARCOAL and BOGHEAD COKE.

Charcoal is obtained when any organic body is imperfectly burned in closed vessels, that is, without the admission of sufficient air to effect its entire combustion. Different organic bodies, therefore, yield different kinds of charcoal; we have, thus, animal charcoals, obtained by the carbonization of bones and of blood, the charcoal of different kinds of wood, the charcoal of peat and coke, the charcoal from coals. Each of these species of charcoal have separate and distinct qualities, resulting from their physical constitution. They all agree in containing a certain amount of carbon; their difference results from the nature and amount of the ash or mineral constituents contained in the original body. This ash seems to divide the carbon, giving it a greater or less amount of porosity and surface.

The peculiar action of charcoal is due to the extent of its surface and the size of its pores. It has the power of absorbing and condensing within these pores many times its volume of different gases and vapours, and thus many bodies which have no power to enter into combination with each other in their gaseous state are so changed in their properties when simultaneously condensed within the pores of a charcoal, that the chemical force is brought into action, and a change of constitution is effected. In this way odorous gases are first condensed and then altered in constitution. Some charcoals have also the property of removing certain bodies from solutions; but the property of condensing gases and the property of removing substances from solutions belong to different species of charcoal. Peat charcoal has been found the most efficacious in condensing offensive odours, and bone charcoal to possess the greatest power of removing colouring and other organic matters from their solutions.

In the first instance, therefore, it was determined to examine the constitution of the boghead coke in comparison with peat charcoal, and animal charcoal derived from bones. The following table will show this comparison:—

	Per cent. of Carbon.	Per cent. of Ash.	Constituents of Ash.
Animal charcoal -	10·2	89·8	Phosphate and carbonate of lime.
Peat charcoal -	74·1	25·9	Silica, alumina, and carbonate of lime.
Boghead coke -	36·8	63·2	Chiefly silica.

From this preliminary examination it would be inferred that the properties of the boghead coke would approach more nearly to those of the bone charcoal than to those of the peat charcoal. The result will be found in the sequel.

One hundred parts of peat charcoal and of boghead coke were added separately to one thousand measures of sewer water in a state of putrefactive decomposition, and giving off offensive odours. After being stirred well together and allowed to subside they were filtered off; a slight diminution of odour was the result, but neither produced complete deodorization of the sewer water. Fresh portions of the charcoals were added, until the whole of the sewer water was absorbed by the charcoal, but deodorization was by no means complete, and on heating the mass over a fire offensive effluvia were abundantly given off. This might have been anticipated. When portions of each kind of charcoal were sprinkled over the surface of the sewer waters, in vessels partly filled, the escape of all odour was entirely prevented. The peat charcoal, however, was speedily saturated with the fluid, and sank to the bottom of the vessel, where its deodorizing power was lost, while the powdered boghead coke floated for several weeks, and entirely prevented the escape of any odour.

Their relative power to condense gases was next determined.

A portion of each charcoal was heated, to expel any gases that might have been condensed by them, and weighed quantities introduced into tubes. Ammoniacal gas, passed through a tube containing quicklime to absorb any water, was then passed into the tubes containing the charcoal until it freely escaped from the outlet. The tubes were then again weighed. The peat charcoal absorbed 1·7, or nearly two per cent. of its own weight. The boghead coke absorbed 0·44, or scarcely one-half per cent. of its weight of dry ammoniacal gas. Dry sulphuretted hydrogen was then passed into the charcoals, which they condensed in about the same proportion, though to a less extent. As these are the principal gases which it is proposed to absorb, it may be inferred that peat charcoal is about four times more efficient as a deodorizer of atmospheres than the boghead coke.

The amount of matters separated from sewer waters by each charcoal was next examined.

Matters in suspension were allowed to subside, and 10,000 measures of the sewer water were passed through 1,000 parts by weight of the charcoals.

The Tottenham sewage was employed for this purpose; before filtration it held in solution 10·5 parts, of which 3·6 were organic and 6·9 mineral; after filtration through peat charcoal 12·5 parts, of which 3·1 were organic and 9·4 mineral; after filtration through boghead coke, 10·4 parts, of which 3·6 were organic and 6·8 mineral.

From this examination it would appear that neither had much power in separating matters in solution from sewer waters, while the peat charcoal actually yields up some of its soluble mineral constituents to the action of the water.

During the progress of these experiments, I noticed a curious property of the boghead coke in the state of powder. I have already mentioned the fact of its floating on the surface of a liquid; indeed, it is with great difficulty that it can be made to mix with water. I was surprised to find the quantity of fluid covered by the boghead coke diminish more rapidly than that with which the peat charcoal was mixed, but which had sunk to the bottom. By another experiment I have satisfied myself that the boghead coke actually promotes the evaporation of water, on the top of which it is sprinkled, while it effectually condenses any odorous gases that would otherwise have escaped from the surface. From these premises we may draw the following conclusions :—

1. That boghead coke does possess the power of condensing odorous gases, to the extent of about one-fourth of that possessed by peat charcoal.

2. That neither boghead coke nor peat charcoal are perfectly efficient in deodorizing liquids when mixed with them.

3. That boghead coke is as good a filtering medium as peat charcoal, if desired to be used for that purpose.

4. That the boghead coke possesses the valuable property of floating on the surface of a liquid and effectually preventing the escape of odorous gases—a property which is not possessed by peat charcoal—while the fact of its promoting the evaporation of water would render it valuable in promoting the drying of deposits obtained from sewage for the purpose of forming manures.

LINDSEY BLYTH.

Laboratory, General Board of Health,
January 31st, 1857.

APPENDIX C.

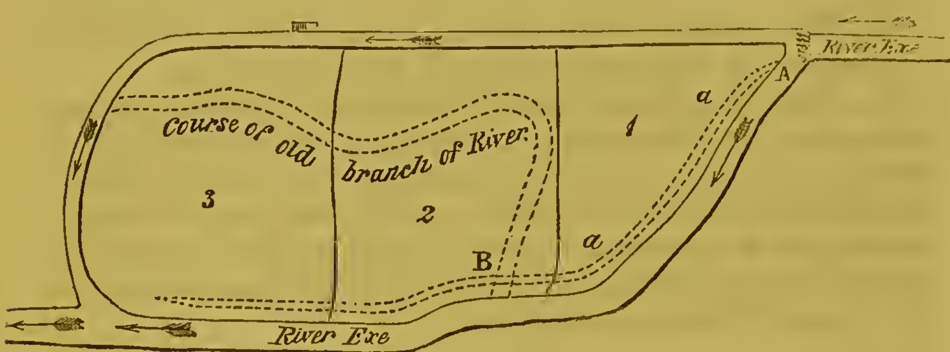
LAYING OUT CATCH-MEADOWS.

(From the *Journal of the Royal Agricultural Society of England*, vol. xiii., part 1.)

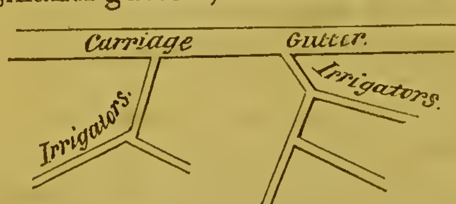
THE improved system of guttering, invented by Mr. Bickford, of Crediton, and of which I have made partial use in some water-meadows in the neighbourhood of Exeter, appears to me to possess great advantages, both in efficiency and economy, over that usually practised in this neighbourhood, and seems likely to be of great value if sufficiently made known.

The meadows to which I refer are situated on the banks of the Exe, about two miles above Exeter, and lie between the river itself and the stream, which is taken out of it at Pynes Weir, for supplying the city with water. The waste water of this stream returns to the Exe immediately below the meadows, so as completely to surround a space of about thirty acres. This space is divided into three meadows, of which the highest has always been in my own occupation, while the two lower pieces have been let off. Till about seven years ago, they were occupied by my steward, and while he held them they were regularly watered; but they have lately been let on lease to a tenant who, for some reason with which I am unacquainted, has not availed himself of the means of irrigation which were at his command. The higher meadow, therefore, is the only one which has been watered of late years. Having now, however, taken the whole of them in hand, I proceeded last autumn to examine the condition of the lower meadows, in order to ascertain what was requisite to be done to supply them with water.

The nature of the ground will be most easily understood by reference to the subjoined diagram.



The water is, in the first place, brought into the higher marsh (No. 1) at A, a point a little below the weir, whence it is carried by means of a large gutter *a a* (3 feet wide and 2 feet deep) along the highest part of the land. From this gutter there are cut, at irregular distances, other and smaller gutters, which traverse the meadow in various directions. By stopping any of these gutters with earth at any point, the water is made to overflow, and thus irrigates whatever part of the land it is desired to benefit.



The carriage gutter *a a*, after passing through the meadow No. 1, enters the meadow No. 2., where it is carried by a wooden shoot B, over a hollow, which was formerly a branch of the river. This branch is now partially filled up, and its communication with the river is entirely cut off. It serves as a drain to carry off the surface water and the waste of the irrigation.

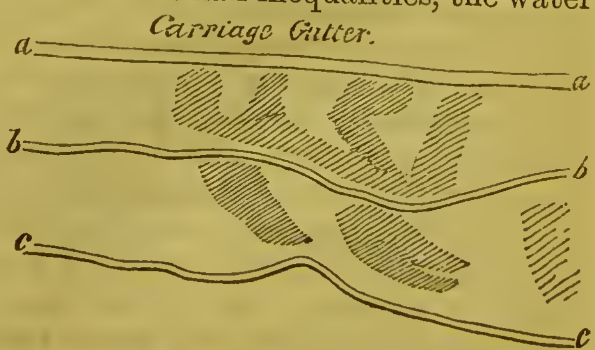
The marsh No. 2 is extremely irregular and undulating in its character, and cannot possibly be watered by a single carriage gutter. The main gutter *a a* is therefore divided into several branches, which diverge very widely from one another after crossing the shoot B. The water in former times used to be brought into one or other of these branches by shutting it out of the others by means of wooden fenders, and it was then distributed over the marsh in the same manner as in the meadow No. 1. The carriage gutters, or some of them, were also continued into the marsh No. 3; but owing to the irregularity of the ground, and the great size of the carriers, it was impossible to water both marshes at the same time; and when it was intended to convey the stream into No. 3, it was necessary to stop the branch gutters in No. 2. I am informed by my steward that it usually took a whole day to bring the water properly over *either* of the marshes. I shall presently explain that, by the improved system, it can now be brought over *both* in about three hours.

The system of irrigation invented by Mr. Bickford is as follows:—

A carriage gutter is, in the first place, cut along the line of the highest ground. This gutter is laid out in the usual manner by means of a spirit level, an inclination being given to it according to the nature of the ground and the quantity of water which can be made available. Where it can be had, a fall of 2 inches in 4 land yards, or 1 in 396, is thought desirable, but a very much less rapid fall will do. The width of the carriage gutter should be about 1 foot, and the depth about 6 inches; but these dimensions are gradually diminished as the gutter approaches its termination, so that at last it dies into the ground.

When the carriage gutter is filled, the water begins to overflow over the sides; and were the slope of the ground exactly uniform in all directions, the water would run equally over the whole; but as the slightest inequality would prevent this, and would cause it to run in streams along the lowest parts, a series of smaller gutters are cut below and in the same direction with the carriage gutter, one below the other, which catch the water, and again distribute it evenly over the land.

Thus, supposing *a a* to be a carriage gutter running along the ridge of a piece of land full of small inequalities, the water instead of making its way along the hollows to the bottom of the field, is caught by the small gutter *b b*, which is so cut as to be nearly level, and without any fall at all from one end to the other.



The water must, therefore, accumulate in the gutter *b b* till it is quite full, when it begins to overflow at all points, and is again caught by the next level gutter *c c*, and so on till it reaches the drain at the bottom of the field.

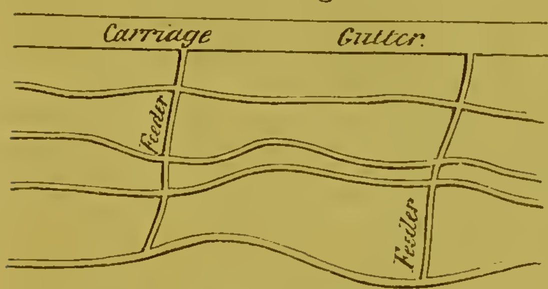
It is in the formation and use of these level catch-gutters that the peculiar merit of Mr. Bickford's system consists. They, as well as the carriage gutters, are cut with a plough, which will presently be described; but in laying them out the use of the spirit level is superseded by an instrument of great simplicity and convenience. It is of the form of the letter A, and stands about 5 feet high the feet being 4 feet apart. A plumb line is suspended from the apex, and a notch is made in the centre of the cross-piece, so that when the two feet stand on the same level the plumb-line crosses the notch. The gutterer rests one of the feet of the instrument on the ground, and, using this as a pivot, turns the whole round like a pair of compasses, till he

finds by the plumb-line that the two feet stand even; then marking the spot where the first foot stood, and using the second foot as the pivot, he finds the next level spot in the same manner, and so proceeds with great rapidity to trace out a level line throughout the field, marking each spot as he goes on; then taking the plough, he cuts a furrow along the line so marked out, which is, consequently, a perfectly level gutter. At points where the ground changes so as to render it impossible to get a level, a stop is put in the gutter, and a fresh level taken for its continuation. Thus, when the higher part of the gutter is full, the water runs over the land alongside of it, and also flows over the stop *a* into

the lower part of the gutter, which distributes it over another portion of the field. The width of these level gutters is usually about 4 inches, and the depth nearly the same, the object being to economise both water and space as much as possible. It is obvious that a number of deep and broad seams, following the tortuous course which must be pursued in search of a level, would take up a great deal of land, besides interposing serious obstacles to hay-making, and proving otherwise inconvenient; they have, moreover, the disadvantage of retaining a great deal of water, which filters away through the bottom of them, depositing the most valuable part of the sediment it contains in the gutter, instead of distributing it over the field; besides, they delay the process of irrigation, which it is desirable to render as rapid as possible; and, where only a small quantity of water can be obtained, they defeat the irrigation altogether;

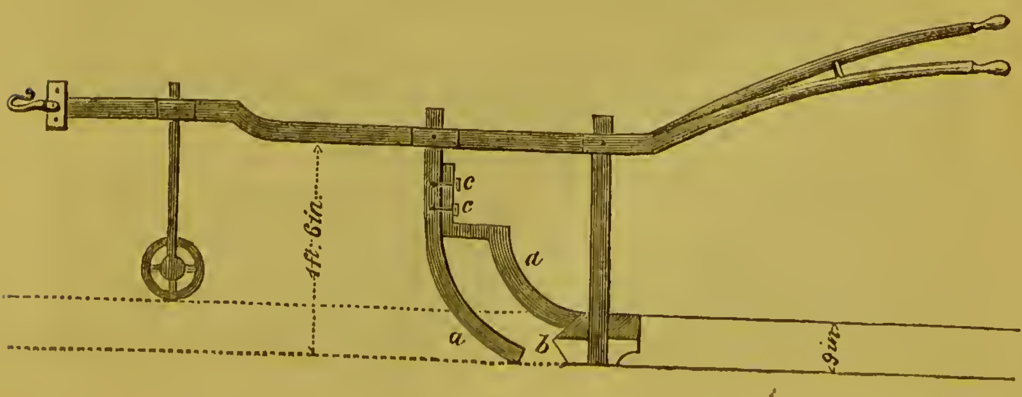
and, lastly, they are more expensive to clean out when the time comes for preparing the land for watering. I am told that 2*s.* an acre is a moderate charge for cleaning out the old class of gutters, while the small level gutters may be cut afresh, when once the levels have been marked out, for just half that sum.

According to the explanation which I have now given, it will appear that the field is watered by stages; and were the system always followed in the manner I have described, the upper stage would always receive the benefit of the greatest amount of sediment when the river is foul after the rains; the second stage would be the next in favour, and so on, till the lowest part of the field received nothing but water in almost a filtered state. This disadvantage is obviated by the use of feeders or small transverse gutters, which run from the carriage gutter at the top across all the level gutters to the lowest of all. By stops in the proper places, the water can thus be conveyed directly from the carrier to any one of the catch-gutters without passing over the intervening land at all, and the lowest portion of the field may be watered first, and the highest last, if desired.



One more contrivance deserves to be noticed, though it is not peculiar to Mr. Bickford's system. In some cases it is desired to carry the water along a level line on the hillside, without any fall at all. In order to make it flow, an occasional sharp turn is made, and the gutter continued at lower level. The fall thus caused communicates motion to the water along the preceding level gutter.

The plough with which the gutters are cut was exhibited at the Exeter meeting in 1850, by Mr. Thomas Moore, of Newton St. Cyres, and was, on that occasion, "commended" by the judges. A drawing of it is annexed. The two



knives *a a* cut a slice of the proper width, and the furrow-slice *b* scoops it out at the proper depth. The width of the slice is regulated by the screws *c c* which attach the right-hand knife to the implement; the left-hand knife is fixed, but the right-hand knife may be taken off by unscrewing it at *c c*. When put on, it may either be screwed close up, or a space may be left, so as to leave 6 inches between the knives; when screwed up close, the distance is 4 inches. In cutting a carriage gutter of a foot wide, it is necessary to go over the line twice. The price of the implement is 3*l*.

Having thus described the chief points in Mr. Bickford's system, I must add, what will perhaps be obvious, that its success much depends upon the judgment with which it is applied. Although the level catch-gutters can be laid out with mechanical accuracy by any intelligent person capable of using the plumb-line, yet, in order to give the best direction both to them and to the carriers, a practised eye is an essential requisite. The gutterers in this part of the country are quick in perceiving irregularities in the ground which would escape an ordinary observer, and can tell, almost at a glance, in what direction the gutters can be laid out so as to economise both ground and labour. They use the plumb-line rather to correct and verify than to guide the formation of the levels. When a water-meadow has once been laid out, there is no difficulty in cutting fresh gutters with the plough along the course indicated by the original ones, and it is recommended that this should be done every season, in preference to cleaning out the old gutters. The expense is not greater; the earth which comes out of the new furrow is used for filling the old one by its side, and the growth of coarse grasses along the gutters is thus prevented. In the first laying out of a meadow, however, the services of a practised gutterer should be put in requisition. The expense—an important question—is very moderate. In the work which I have been executing in my own meadows, I have employed Mr. Edward Ellis, of Newton St. Cyres, whose charge for "irrigating, cutting, and regulating 23 acres of marsh land," amounts only to 8*l*. 12*s*. 6*d*. or 7*s*. 6*d*. per acre. In addition to this, I paid 3*l*. 8*s*. 6*d*. to my own labourers employed in assisting Mr. Ellis, and I lent one of my own horses for the work. The plough was the property of Mr. Ellis.

It will be observed that, in these meadows, the carriage gutters had already been partially laid out; this, of course, saved a great deal of labour. The ground is, however, remarkably uneven, and the expense of the level gutters was consequently greater than would usually be the case.

Some new carriage gutters were cut, and a good deal of labour was bestowed on reducing the size of the old gutters, which have been diminished from 3 feet wide by 2 feet deep to 1 foot 9 inches wide by 1 foot deep. (They are still larger than is desirable.) Taking all these circumstances into consideration, I am of opinion that water-meadows similarly situated might be completely laid out at an expense not exceeding 1*l.* per acre. The annual expense of cleaning them, or of cutting fresh gutters by the side of the old ones, may be taken at 1*s.* an acre; and for these very low sums the land may be as fully, and more fully, benefited than by the old system, under which the cost could not be taken at less than 4*l.* or 5*l.* an acre; while the annual expense of cleaning the gutters amounted to fully 2*s.* an acre, or double the sum now required.

As an instance of the advantage of this system of watering, where only a limited supply of water can be obtained, I may mention that my steward has recently availed himself of Mr. Ellis's services in laying out two meadows of about 15 acres in extent, which are watered from a pond estimated to contain something like 50 hogsheads. In this case the water is carried along a level ridge by a carriage gutter, in which two breaks and sharp turns (as above described) occur. When it is desired to water the first part of the meadow, a stop is put at the first break, and the water overflows, and is caught by the level gutters below.

To water the second part of the meadow, the stop is put at the second break, and the water, therefore, runs out of the first part of the carriage gutter, and fills the second till it overflows.

To water the third part, the stops are removed, and the water runs, without overflowing, into the third portion of the carrier, whence it is distributed over the ground below.

STAFFORD H. NORTHCOTE.

Pynes, Exeter, June 29, 1852.

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APPENDIX D.

List of Owners and Occupiers of Farms* on which Works are established for the Application of Liquid Manure by Pipes and Jet.

In England and Wales.

J. J. Mechi, Esq. - -	Tiptree.
J. Daw, Esq. - -	Exeter.
Earl of Essex - -	Watford.
R. Neilson, Esq. - -	Liverpool.
H. Littledale, Esq. -	Birkenhead.
Duke of Sutherland -	Trentham.
Lord Grey - - -	Alnwick.
Rev. R. W. Bosamquet -	,,
F. Stainer, Esq. - -	Staffordshire.
Sir M. Cholmeley -	Lincolnshire.
J. Wheble, Esq. - -	Near Reading, Berkshire.
— Naylor, Esq. - -	Near Welshpool, Glamorganshire.
— Romilly, Esq. - -	Near Cardiff, Montgomeryshire.

In Scotland.

P. W. Kennedy, Esq. -	Ayrshire.
A. B. Telfer, Esq. - -	,,
A. Ralston, Esq. - -	,,
Marquis of Ailsa - -	,, Castle hill, and Newark.
J. Kennedy, Esq. - -	Dumfrieshire.
F. McConnell, Esq. -	,,
D. Baird, Esq. - -	,,
N. Malcolm, Esq. - -	Argyleshire.
Duke of Argyle - -	,,
Lord Strathallan - -	Perthshire.
Robert Harvey, Esq. -	Glasgow.

In Ireland.

Model Farm - -	Glasnevin.
J. Fagan, Esq. - -	Turvey House.

* For the names in this list of the places which I have not visited, I am chiefly indebted to Mr. Young, engineer, of Ayr, by whom much of this work has been executed.

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